Skill India
कौशल भारत - कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

N·S·D·C
National
Skill Development
Corporation
Transforming the skill landscape

HSSC
HYDROCARBON SECTOR
SKILL COUNCIL

Participant Handbook

Sector
Hydrocarbon

Sub-Sector
Midstream, Downstream

Occupation
Pipe Fitting

Reference ID: **HYC/Q6103, Version 4.0**
NSQF Level 4

Pipe Fitter
Oil & Gas/City Gas Distribution

This book is sponsored by

Hydrocarbon Sector Skill Council

OIDB Bhawan Tower C, 2nd Floor, Plot No. 2, Vikas Marg, Sector 73, Noida 201301 (UP)

Printed in India at

Disclaimer

The information contained herein has been obtained from sources reliable to Hydrocarbon Sector Skill Council. Hydrocarbon Sector Skill Council disclaims all warranties to the accuracy, completeness or adequacy of such information. Hydrocarbon Sector Skill Council shall have no liability for errors, omissions, or inadequacies, in the information contained herein, or for interpretations thereof. Every effort has been made to trace the owners of the copyright material included in the book. The publishers would be thankful for any omissions in the book being brought to their notice; which will be acknowledged as applicable in future editions of the same. No entity in Hydrocarbon Sector Skill Council shall be responsible for any loss whatsoever, sustained by any person who relies on this material. The material in this publication is copyrighted. No parts of this publication may be reproduced, stored or distributed in any form or by any means either on paper or electronic media, unless authorized by the Hydrocarbon Sector Skill Council.

"Skilling is building a better India.
If we have to move India towards
development then Skill Development
should be our mission."

Shri Narendra Modi
Prime Minister of India

Certificate

CURRICULUM COMPLIANCE TO
QUALIFICATION PACK – NATIONAL OCCUPATIONAL STANDARDS

is hereby issued by the

HYDROCARBON SECTOR SKILLS COUNCIL

for the

PARTICIPANT HANDBOOK

Complying to National Occupational Standards of
Job Role/Qualification Pack: 'Pipe Fitter (Oil & Gas/City Gas Distribution) QP No. 'HYC/Q6103 NSQF Level 4'

Date of Issuance: June 22nd, 2017

Valid up to: June 21st, 2019

** Valid up to the next review date of the Qualification Pack or the 'Valid up to' date mentioned above (whichever is earlier)*

Authorised Signatory
(Hydrocarbon Skill Development Council)

Acknowledgements

National Skill Development Corporation (NSDC) working with the object of developing unskilled and semi-skilled labour force into productive and skilled labour through Sector Skill Councils (SSCs) and Assessment agencies has entrusted the responsibility of developing participant handbooks with National Instructional Media Institute (NIMI).

NIMI, set up by the Government of India to develop instructional material for the overall improvement in the standard of training in ITIs and skill development programmes is happy to widen the scope of its outreach by developing content for NSDC.

NIMI sincerly acknowledges the co-operation rendered by the media developers and their sponsoring organisations to bring out the participant handbook under Hydrocarbon Sector for Qualification Pack for Pipe Fitter (Oil & Gas/City Gas Distribution).

This book is the outcome of teamwork by Hydrocarbon Skill Development Council and experts from the Oil and gas/City Gas Distribution industry.

NIMI thanks the media development committee members, data entry operators, CADD personnel and all others for their dedicated and continued support.

About this book

Hydrocarbon industry is the second largest employer in India. As one of the leading avenues for employment in the country, the role played by this industry in the economic development of India is pivotal. However, despite its vast potential, the construction industry faces challenge of shortage of skilled manpower. This hampers the progress of the industry, as the quality of constructed structure is poor and most projects fail to be completed in the stipulated time.

There is a vast difference between the required skill sets and available skills amongst workers in the industry today. To reduce the skill gap, appropriate skilling of the workforce is of paramount importance. It will not only empower the worker, but also benefit the construction framework.

This participant handbook is developed to impart skill training with appropriate and relevant knowledge required to work as an Pipe Fitter (Oil & Gas/City Gas Distribution) in the Oil and gas industry. It is designed based on Pipe Fitter (Oil & Gas/City Gas Distribution) Qualification Pack under the National Skill Qualifications Framework. It comprises the following NOS/topics:

NOS code	Major function/Task
ELECTIVE - I (Oil & Gas)	
1. HYC/N6109:	Perform pipe fitting activity
2. HYC/N6110:	Perform pipe laying and joining activities
ELECTIVE - II (City Gas Distribution)	
3. HYC/N6105:	Fitting, Welding Basics and Jointing Process of Materials (CGS)
4. HYC/N6106:	Perform Electrofusion Welding
COMPULSARY NOS (Non-Core)	
5. HYC/N9301:	Work effectively in a team
6. HYC/N9302:	Maintain Health Safety and Security procedures

This book is designed considering the lower educational background of the Hydrocarbon workforce. Therefore, special efforts have been taken to explain the concepts required for the job with ample visual support and illustrations.

Units and symbols used in the book have been listed below:

Symbols Used

Key Learning Outcomes | Steps | Unit Objectives | Notes | Tips | Exercise | Practical

Table of Contents

It is recommended that all trainings include the appropriate Employability Skills Module Content for the same is available here:

https://www.skillindiadigital.gov.in/content/list

1. Perform Pipe Fitting Activity (Oil & Gas)

HYC/N6109

Key Learning Outcomes

At the end of this module, you will be able to:

1. wear proper PPE and exhibit proper safe working principles and practices duly implementing all HSE requirements
2. read and interpret drawings and approved work procedures
3. receive materials, ensure material release for construction and check for any material damage
4. carryout measuring, marking, cutting and transfer/maintain ensuring material identification and traceability
5. identify and make readily available appropriate consumables, tools and equipment for piping edge preparation and fit up work activities
6. prepare joints for edges of pipes to meeting drawing requirements and perform pipe fit up activities approved procedures requirements
7. perform / ensure functional checks of valves and other instruments / accessories and install them as per approved construction drawings
8. install gaskets, bolts / studs, nuts, washers, clamps, etc., and perform proper bolt tightening / torqueing in sequence
9. perform pipe stringing, fitting activities at pipeline installation site
10. ensure proper trench preparation and pipe bedding and pipeline lowering
11. prepare for hydrotest / pneumatic test and perform the test with appropriate work permit duly complying with all safety precautionary requirements
12. perform depressurizing, dewatering and cleaning piping / pipeline systems.

Unit 1.1 Introduction

Unit Objectives

At the end of this unit, you will be able to:

1. identify the importance of pipe fitter training
2. recognise the organisation chart, pipe fitter roles
3. distinguish between piping and pipeline.

1.1.1 Introduction to the Training Program

Introduction to QP and NOS

This training program is based on Qualification Pack (abbreviated as 'QP') named as "Pipe-Fitter Oil and Gas Industry". The code for the QP is "HYC/Q6103". HYC stands for "HydroCarbon". This QP consists of a set of National Occupational Standards (NOS). NOS specifies the standard competency a pipe fitter must achieve when carrying out a function in the workplace. Under this QP, there are four NOS. They deal with the oil and gas pipes and pipelines related functions to be performed in worksite duly complying with all safety requirements.

NOS Code	Major Functions / Task
HYC/N 6109	Perform pipe fitting activity
HYC/N 6110	Perform pipe laying and joining activities
HYC/N 6103	Work effectively in a team
HYC/N 6104	Follow health, safety and security procedures

Benefits of this training

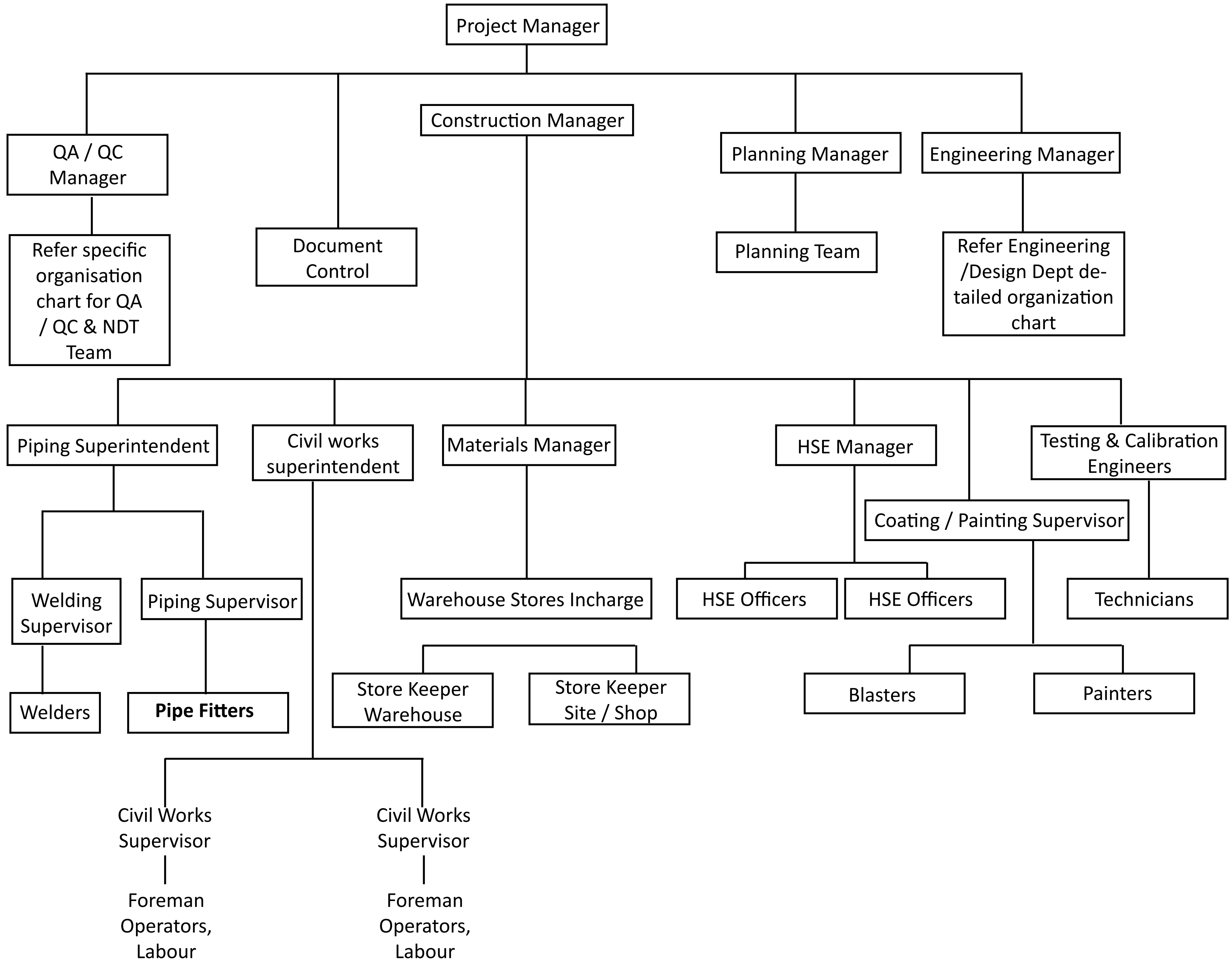
After successful completion of training and passing the assessment, the candidate will be issued a certificate. The certificate will help the candidate to get employment in fabrication, and construction industries in oil and gas sector. Oil and gas industries need a great number pipe fitters all over the world. Pipe fitter is not only trained on simple pipe fit up, but are trained in the basics of engineering drawings, pipe materials, pipe fitting materials, all type of joints related to oil and gas piping / pipeline. The oil and gas pipe fitters can be directly employed to perform pipe fitting activities without site / on the job training at the worksite. Oil & Gas industry pipe fitters are one of the highest paid of all the trades, with more job openings in the near future. Job growth for the pipe fitting industry is expected to expand in the forthcoming years in India as well as abroad. Satellite cities development in all over India needs more infrastructure for oil and gas transportation and distribution . Hence a lot of opportunities are getting lined up for Pipe fitters trained to oil and gas related facilities construction (including transportation and distribution) requirements.

1. Organization and its process

Oil and Gas pipe fitter shall have enough information / knowledge about the organization and its process to thoroughly understand the organization and its context. He / She shall go through the company policies on personnel management, duty reporting procedures and comply with the same duly maintaining discipline. Pipe fitter must be aware of and comply with the respective legislation, standards, policies, and procedures followed in the company mainly those relevant to his employment and performance conditions. He / She shall receive employment terms and entitlements from the employer along with job description, roles and responsibilities.

The pipe fitter shall receive adequate induction in problem escalation procedure and escalation matrix for reporting work and employment related issues. Pipe fitter shall have access to company standard operating procedures so as to refer and meet the respective procedures requirements while working. He shall be aware of documentation and related procedures applicable in the context of employment and work. Pipe fitter must have adequate information about his reporting structure within the organization and relevant people and their responsibilities within the workarea with whom he has to liaise for day–to–day work activities.

TYPICAL ORGANIZATION CHART



2. Health, Safety and Environment (HSE) System Requirements

Pipe fitter shall strictly adhere with relevant health and safety requirements applicable in the work place. Safety should be the top priority in any facility to keep productivity at its best and to avoid injury or health concerns. Pipe fitter shall be aware about importance of working in a clean and safe environment. One of the most effective ways to improve the safety of worksite is to make sure that it is cleaned properly maintained. Cleaner work environment reduces injuries on the job. Poorly cleaned / poorly maintained / faulty / broken equipment or slippery surfaces could lead to a potential fall /injury / accident. The cleaner the working facility is, the better the quality of products and services.

3. Importance and Purpose of Documentation

Documentation is a record of information which can be referred to or used, whenever required. Documents act as the store of collective organizational knowledge regarding the processes. They can be accessed by anyone whenever needed. Documented information shall be maintained to support the operation and its processes:

- to provide evidence of results achieved and contain statement of fact.
- to provide evidence of fitness for purpose of the monitoring and measuring activities
- to show conformity of products and services that meet the requirements.

Pipe fitter must know and follow the review and approval process of the requisition of materials/equipment by assigned employees. Pipe fitter shall be aware of required records to be prepared and maintained. Knowledge in preparing reports and recording repairs and successful completion of repair are important.

Pipe fitter shall be trained in implementation of inspection and test plans that includes inspection and test stages along with customer inspection and meeting quality standards requirements.

Pipe fitter roles, responsibilities and tasks include:

a. reporting to foreman / supervisor and following their instructions for everyday pipe fitting work activities.

b. duly discussing with supervisor / foreman, prioritising work schedule and process implications for own work and schedule of others.

c. attending site daily Tool Box Talks and Safety Meetings without fail.

d. reading and understanding organization procedures for necessary approval, work permit (PTW- Permit To Work) and for receiving materials.

e. reading and interpreting piping drawings, specifications and work procedures.

f. following all safe work practices and handling all piping works related equipment carefully.

g. selecting pipe sizes, types and related materials and planning the fit up work sequence.

h. ensuring that pipes and pipe fittings have been inspected on receipt and released for fabrication / installation.

i. measuring, marking and cutting pipes duly maintaining identification and traceability.

j. using appropriate tools, instruments and equipment for pipe edge preparation, cutting, fit up and tack welding / deburring tools.

k. piping ends and edge preparation for for welding / jointing as required by the drawing / specification.

l. for cutting and edge preparation employing appropriate methods such as gas cutting, hacksaw cutting, grinding, machining, etc.

m. checking all pipes and fitting inside for cleanliness / any objects.

n. aligning / joining pipes using various methods such as tack welding, brackets and wedging, clamping (internal & external).

o. performing piping / pipeline stringing & alignment.

p. assembling and securing pipes, tubes, fittings and related equipment according to specifications / drawings using techniques such as welding, bolting, threading joints.

q. performing dimensional check and ensuring the correct size, length, orientation, position / location.

r. checking piping / pipeline alignment, straightness, level and all other dimensional checks.

s. assembling valves and other instruments / accessories by taking into account the flow directions.

t. Marking the hole locations and cut / bore/ drill holes in structures / supports.

u. install pipe supports as per drawing / specifications.

v. performing bolting in sequence with required torque by the approved / permitted torque method. Some cases minimum torque will be specified. In some cases, torque may be limited to certain limit / range to avoid gasket / joint face damages.

w. preparation for hydotesting / pneumatic testing and reinstatement after test completion.

Exercise

I. Answer the following questions.

1. List any two objectives of this training program.

----

2. What is the need for oil and gas pipe fitter training?

----

3. What are the benefits of pipe fitter training?

----

4. Briefly describe organizational context and processes with respect to piping / pipeline works.

----

5. Describe Pipe fitter roles, responsibilities and tasks.

II. State whether the following statements are True or False.

1. Purpose of oil and gas pipe fitter training includes “familiarising with various pipe and pipe fitting materials.

   True ☐ False ☐

2. Pipe fitter need not perform piping / pipeline stringing activities.

   True ☐ False ☐

3. Safety standards are not relevant to pipe fitting activities.

   True ☐ False ☐

4. Welded pipe systems demand the least degree of excellence in materials and quality of work.

   True ☐ False ☐

5. Pipe fitters perform joints preparation.

   True ☐ False ☐

6. Oil and gas pipe fitter certificates issued to the trainee will not be useful for fabrication industries.

   True ☐ False ☐

7. Pipe fitter must be aware of and comply with the respective legislation, standards, policies, and procedures followed in the company.

   True ☐ False ☐

8. Ensuring clean and safe environment is not pipe fitter's responsibility.

   True ☐ False ☐

Notes

1.1.2 Introduction to Piping and Pipeline

At the end of this topic, you will be able to:

1. define piping and pipeline construction methods in oil and gas industry
2. describe codes and standards
3. define terms and definitions.

Piping and pipeline: Oil and Gas piping / pipeline fitter shall have knowledge on various piping and pipeline systems and their standards / specifications so that they have proper understanding about what they are doing and the purpose. Pipe fitters need to know that the oil and gas industry is usually divided into three major sectors – midstream, upstream and downstream.

Upstream: The upstream sector also known as "Exploration and Production – E&P" includes finding underground or underwater crude oil and natural gas fields, locating exploratory wells, and subsequently drilling and operating the wells that recover and bring / lift the crude oil or raw natural gas to the surface and get it ready for transportation.

Midstream: The midstream sector involves transportation (by pipeline, rail, barge, oil tanker or truck), and storage of crude or refined petroleum products. Pipelines and other transport systems can be used to move crude oil from production sites to refineries and deliver the various refined products to downstream distributors. Natural gas pipeline networks aggregate gas from natural gas purification plants and deliver it to downstream customers such as local utilities.

Downstream: The downstream sector also known as "Refining and marketing- R & M" is further processing of crude oil and natural gas into useful final product or raw material for other industry. Downstream process includes refining of petroleum crude oil and the processing and purifying of raw natural gas as well as distribution of products derived from crude oil and natural gas. The downstream sector reaches consumers through products such as gasoline or petrol, kerosene, jet fuel, diesel oil, heating oil, fuel oils, lubricants, waxes, asphalt, natural gas, and liquefied petroleum gas (LPG) as well as hundreds of petrochemicals.

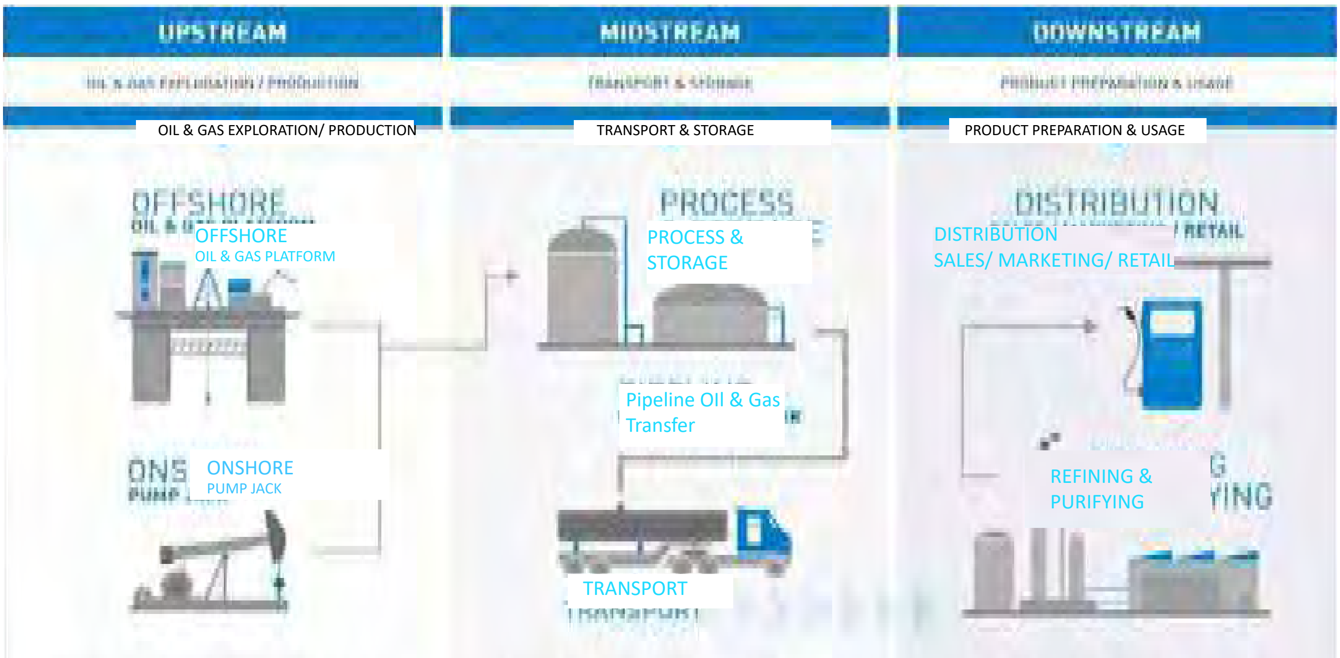


Fig. 1.1.1 Oil & Gas - upstream, Midstream, Downstream

Piping

Piping is the term normally used to describe plant or process piping or station piping in oil and gas industries. Process plant is a place where a series of activities are performed with various piping systems in an ordered manner to convert raw material into useful products or transfer fluid from one equipment to another within the plant boundary.

Piping is a complex network of pipe and fittings including pipe, pumps, equipment, valves, fittings, flanges, bolts, gaskets, regulators, pressure vessels, pulsation dampeners, relief valves / devices, appurtenances attached to pipe, compressor units, metering facilities, pressure regulating stations, pressure limiting stations, pressure relief stations and fabricated assemblies and pressure containing parts within the defined boundaries of the plant. It also includes hangers and supports, and other equipment necessary to prevent overstressing the pressure containing parts. Process plant piping is mostly above ground with very few underground services such as, sewage and drainage piping.

On plot piping: On plot is a location inside the designated plant boundaries and, generally, piping inside the on–plot boundaries comes under process piping.

Petroleum refinery is an industrial plant for processing or handling of petroleum and products derived directly from petroleum / oil and gas wells. Such a plant may be an individual gasoline recovery plant, a treating plant, a gas gathering and compression plant, gas processing plant (including liquefaction), or an integrated refinery having various process units and attendant facilities.

Large series and networks of pipes are within the well defined boundaries of the plant/plot with all fittings and equipment like pump, valves, instruments, equipment, unions and other miscellaneous items with an intention to transfer fluid from one facility to another within those boundaries as required.

Pipeline

The pipeline is series of straight pipes, welded together over a long distance for conveying oil or gas over long distances. A system of pipes and other components are used for the transportation of fluids, between (but excluding) plants. A pipeline extends from pig trap to pig trap (including the pig traps) or, if no pig trap is fitted, to the first isolation valve within the plant boundaries. Pipelines used in the oil and gas industry vary according to many factors, such as the product to be transported, the delivery stage and whether it is part of the upstream, midstream or downstream sector. Natural gas is transported through the transmission pipeline system, which is composed of large diameter steel pipes.

Pipelines are mostly large in diameter and transport bulk liquid or gas from one place to another sometimes along 1000 kilometre long distances. Pipeline system comprise all parts of physical facilities through which liquid or oil / gas moves in for transportation. Included within this definition are transmission and gathering lines, which transport liquid / oil / gas from production facilities to onshore locations and storage area.

Other Pipeline Components are Pig launcher / Pig receivers, Barred Tees, Isolation Joints, Pig signallers, Corrosion monitoring fittings, Shrink sleeves / External coatings / Cathodic protection for buried lines. The pipelines are laid underground, above the ground and underwater such as a subsea pipelines.

Table 1 Piping and pipeline comparison

Sl. No.	Pipe / Piping System	Pipeline / Pipeline system
1.	Series and networks of pipes and fittings within the defined boundaries of the plant	Many straight pipes are welded together for conveying / transporting oil or gas, over long distances.
2.	These are plants or process piping, generally not exceeding 400 meter in length.	Mostly transporting bulk liquid or gas from one place to another. Sometimes 1000 kilometers long distances.
3.	Wide range of many pipefittings are used.	Pipe fittings are comparatively very less in pipeline system.
4.	Mostly above the ground with very few underground services.	Pipelines are laid underground, above the ground and underwater such as subsea pipeline.
5.	Piping system includes very small size piping to large diameters from ½" to 36" in diameter.	Comparatively and mostly larger size pipes are installed.
6.	Comprise many equipment within the piping system.	Few equipment are used within the pipeline system.
7.	Piping system design code includes ASME B31.1, ASME B31.3	Pipeline system design code includes ASME B31.4, ASME B31.8
8.	In general on plot	In general Off plot.

III. Types of Pipeline in Oil & Gas Industry

Gathering lines: Pipelines form network and are connected from the wells to processing facilities. Gathering pipelines are used to deliver the oil or gas product from the source to processing plants or storage tanks. These are commonly fed by 'flow lines', each connected to individual wells in the ground.

Transmission Pipelines: Transmission pipelines are used to transport crude oil, natural gas and refined products for long distances across states, countries and continents. They are used to move the product from the production regions to distribution centres or refineries.

Flow lines: Flow line is a pipeline transporting untreated hydrocarbons and other reservoir fluids. Pipelines from the well are sent to the nearest processing facility / gathering station when is also called flow lines. Their purpose includes moving the raw product from the well to the gathering lines. They carry a mixture of oil, gas, water and sand and are normally no more than 12" diameter in size.

Loading lines / Export lines: Loading / exporting pipeline is a pipeline between an onshore facility and an offshore loading facility. In other words, this is the pipeline from the processing facility to the loading or export point.

Trunk lines / Inter field lines: This is also a main transmission pipeline to which spurlines and offtake lines may be connected. Pipelines between two processing facilities or from pig trap to pig trap or from block valve station to block valve station are also called trunk line.

Spur lines / Transfer lines: It is the branch line exiting into trunk line or export line. That is, Spurline is a pipeline transporting fluid into a larger pipeline.

Injection lines: Injection lines are pipelines, injecting water / steam / polymer / gas into the wells to improve the lift by injected fluid pressure.

Off plot piping: Off plot is a location outside the designated plant boundaries and, generally, comes under the category of pipelines.

Disposal lines: Pipeline which disposes (normally water) into disposal wells (shallow / deep).

Subsea pipelines: Pipelines connecting the offshore production platforms to onshore processing facilities. Pipelines under deep seawater of floating platform facilities are also called subsea pipelines.

Distribution pipelines: They are a system made up of 'mains' and 'service' lines, used by distribution companies. Together they deliver natural gas to the neighbourhoods of homes and cities.

Mains pipelines: Distribution pipelines classed as 'mains' are the step between high pressure transmission lines and low pressure service lines. Materials used for these pipes include steel, polyethylene, cast iron, plastic and copper.

Feeder pipelines: Feeder pipelines are used to move the product from processing facilities and storage tanks to the long distance transmission pipelines.

Service pipelines: Service pipelines connect to a meter and deliver natural gas to individual customers. Materials used for service pipes include plastic, polyethylene, steel or copper. Pressure of the gas in these pipes is low at around 60 psi.

Piping and pipeline codes / standards

1. **ASME B31.1 Power Piping**

   Piping that is typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, heating and cooling plants.

2. **ASME B31.3 Process Piping**

   Piping that is typically found in petroleum refineries, chemical, pharmaceutical, textile, cryogenic plants and related processing plants and terminals.

3. **ASME B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids**

   B31.4 prescribes requirements for the design, materials, construction, assembly, inspection, and testing of pipeline transporting liquids between production facilities, between plants and terminals and within terminals, pumping, regulating, and metering stations, tank farms, natural gas processing plants, refineries, ammonia plants, terminals (marine, rail, and truck), and other delivery and receiving points.

4. **ASME B31.5 Refrigeration Piping**

   Piping for refrigerants and secondary coolants.

5. **ASME B31.8 Gas Transportation and Distribution Piping Systems**

   Piping transporting products which are predominately gas between sources and terminals including compressor, regulating and metering stations, gas gathering pipelines. This code covers the design, fabrication, installation, inspection, and testing of pipeline facilities used for the transportation of gas.

6. **ASME B31.9 Building Services Piping**

   Piping that is typically found in industrial, institutional, commercial and public buildings and in multi-unit residences which does not require the range of sizes, pressures and temperatures covered in B 31.1 (power piping).

7. **Pipeline related ISO standards include**

- ISO 3183 – Petroleum and Natural gas industries – Steel Pipe
- ISO 14692 – Petroleum and Natural gas industries – Glass Reinforced plastic piping

- ISO – 15590 – 1, 2 and 3 Pipeline fittings
- ISO 14313 – Petroleum and Natural gas industries – Pipeline valves

Abbreviations and Definitions

Many abbreviations are used in piping and pipeline works. The pipe fitter shall be familiar with those abbreviations and definitions as he/she may encounter these abbreviations in his routine work. Important abbreviations and corresponding definitions are listed herewith.

Abbreviations	Definitions
Abs	Absolute
AFC	Approved For Construction (Mostly specified in drawings & procedures)
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Standard for Testing Materials
Assy	Assembly
BIS	Bureau of Indian Standard
BLDG	Building
Btu	British thermal unit(s)
BOM	Bill Of Material
BOP	Bottom of pipe
BW	Butt Weld
CI	Cast Iron
CS	Carbon Steel
°C	Degrees Centigrade
°F	Degrees Fahrenheit
Dia / ϕ	Diameter
Drg	Drawing
DSS	Duplex Stainless Steel
EL	Elevation
EN	European Norms (Standards)
ERW	Electric Resistance Weld
FCAW	Flux Cored Arc Welding
FLG	Flange
FF	Flat Face (of Flange)
G	Gage or Gauge
GA	General Arrangement
GAIL	Gas Authority of India Limited
GALV	Galvanised
Gr	Grade
GTAW	Gas Tungsten Arc Welding
HDPE	High Density Poly Ethylene
Hex	Hexagonal
HSE	Health Safety and Environment
IBR	Indian Boiler Regulation
ID	Inside Diameter
IFC	Issued For Construction
INS	Insulation
IS	Indian Standards
ISO	International Organization for Standardisation
Kw	Kilowatt(s)
LC	Lock Closed
LO	Lock Open

LR	Long Radius
Max	Maximum
MFG	Manufacturing
Min	Minimum
mm	Millimeter
MSS	Manufactures Standardization Society
MT / MPT	Magnetic Particle Testing
NDT	Non Destructive Testing
NPS	Nominal pipe size
OD	Outside Diameter
ONGC	Oil and Natural Gas Corporation
PCD	Pitch Circle Diameter
P&ID	Piping & Instrumentation Diagram
PNGRB	Petroleum and Natural Gas Regulatory Board
PPE	Personnel Protective Equipment
PQR	Procedure Qualification Record
PRV	Pressure Relief Valve
Psi	Pounds per square inch
PSV	Pressure Safety Valve
PT	Penetrant Testing
PVC	Polyvinyl Chloride
RED	Reducer
RF	Raised Face
RT	Radiographic Testing
RTJ	Ring Type Joint
SMAW	Shielded Metal Arc Welding
SAW	Submerged Arc Welding
Sch	Schedule
SMLS	Seamless
Spec	Specification
SO	Slip On
SQ	Square
SR	Short Radius
SS	Stainless Steel
Std	Standard
STL	Steel
SWG	Swage
Temp	Temperature
T.O.C	Top Of Concrete
TOS	Top Of Steel
TYP	Typical
UT	Ultrasonic Testing
VT	Visual Testing
WN	Weld Neck
WT	Weight
XS	Extra strong
XXS	Double extra strong

Exercise

I. Answer the following questions.

1. Explain process piping.

----

2. What do you understand by the term "onplot" piping?

----

3. Explain oil and gas major sectors – upstream, midstream and downstream.

----

4. Distinguish piping and pipeline system.

----

5. Explain the purpose and significance of ASME B31.4 Pipeline Transportation Systems.

----

6. Write down the expansions for the following abbreviations related to piping and pipelines.

   AFC, ASTM, BOM, ERW, NPS, PRV, SMLS, T.O.C, XXS

II. State whether the following statements are True or False.

1. Off plot is a location inside the designated plant boundaries and for generally piping inside the plant boundaries.

   True ☐ False ☐

2. Pipeline is series of straight pipes, welded together over a long distance, for conveying oil or gas.

   True ☐ False ☐

3. Exploration and production is a "midstream stream process" in oil and gas industry.

   True ☐ False ☐

4. Further processing of crude oil and natural gas into useful final product is a "downstream process".

   True ☐ False ☐

5. Pipelines comprise many equipment and accessories within the pipeline system.

   True ☐ False ☐

6. Pipeline system design code includes ASME B31.4.

   True ☐ False ☐

7. Pipelines used to move the product from the production regions to distribution centres or refineries are called gathering lines.

   True ☐ False ☐

8. Transmission pipeline is a pipeline from the processing facility to the loading or export point.

   True ☐ False ☐

Notes

UNIT 1.2 Piping and Pipeline Layout Drawing

Unit Objectives

At the end of this unit, you will be able to:

1. read and interpret basics of engineering drawings and symbols
2. read, interpret piping isometric drawings, pipeline layout drawings, hangers and pipe support drawings and related engineering drawings
3. draw and illustrate pipeline system and bill of materials
4. describe various pipe supports.

1.2.1. Piping and Pipeline Drawings- Basics of Engineering

At the end of this topic, you will be able to:

1. describe basics of engineering drawings
2. read and interpret engineering drawings / projections
3. prepare simple drawings both in 1st angle and 3rd angle projections.

Introduction

Transmission of oil and gases subjects the pipe to intense stresses and strains and this demands the highest quality throughout the construction process from material sourcing, fitup, welding till installation. All pipework must be designed and fabricated in a way that ensures the safety of plant operators, the plant, the public and the environment and to the medium being transmitted.

Process piping is designed, constructed and installed in accordance with ASME B31.3 code. Power plant piping is designed, constructed and installed in according with ASME B 31.1.

In Oil and Gas Industries, a pipeline is designed in accordance with ASME B31.4 code for Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum, Anhydrous Ammonia, and Alcohol and ASME B31.8 that is the governing code for Gas Transmission and Distribution Piping Systems. Pipelines are laid above the ground, below the ground, river and in subsea.

Basics of Engineering Drawings

a. Drawings are prepared in grids with title blocks and coordinates.
b. Bill of materials, notes and instructions, if any, are incorporated into the applicable drawings.
c. Drawings may be prepared with or without scales.
d. Different types of drawings are prepared for piping and pipelines. They include GA – General Arrangement Drawings, Assembly drawings, plot plan, layout drawings, pipeline drawings, PID – Piping and Instrument Diagram, PEFS – Process Engineering Flow Scheme Isometric drawings, detailed drawings etc.
e. Drawings may be prepared in projectional view or isometric view.

Drawing line indications need to be:

- Visible continuous lines to depict edges directly visible from a particular angle and represent the features that can be seen in the current view.
- hidden / dotted or short dashed lines indicate the features that cannot be seen in the current view, representing edges that are not directly visible.

- centre line represents axis and symmetry of the object, path of motion, center of circle. Center line is drawn as long and short dashed lines, alternately.
- dimension, extension and leader lines indicate the sizes and location of the features.

1. Orthographic Projection

Piping drawings may be prepared in orthographic projection, isometric and block diagrams. Orthographic projection is a two dimensional drawing showing the true size / shape of the three dimensional object. It is a way of representing a three dimensional object on a drawing sheet. Image of a three dimensional object is projected and viewed / seen in directions that are right angle with each other. Orthographic drawings usually consist of the following:

Elevation / front view: This is a view of the object from the front side.

Top / plan view: This is the view of the object from the top.

Side view: This is the view of the object from the leftside or right side.

Sectional View: This is a cross – sectional view used to show the inside configurations / details.

Normally, in case of third angle projection, front view is drawn in lower left corner of the drawing; top view is drawn in the upper left corner and right side view on the lower right corner of the drawing. Same scale is used for drawing all the views. Orthographic Projection drawings may be prepared and presented in 1st angle or 3rd angle projection.

Orthographic projection symbols depicts whether the drawing is prepared in the first angle or third angle projection as given in the figure that following.

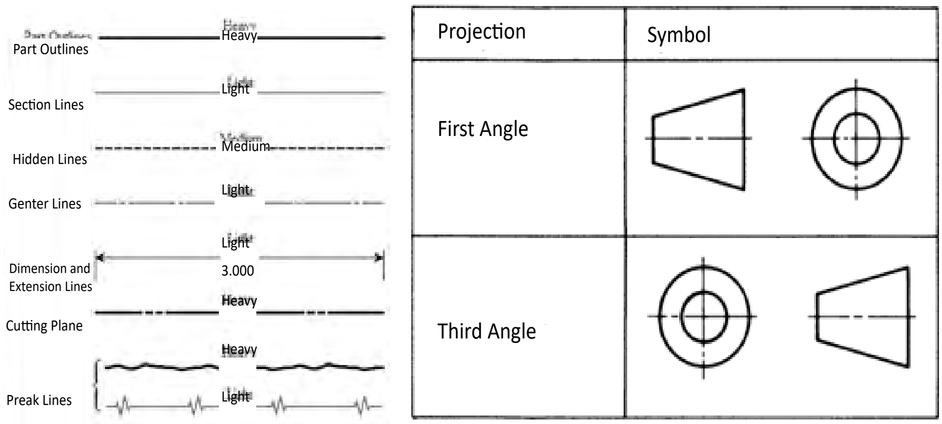


Fig. 1.2.1 Orthographic drawing projection symbols

a. First Angle Projection Method

First angle projection means viewing a body in the first quadrant. In India, at present, generally first angle projection drawings are used. Referring to 1.2.2 of the Tea cup, top view is drawn below front view and left side view is drawn in right side of the front / elevation view:

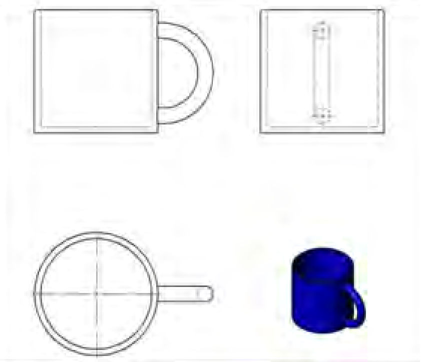


Fig. 1.2.2 First angle projection drawing of a Tea Cup

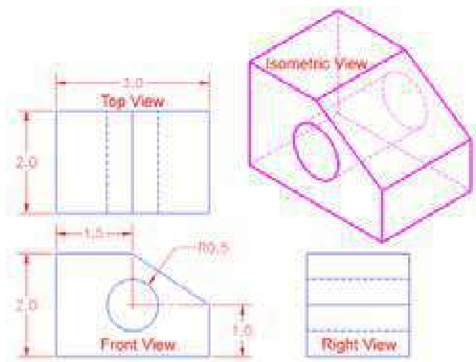


Fig. 1.2.3 Third angle projection drawing example

b. Third Angle Projection Method

Referring to Fig 1.2.3, the object is placed in the third quadrant. Vertical plane is a view from front of the object. Horizontal plane is a view from above the object. Top view is drawn above front view and right side view is drawn in the right side of the front / elevation view.

c. Piping system drawn in both 1st and 3rd angle projection

A simple piping system (consisting of run pipe, tube support welded to a flange, bolted to a stationary steel plate structure) drawn in both first and third angle projection methods has been illustrated in Fig.1.2.4.

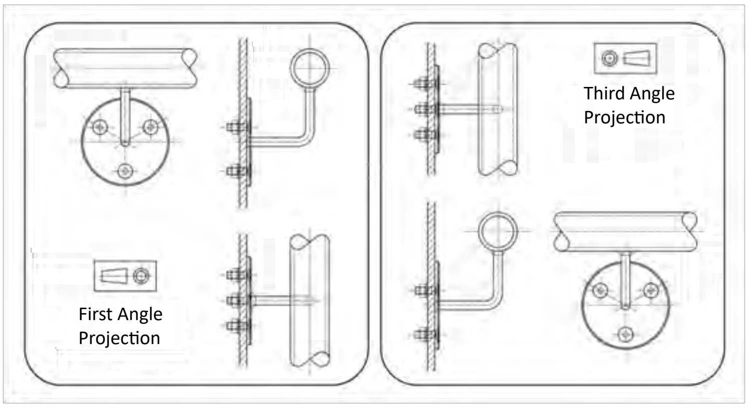


Fig. 1.2.4 – A simple piping system drawn in both 1st angle and 3rd angle projection.

Making Simple Drawings

1. Drawings shall include title block, revision block, notes list, bill of materials, views and sections, zone grids, scales, etc.

a. **Title Block:** Drawings shall include a title block. Contents of title block include project name, drawing title, drawing number, revision number, drawing scale, drawn by, reviewed / checked by, approved by, direction, first / third angle projection symbol, Issue status (such as AFC– Approved for Construction / IFC, Issued for Construction).

b. **Revision Block:** The revisions block is a tabulated list of the revisions (versions) of the drawing, documenting the revision history. Traditional location for the revisions block is the top / adjoining the title block.

c. **Zones / Grids:** Drawings contain letter and number labels along the margins such as A,B,C,D in sides and 1,2,3,4,5,6 along the top and bottom. Names of grids / locations are specified as A5, D2, or B1. This grid identification helps to reference particular areas of the drawing.

d. **Section Views:** Section views are projected views, showing crosssection of the source object along the specified cut plane. These views are commonly used to show internal features with more clarity than may be available using regular projections or hidden lines.

e. Revision locations are represented with clouded area and a triangle with the revision number.

f. Dimensioning in drawing shall be performed with unique practice. Examples of dimensioning has been shown in the Fig. 1.2.5 and 1.2.6.

h. Drawing to scale

1. When a drawing is to be preparded, all dimensions shall be proportional. Otherwise it will look like a cartoon.

2. If a house elevation drawing is to be propared, the drawing sheet shall not be to full height and length / width of the house. Hence, drawings are to be prepared to a reduced scale. All dimensions shall be converted to the convenient scale and drawn.

For example scale 1:20 means,

1mm in drawing represents the true size of 20mm

10mm in drawing represents the true size of 200mm

100mm in drawing represents the true size of 2000mm

For example scale 10:1 means,

10mm in the drawing represents the true size of 1mm

100mm in the drawing represents the true size of 10mm

g. **Dimensioning Sample:** It is a cylindrical solid object 2 inch (50.8 mm) long with major diameter (outside diameter) of 1 inch (25.4 mm) and a step having 0.65 inch (16.51 mm) diameter for 0.4 inch (10.16mm) depth.

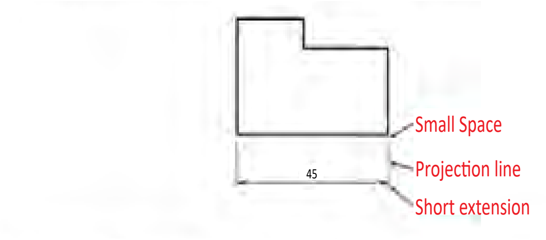


Fig. 1.2.5 Dimensioning system

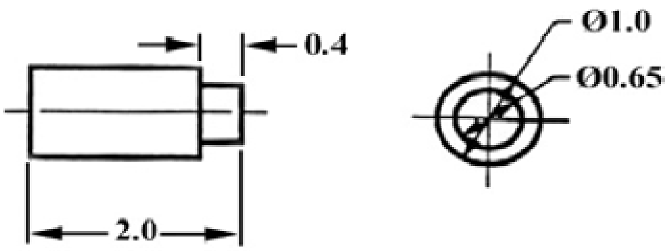


Fig. 1.2.6 Dimensioning(in inch unit) a cylindrical solid object having two different diameters

Spool drawings

A spool is an assembly of fittings, flanges and pipes that are to be prefabricated.

Piping Isometric views showing details and dimensions of all lines are produced from general arrangement drawings. These are called piping spool isometric drawings or simply spool drawings. A spool drawing will contain

- title block information
- the piping schedule
- the orientation symbol
- view of the pipe spool
- dimensions, elevation (height level) and location / position with respect to coordinates
- adjoining pipe spools
- the direction of flow of the conveyed fluid or gas.

Each pipe spool drawing may also list the materials required for fabrication of the spool.

Guidelines for making simple drawings

1. Choose the scale of the drawings considering the drawing size and object size. The scale shall be chosen in views that can be drawn in single sheets.
2. Draw the title block, revision block and grids.
3. Use appropriate pencils 2H, H, HB, etc., to draw the lines, outlines, section line, hidden line, centre line, etc.
4. Study the object and draw the elevation / front view.
5. Draw top / plane view.
6. Draw side / section view.
7. Assign dimensions and dimension lines with ‘H’ pencil and arrow with HB pencil.
8. Show the internal details such as holes, key ways, etc., in dotted line using “H” pencil.

1.2.2 1st and 3rd Angle Projection Drawing

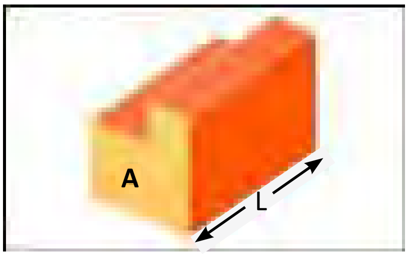
At the end of this exercise, you will be able to:

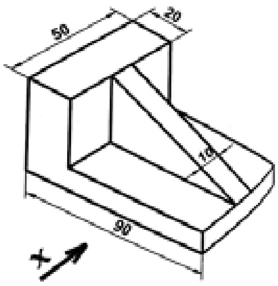
1. draw the 1st angle projection drawing for cylindrical pipe
2. draw the 3rd angle projection drawing of any given object
3. draw the orthographic projection drawing.

Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Geometry box	– 1 No.		
Steel rule	– 1 No.	Paper	–1No.
Set Sqaure	– 1 Set	Pencil	–1No.
		Drawing Sheet	–1No.
Equipment/Machines			
Personal Protective Equipment	– 1 Set		

1. Draw 1st angle projection drawing for a cylindrical pipe of sizes – 10 mm thickness, 220 mm outside diameter and one meter long (Scale 1:5).
2. Draw the 3rd angle projection drawing of the following object, looking at the side A (front view / elevation).
3. Draw the orthographic projection of the following object in 1st angle projection method and then in 3rd angle projection method, looking from X (Scale 2:1).





Exercise

I. Answer the following questions.

1. Draw the first angle projection symbol to be incorporated in the first angle projection drawings.

----

2. How is the axis / symmetry centre line represented in the orthographic projection drawing?

----

3. Distinguish Ist angle and 3rd angle projections.

----

4. What are the typical contents of a piping spool drawing?

----

5. What are the typical contents of the “Title block” of a drawing?

----

6. A drawing has been prepared to a scale of 1:100. If the length, width and height are measured in the drawing as 270mm, 180mm and 190mm respectively, what is the actual length, width and height of the object?

II. State whether the following statements are True or False.

1. Hidden / dotted or short dashed line in orthographic projectional drawing, indicates the features that cannot be seen in the current view.

   True ☐ False ☐

2. Orthographic projection drawings are drawn in a manner in which the length, width and depth are shown in a single view.

   True ☐ False ☐

3. In first angle projection drawing, top view is drawn below the front view and right side view is drawn in the left side of the front / elevation view.

   True ☐ False ☐

4. In revised drawings, revision locations are represented with clouded area and a triangle with the revision number

   True ☐ False ☐

Notes

1.2.3 Illustration of Pipeline System – Isometric Drawings

At the end of this topic, you will be able to:

1. describe various oil and gas pipe and pipeline drawings
2. read and interpret drawings for site / plant piping coordinates, elevation and plane North
3. describe significance of isometric drawings
4. read and interpret isometric drawings
5. prepare isometric drawings.

Major Types of Piping and Pipeline Drawings

Two major types of piping system drawings are

Orthographic – Plans and Elevations

Pictorial – Isometric Views

Orthographic drawings are views (front, side, top, etc.) of a piping system, and called "Piping Arrangements" while they represent piping system. (Select suitable scale.) An orthographic view shows only one side, and therefore multiple drawings (views) are necessary to show a complete piping arrangement.

Orthographic views are not really a best option, as a piping system is to be drawn in several planes (North to South, then down and then to the West, etc.). In an orthographic view, it is not a problem if the pipe runs in one plane. But when a pipe in two or three planes is to be drawn, an orthographic view can be unclear.

Isometric view of an object can be obtained by choosing the viewing direction such that the angles between the projections of the x, y, and z axes are the same, or 120°.

Illustration of Coordinates, Elevations and Plant North

Indicating the starting point of the piping installation site related to the North / South direction, is one of the first steps in setting up a coordination system. Coordinates are normally specified with reference to East or West and North or South directions. Fig 1.2.7 isometric drawing has east coordinate as 360.235 and South coordinate as

177.300 at one end of the spool and E 360.235 and S 180.300 at the other end of the spool. This indicates that both ends are at the same location/ position with respect to East – West direction and the distance between the spool ends are 3000 mm (180.300-177.300) with respect to North-South direction.

Elevations (height locations) are shown as EL + xxxxxx or E.xxxx. In fig 1.2.7, both end elevation (height with respect to datum) is EL =3.200 m which means that both ends are at the same height + 3.200m.

In principle, with a simple reliable compass the direction of the magnetic North can be determined.

In the Fig. 1.2.8 the true North is at 18°. As a draftsman would work with the true North coordinates, he will immediately find out that each line from West to East and from North to South at an angle of 18° must be drawn.

To avoid this, a Plant North will be determined. In the example is Fig. 1.2.8, the true North, 18° is reversed.

General rule is, that the angle between true North and Plant North cannot exceed 45°.

1 = Official reference point

2 = South West angle of new plant

X = East West distance from new plant to reference point

Y = North South distance from new plant to reference point

The highest point of finished grade refers to an official reference point on which all vertical measurements are related.

Isometric View Drawings

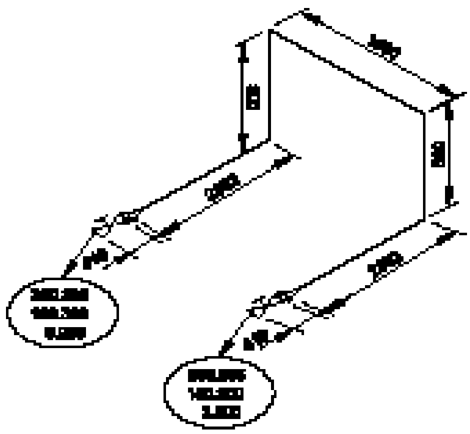


Fig. 1.2.7 Simple isometric drawing of a piping spool

Fig. 1.2.8 Plant North Illustration

1. Introduction to Isometric Drawings

- Piping components are represented on the drawing by simple & stylised symbols which are widely accepted and self-explanatory.
- Isometrics are used in fabrication / shop drawings for pipe fabrication.
- Isometric spool drawings show the pipe spool in a pictorial view. Isometric drawing is a view of an object from a corner angle so that all the different views can be represented.
- Piping isometrics are drawn in a manner in which the length, width and depth are shown in a single view.
- Usually, piping isometrics are drawn with lines of equilateral triangles of 60°.
- Vertical lengths of pipes are calculated using elevations, while horizontal lengths are calculated using north-South and East-West coordinates.

2. Isometric Drawing Direction and Location

- Location and direction help to properly orient the isometric drawing.

- The orientation symbol or 'North arrow' appears on all piping drawings. The orientation symbol is of the utmost importance as it shows the direction of the piping run through the plant. It also shows the position of pipes relative to others and the relationship between pipes and other items of equipment.
- A north arrow gives direction and should always point to the upper-right corner of the drawing.
- South is opposite from North and points downside of the drawing and to the left. West is 90° from North however, in the isometric, it becomes the opposite 120° line. In this case, running up and to the left. East will be opposite to West and will run down and to the right. Pipelines running North/South or East/West will run parallel to the ground unless they are noted as otherwise.
- Coordinates and elevation should also be shown on the isometric drawing.
- Isometric drawings are drawn with hatches to indicate that a pipe runs (rotates) at a certain angle and in a certain direction.

3. Piping Isometric Reading and Interpretation

a. A piping in isometric view, is always drawn as a single line.

b. This single line is the centerline of the pipe and dimensions are measured from that line.

c. The Fig. 1.2.10 shows orthographic view of a butt welded pipe with three sizes (A, B, C).

- Size A is measured from the front to the center line of the elbow / pipe.
- B size is measured from center line to center line.
- C size is like A, measured from the front to the center line of the elbow / pipe.

4. Isometric view drawing preparation

The same object drawn in an orthographic projectional view as in fig 1.2.9 is drawn in isometric view as below.

The above drawing lines is drawn in a simple manner the showing the pipe with black dots. The black dots denote the butt welds. A, B and C are the dimensions of the front to the centre line, the centre line to the centre line and the centre line to the edge, respectively.

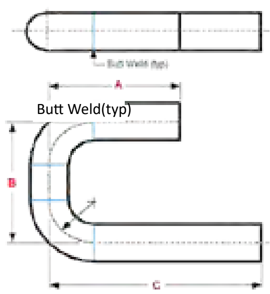


Fig. 1.2.9 Orthographic View (Double line presentation)

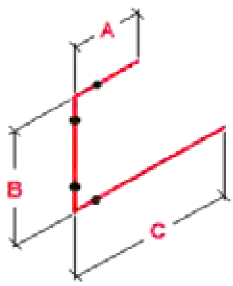


Fig. 1.2.10 Isometric view drawing sample

5. Interpreting Isometric views in more than one plane

i. Below are some examples of isometric drawings. (Fig. 1.2.11 & 1.2.12). The auxiliary lines in the shape of a cube, ensure better visualization of the piping / pipeline routing.

For pipeline which runs through three planes, has flanges at both ends. Routing starting point X (Fig. 1.2.11)

- pipe runs to the East
- pipe runs up
- pipe runs to the North
- pipe runs to the West
- pipe runs down.

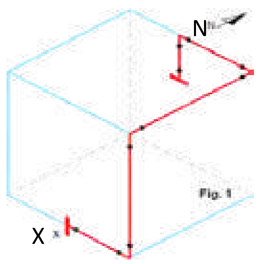


Fig. 1.2.11 Isometric view drawing representation in three planes

ii. Almost identical to the drawing above. A different perspective is shown, and the pipe that comes from above is longer. As this pipe runs behind the other pipe, it is indicated by a break in the line. Routing starting point X (Fig. 1.2.12)

- pipe runs to the South
- pipe runs up
- pipe runs to the West
- pipe runs to the North
- pipe runs down.

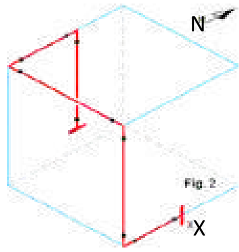


Fig. 1.2.12 Isometric view of different prospective

iii. Pipe that runs through three planes, from one plane to the opposite plane.

Routing starting point X (Fig. 1.2.13)

- pipe runs to the South
- pipe runs up
- pipe runs up and to the North-west
- pipe runs to the North.

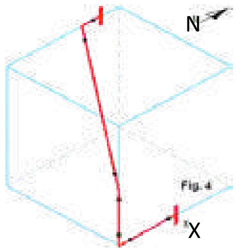


Fig. 1.2.13 Isometric view of a pipe from one plant to opposite plane

6. Hatches on Isometric Drawings

Hatches on isometric drawings are applied to indicate that a pipe runs at a certain angle and direction. Sometimes, with small changes in the hatch, the routing of a pipe is no longer the East, but suddenly becomes the North.

i. Pipe, where the hatch indicates that the middle leg runs to the east.

Routing starting point X (Fig. 1.2.15)

- pipe runs up
- pipe runs up and rolls to the East
- pipe runs up

ii. Pipe, where the hatch indicates that the middle leg runs to the North.

Routing starting point X (Fig. 1.2.16)

- pipe runs up
- pipe runs up and rolls to the North
- pipe runs up.

The above two drawings show that changing from only the hatch, a pipeline receives a different direction. Hatches are particularly important in isometric views.

iii. Pipe, where the hatches indicate that the middle leg runs up and to the North-West.

Routing starting point X (Fig. 1.2.17)

- pipe runs up
- pipe runs up and rolls to the North-West
- pipe runs to the North.

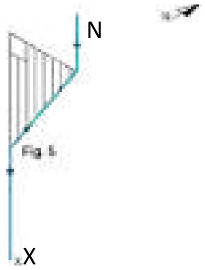


Fig. 1.2.14 Isometric view of piping with rolling and running to east

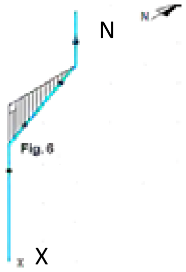


Fig. 1.2.15 Isometric view of piping with rolling and running to east

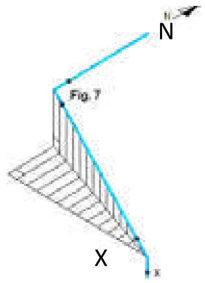


Fig. 1.2.16 Isometric view of piping with rolling north-west

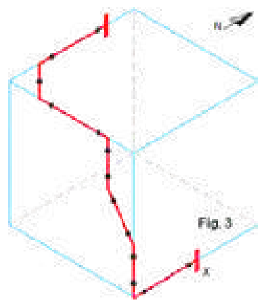
1.2.4 Pipe Spool Fabrication Simulation Practice

At the end of this exercise, you will be able to:

1. read and interpret isometric drawings with respect to pipe flow and rolling direction
2. fabricate pipe spools from raw materials as per the given isometric drawing.

Required	
Tools Instruments: Measuring tape Scale, Angle Bevel protractor, Try-square, Cutting plier.    	**Materials / Components:** MS / Copper solid wire 1.6 or 2 mm diameter – to the required length (500 to 900 mm approx). 

Work Instruction



1. Go through the drawings, read and interpret. North direction has been shown in the drawing as “N”. From this north direction, you can identify other directions.
2. Take a solid wire of the required length,which shall be flexible for bending by hand.
3. Routing starting point X and pipe runs to the South horizontally. Cutting plier can be used to twist / bend the wire.
4. Bend the wire to 90˚ up from one end, so as to show that the pipe runs up vertically.
5. After a certain distance, bend the wire to 45˚ inclination to vertical to show that the “pipe runs up and bows to the West”.
6. After a certain distance of inclined portion, bend the wire towards vertical up to show that the “pipe runs up” vertically.
7. Again a after certain proportional distance, bend the wire at 90 ˚ to show that the “pipe runs to the West” horizontally.
8. After a certain distance, bend the wire 90˚ to vertical up to show that the pipe “goes up” vertically.
9. Finally, bend to 90 ˚ along and towards North, horizontally. Check the angle using a bevel protractor.
10. Ensure that the bend wire end is parallel to the initial wire direction started at point ‘X’.

Figure 1. 2.12 shows a pipe spool that runs through three planes. There is a bow (rolling) in one plane 45 ˚ towards West .

Tips

- During practice, all lengths need to be proportionate and approximate. “Not to scale”.
- Bend angle is also approximate for practice. Try Square and angle protractor can be used if needed.
- **Safety:** Take care of sharp edges of solid wire while twisting as it may pierce / injure the hand. Use appropriate PPE.

1.2.5 Practising Isometric Drawing

At the end of this exercise, you will be able to:

1. draw the isometric drawing
2. make pipe spool model using solid wire.

Practical

Requirements **Tools/Instruments**		**Materials/Components**	
Steel rule	– 1 No.	Paper	–1No.
Set Sqaure	– 1 Set	Pencil	–1No.
Geometry Box	– 1 No.	Drawing Sheet	–1No.
		Steel solid line / Copper wire	–1No.
Equipment/Machines			
Personal Protective Equipment	– 1 Set		

1. Draw an isometric drawing for the piping system with 2” inch diameter piping when has flanges at both ends and has four 90° elbows of 2” inch diameter size duly getting welded with five pipe pieces. Routing shall starts at the entry point of the fluid at the lower point and flows towards cast. 250 mm long pipe runs to the East then 500 mm long pipe runs up 500 mm long pipe to the North. 260 mm long pipe runs to the West 150 mm pipe runs down.

Exercise

I. Answer the following questions.

a. Describe isometric drawings.

----

b. Explain drawing coordinates, elevation and plant north illustration.

C. Distinguish between isometric and orthographic drawings.

II. State whether the following statements are True or False.

1. Isometric drawing is a pictorial representation type of drawing.

   True ☐ False ☐

2. Hatches in isometric drawings indicate that a pipe runs at a certain angle.

   True ☐ False ☐

3. In isometric view, the pipe is always drawn as a double line.

   True ☐ False ☐

4. In piping isometric drawing length, width and depth are the same.

   True ☐ False ☐

Notes

1.2.6 Piping and Pipeline System – Plot Plan, GA Drawing, P & ID

At the end of this topic, you will be able to:

1. describe plot plan, general arrangement, piping arrangement drawings
2. explain the significance of single and double line representation
3. determine the contents of P & ID drawing.

Plot Plan

Plot Plan is generally drawn to a scale. Plot plan gives an overview (top view) of the entire plant. All roads, buildings, equipment, entrance, etc., will be shown on a plot plan. It also contains arrow indications to show the true North direction and Plant North. Plot plans may be overall plot plan called site plan in which only major items will be shown or detailed plot plan which may be drawn for each elevation level.

Detailed Plot Plan: Detailed Plot Plan gives an overview (top view) of a part of a process plant. Generally, it shows a part of a certain area, floor or unit.

General Arrangement (GA) / Equipment Arrangement Drawings

These drawings indicate the locations / general arrangement of main equipment in the plant. The main piping items, valves, and fittings are also indicated in the General Arrangement (GA) drawings. Most often the piping is indicated using a top view. Sometimes, a side view of the pipe rack is also presented on the GA drawing.

Equipment Arrangements are drawings which show the top and side view of a part of a process plant. The top view is similar to a detailed Plot Plan, except that only the equipment is shown. Equipment arrangements drawing shows the equipment in a particular area, and sometimes, a few details around a specific device.

Plot Plans and equipment arrangements are resources to help determine relative and specific positioning of equipment on a process plant, related to the plant North.

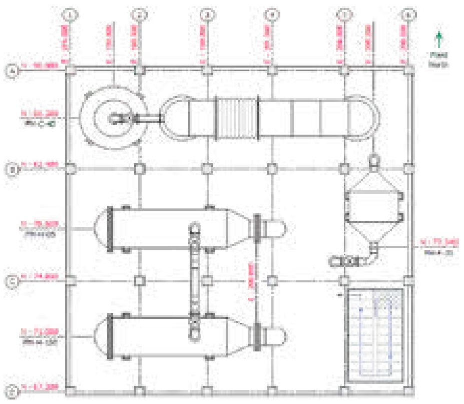


Fig. 1.2.17 Top view 4th floor detailed plot plan at EL.129200

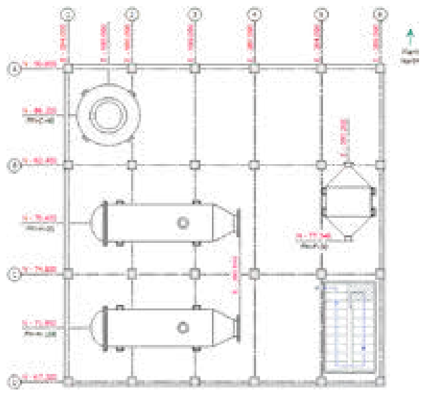


Fig. 1.2.18 -4th floor equipment arrangement at EL.121900

Piping Arrangement Drawings

Pipelines on a piping arrangement are shown as single lines and double lines. In single line representation only the center line of the pipeline is drawn using a solid line. In double line representation the actual size to scale is drawn with center line marked in chain dotted lines. When orthographic projection is used, pipelines may be drawn as either single line or double line drawings.

a. Double line presentation

Double line representation shows the two edges of the pipework and is usually used for pipes over Ø 350. Double line drawings show more graphic representation of the pipework; however, these are more difficult and more expensive to produce.

b. Single line presentation

Single line orthographic drawings represent the pipe by its centre line only, which is drawn as a continuous heavy line (usually the darkest line on the drawing). The size of the pipe is shown by drawing a representation of the pipe end to scale, either at the end of the line or some other convenient place.

- On single-line diagrams, all fittings except reducing fittings are drawn as single lines. Flanges are shown as thick lines drawn to the scale, outside the diameter of the flange.
- For flanged joints, a small gap between dimension lines will be shown to indicate a gasket.
- Valves are shown with identification number and a handwheel is drawn with the stem fully extended. If a valve is lever operated, then the movement of the handle's position is given.
- Dimensions for flanged valves are given to the flange faces, while non – flanged valves are dimensioned to the center lines of their stems.

Piping and Instrumentation Diagram

1. Piping and Instrumentation Diagram (P & ID) is a detailed diagram in the process industry which shows the piping, vessel / equipment, interconnection of process equipment and the instrumentation and control devices used to control the process. In the process industry, a standard set of symbols is used to prepare drawings of processes. They usually contain the following information:
    - process piping sizes and identification
    - pipe classes or piping line numbers
    - flow directions
    - interconnections references, vents, drains, reducers, swages
    - permanent start up, flush and bypass lines
    - mechanical equipment and process control instrumentation and designation (names, numbers, unique tag identifiers)
    - valves and their identifications (isolation, shut off, relief and safety valves)
    - control inputs and outputs (sensors and final elements, interlocks)
    - miscellaneous – vents, drains, flanges, special fittings, sampling lines, reducers, etc.
    - interfaces for piping class changes
    - identification of components and subsystems delivered by others, such as vendors, suppliers.

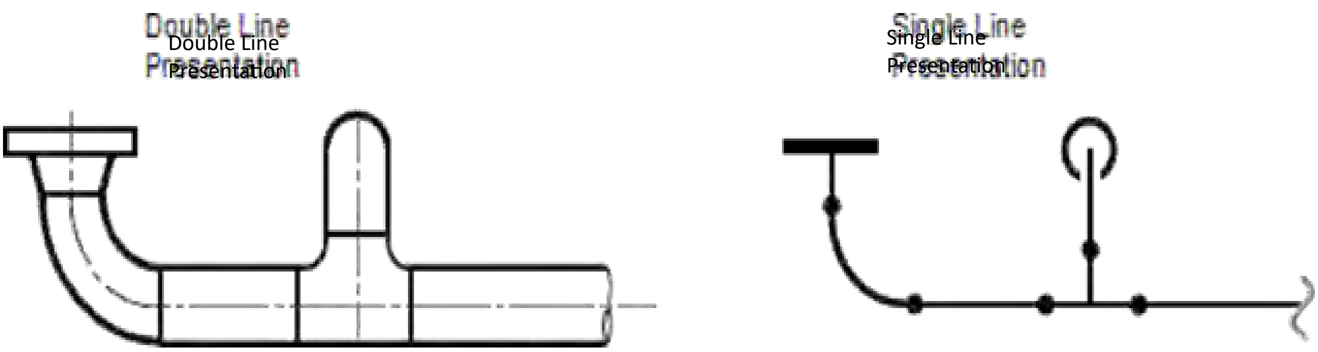


Fig. 1.2.19 Example of a single line and double line representation of a piping

2. P & ID provides a schematic representation of the piping, process control, and instrumentation which shows the functional relationships among the system components. The P & ID also provides important information needed by the constructor and manufacturer to develop the other construction input documents (the isometric drawings or orthographic physical layout drawings).

3. The P & ID provides direct input to the field for the physical design and installation of field-run piping. It accomplishes this by showing all the piping, equipment, principal instruments, instrument loops, and control interlocks.

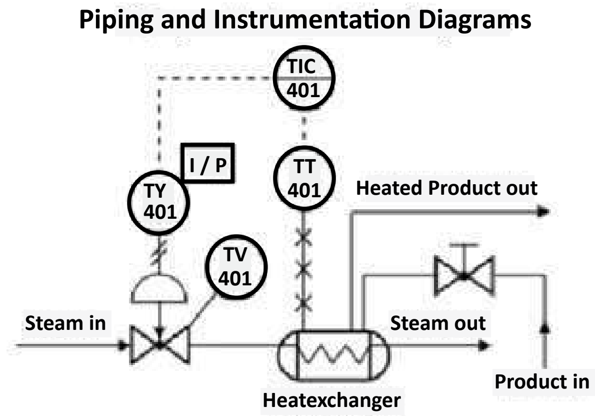


Fig. 1.2.20 Large image of a simple Piping & Instrument Diagram

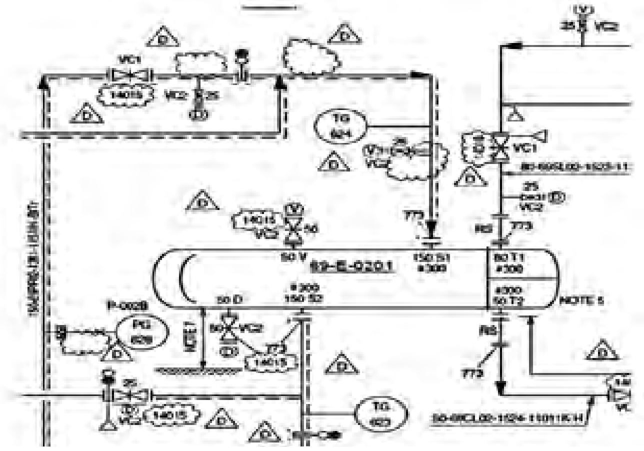


Fig. 1.2.21 Sample Piping & Instrument Diagram

Exercise

I. Answer the following questions.

1. Describe plot plan and general arrangement drawings.

----

2. List out any six contents of P & ID drawings.

----

3. Distinguish between single line and double line representation drawings.

II. State whether the following statements are True or False.

1. Pipelines may be drawn as either single line or double line drawings in the orthographic projection.

   True ☐ False ☐

2. P & ID will not show flow direction.

   True ☐ False ☐

3. P & ID provides a schematic representation of the piping, process control, and instrumentation

   True ☐ False ☐

4. On single line diagrams, reducing fittings are drawn as double lines.

   True ☐ False ☐

Notes

1.2.7 Reading Pipe Chart, and Preparing Bill of Materials

At the end of this topic, you will be able to:

1. describe pipe and tube
2. specify pipe size / diameter in different nomenclatures
3. read pipe chart / pipe thickness table
4. recognise dimensional tolerances
5. prepare bill of materials.

1. Pipe and Tube

International standards do not differentiate tube and pipe. Pipe is a pressure tight cylindrical hollow item, used in the piping system to transport liquid, gas and rarely solids. Tube is the common word used for hallow sections, like square tube, rectangular tube and round tube. Pipe is the word used for round tube only. However, the manufacturing industry provides the differentiation of pipe and tube based on diameter duly stating that tubes are always assigned with OD (all sizes) and pipes with inside diameter basis.

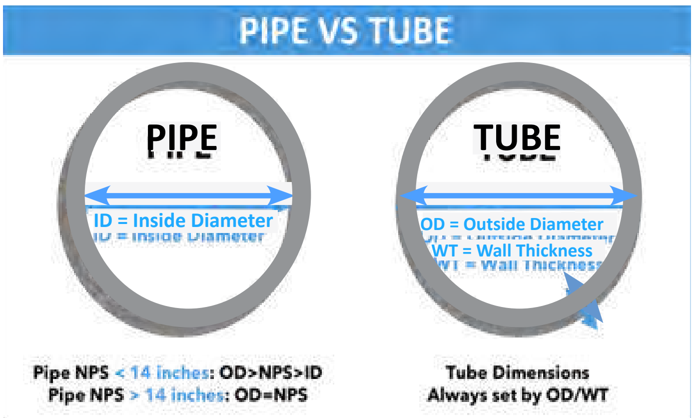


Fig. 1.2.22 Sample Piping & Instrument Diagram

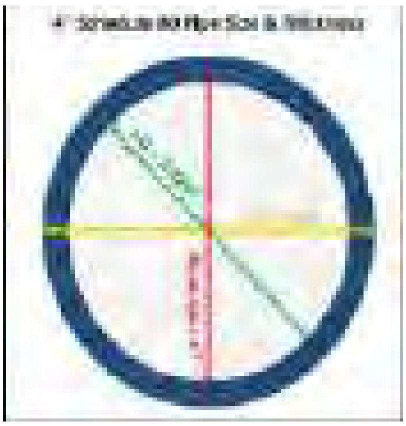


Fig. 1.2.23 – Pipe - OD & ID indication

2. Specifying pipe sizes – Pipe diameter

Pipe diameter sizes are specified with different abbreviations such as – NPS, NB, DN, etc.

a. **Nominal pipe size (NPS)** is the size of the pipe diameter based on inches. 6” pipe means 6” is the nominal size of that pipe.

For pipe sizes, NPS 14 and above outside diameter is same as NPS, meaning that NPS 14 (DN350) and above pipe OD is corresponding to the Nominal Size of a pipe.

NPS 1/8 (DN 6) to NPS 12 (DN 300) pipe is based on fixed outside diameter (OD). So, any increase in the wall thickness decreases the inside diameter (ID) of the pipe.

Table1 Specifying nominal pipe size

OD in Inch	OD in MM	Thickness in Inch	Thickness in mm	ID in inch	ID in mm
For NPS 2” Schedule 40 pipe					
2.375NPS	60.3	0.154	3.91	2.067	52.5
For NPS 4” Schedule 40 pipe					
14	350	0.438	11.13	13.124	333.3

Table 2 Specifying nominal pipe size

Nominal Pipe Size	Diameter Nominal	Nominal Pipe Size	Diameter Nominal
NDN (mm)nches)	DN (mm)	NPS (inches)	DN (mm)
1/8	6	20	500
1/4	8	22	550
3/8	10	24	600
1/2	15	26	650
3/4	20	28	700
1	25	30	750
1 ¼	32	32	800
1 ½	40	36	900
2	50		
2 ½	65		
3	80		
3 ½	90		
4	100		
5	125		
6	150		
8	200		
10	250		
12	300		
14	350		
16	400		
18	450		

From the table 2, it can be observed that for NPS 2, Pipe ID is near pipe NPS and for NPS 14 pipe OD is the same as NPS.

Pipe size‘inch’ dimension to ‘mm’ by multiplying it with 25.4 and rounding as follows.

i. outside diameter above 16 inches rounded to nearest 1 mm

ii. outside diameter 16 inches and below rounded to nearest 0.1 mm

iii. pipe wall thickness is rounded to nearest 0.01 mm

b. **Pipe Nominal Bore (NB):** NPS is frequently referred as an NB (Nominal Bore). As such, there is no difference between NB and NPS.

c. **DN (Diameter Nominal) Pipe Sizes:** DN or Diameter Nominal is International designation (SI or Matric Designator). 2” pipe is simply mentioned as DN 50. There is no change in other dimensions when the term DN is used.

d. Pipe diameter comparison is given in Table 2.

3. **Specifying pipe sizes – Pipe Thickness:**

Table 2.3 – Standard Pipe thickness designation

For Carbon Steel and Wrought iron Pipe as per ASME B36.10	5, 10, 20, 30, 40, 60, 80, 100, 120, 140, 160, STD, XS, XXS
For Stainless Steel Pipe as per ASME B36.19	
STD (Standard) and Schedule 40 has same thickness up to NPS 10 (DN 250)	
Above NPS 10 STD have a wall thickness of 3/8 in. (9.53 mm)	
XS has same thickness as Schedule 80 for up to NPS 8 (DN 200)	
Above NPS 8 XS have a wall thickness of ½ in. (12.5 mm)	

Table 2.4 pipe thickness chart (ASME B 36.10)

Nominal Pipe Size (NPS)		Outside Diameter		Nominal Wall Thickness																			
				Sch 40		Sch 60		XS		Sch 80		Sch 100		Sch 120		Sch 140		Sch 160		XXS	
A	B	MM	IN	A	B	MM	IN	A	B	MM	IN	A	B	MM	IN	A	B	MM	IN	MM	IN
8	1/4	13.7	0.540	2.24	0.088	-	-	3.02	0.119	3.02	0.119	-	-	-	-	-	-	-	-	-	-
10	3/8	17.1	0.675	2.31	0.091	-	-	3.20	0.126	3.20	0.129	-	-	-	-	-	-	-	-	-	-
15	1/2	21.3	0.640	2.77	0.109	-	-	3.73	0.147	3.73	0.147	-	-	-	-	-	-	4.78	0.188	7.47	0.294
20	3/4	26.7	1.05	2.87	0.113	-	-	3.91	0.154	3.91	0.154	-	-	-	-	-	-	5.56	0.219	7.82	0.308
25	1	33.4	1.32	3.38	0.133	-	-	4.55	0.179	4.55	0.179	-	-	-	-	-	-	6.35	0.250	9.09	0.358
32	$1^{3/2}$	42.2	1.66	3.56	0.140	-	-	4.65	0.191	4.85	0.191	-	-	-	-	-	-	6.35	0.250	9.70	0.382
40	$1^{3/2}$	48.3	1.9	3.68	0.145	-	-	5.08	0.200	5.05	0.200	-	-	-	-	-	-	7.14	0.281	10.15	0.400
50	2	60.3	2.38	3.91	0.154	-	-	5.54	0.218	5.54	0.218	-	-	-	-	-	-	8.74	0.344	11.07	0.436
65	$2^{1/2}$	73.0	2.68	5.16	0.203	-	-	7.01	0.276	7.01	0.276	-	-	-	-	-	-	9.53	0.375	14.02	0.552
80	3	88.9	3.5	5.49	0.216	-	-	7.62	0.300	7.62	0.300	-	-	-	-	-	-	11.13	0.438	15.24	0.600
90	$3^{1/2}$	101.6	4	5.74	0.226	-	-	8.08	0.318	8.08	0.318	-	-	-	-	-	-	-	-	-	-
100	4	114.3	4.5	6.02	0.237	-	-	8.56	0.337	8.56	0.337	-	-	11.13	0.438	-	-	13.49	0.531	17.12	0.674
125	5	141.3	5.56	6.55	0.258	-	-	9.53	0.375	9.53	0.375	-	-	12.70	0.500	-	-	15.88	0.625	19.05	0.756
150	6	165.3	6.62	7.11	0.250	-	-	10.97	0.432	10.97	0.432	-	-	14.27	0.562	-	-	18.26	0.719	21.95	0.664

a. Pipe schedule is one way of mentioning pipe wall thickness. Schedule 40 means a pipe thickness designator. If the schedule number increases, the thickness also increases. Schedule 80 pipe is thicker than schedule 40 pipe. For stainless steel piping, ASME has introduced different schedule numbers for stainless steel pipe and fittings. "S" suffix is introduced for SS pipe. For example, 10S.

b. Three more symbols are used for piping thickness 'STD, 'XS' and 'XXS'.

- STD is identical to SCH 40 for NPS 1/8 to NPS 10, inclusive.
- XS is identical to SCH 80 for NPS 1/8 to NPS 8, inclusive.
- XXS wall is thicker than SCH 160 from NPS 1/8" to NPS 6" inclusive, and
- SCH 160 is thicker than XXS wall for NPS 8" and larger.

c. Standard Pipe Schedule are as per ASME B36.10 and B36.19 as summarised in table 3 and 4.

4. **Pipeline diameter and thickness tolerances**

Unless specific tolerances are stipulated and specified in the drawings or project specific specifications, respective manufacturing standards shall be followed for diameter and thickness tolerances for all pipes and fittings. As an example, pipeline standard -API 5L diameter and thickness tolerance tables

5. **Calculation of Pipe Inside Diameter** (ID) is done with the help of Outside Diameter (OD) and thickness of the pipe by using formula given below.

Pipe ID = [Pipe O.D. – (2×Pipe wall thickness)

For example, 2.1: If Pipe OD is 610 mm and wall thickness is 16 mm, find out pipe ID

Pipe ID = 610-2 x16 = 578 mm.

Bill of Materials preparation for piping / pipeline fabrication

- Bill of Materials is a list of raw materials, sub-assemblies, intermediate assemblies, sub-components, parts, and the quantities needed for piping / pipeline manufacturing, construction and installation. It is the basis for preparation of Material Take Off list (Part No).
- Bill of Materials:
- is essential for piping materials planning
- helps to accurately plan material requirements
- helps for material sourcing,
- makes easier material forecasting and expediting easier
- makes the estimation of material requirements, material and products cost easy
- helps to plan in advance about which materials that are available in stock and the materials that are to be purchased
- helps to prepare Master Production Schedule / tasks / targets in sequence considering materials availability in stock / purchase duration.

Bill of Material Preparation

i. Bill of materials shall include – Part / Item number, List of items, description, size, unit of measure, material specification / standard, quantity etc. It shall list all piping / pipeline components shown in piping / pipeline drawings. While preparing bill of materials, there shall be adequate length of pipe for field joints allowance, cutting and edge preparation etc. Additional / extra bolts, nuts, gaskets and other fasteners shall be listed considering the testing requirements, spare parts and replacement after testing.

ii. Part Number shall be assigned to each part or assembly to quickly reference and identify parts.

iii. Unique name / material item description shall be given to each part or assembly to help distinguishing between similar parts and identify specific parts more easily.

iv. Quantity / number of parts or items shall be specified for each assembly or sub – assembly. Extra / additional quantities for testing requirements, spare parts requirements and replacement after testing shall be specified.

v. Unique, consistent and standard unit of measure such as feet, inches, millimetre or meter shall be specified.

vi. Necessary notes shall be incorporated for more clarity / explanation.

1.2.8 Pipe Spool Fabrication-Bill of Material (BOM) Preparation

At the end of this exercise, you will be able to:

1. Prepare Bill and Materials for the given pipe spool fabrication.

Practical

Required Tools / Instruments	Required Materials / Components:
Scale for drawing lines to form table.	Isometric drawing, paper and pen

Work Instruction

1. Prepare a table with columns for part number, material description and size, material standard with specification, size with unit of measurement and quantity.
2. Add 100 mm extra length for each pipe spool free end, either for cutting allowance or for field adjustment.
3. Check for number of same size pipes and group same size pipes together.
4. Add same size pipe length together and calculate total running length for each pipe size.
5. Specifythe length in "size and unit" column. If the pipe length is more than 6 meter, it is usual practice to calculate the number of pipes considering each pipe length as 6 meter long.
6. Count the number of flanges of same material, same size and same rating together and add the quantity in the BOM. Repeat this exercise for each group (size, rating, material) of flange.
7. Similarly, count the quantities of fittings elbows, weld o lets etc for each group and fill the BOM.
8. Calculate the quantity of fasteners (stud bolts and nuts) of each diameter /size , grade, material etc.
9. Add 10 % spare for each fasteners group to keep in the store as "spare item" and use later during any repair / replacement at the time of operation / maintenance.
10. Similarly, calculate the gaskets required and specify in the BOM.
11. First, list all pipes in the BOM on pipe size descending order. Then list all fittings, flanges, bolts and nuts, valves, gaskets duly leaving a blank row between each material type.

BILL OF MATERIAL / MATERIAL TAKE OFF				
Part No	**Item / Material Description and size & unit**	**Material Std / Spec**	**Qty**	**Remarks**
1	2"Ø sch 80 Pipe -3.5 meter long	ASTM A 106 Gr B	1	
2	¾ " Ø sch 80 pipe- 300 mm long	ASMT A 106 Gr B	1	
3	2"Ø-300# WNRF BW RTJ flange sch 80	ASTM A 105 / B16.5	1	
4	¾" Ø -3000# WNRF flange sch 80	ASTM A 105 / B16.5	2	
5	2" Ø-45˚ LR BW Elbow Sch 80	ASTM A 234 WPB	2	
6	¾" Ø-90˚ LR BW Elbow Sch 80	ASTM A 234 WPB	1	
7	2"x ¾"Ø Branch outlet – Sch 80	ASTM A 105	2	
8	2"Ø –300# RTJ – Metallic gasket R23	ASTM B16.20	2	
9	¾"Ø – 3000# Spiral wound gasket	ASTM B16.20	6	
10	¾" Ø – 300# ball valve	ASTM B 16.33	1	
11	5/8" Ø -110 mm long stud bolt – B7	ASTM A 193	8	
12	5/8" Ø- nut- 2H	ASTM 194	16	
13	5/8" Ø- 65 mm long stud bolt- B7	ASTM 193	20	
14	5/8" Ø- nut -2H	ASTM 194	40	

Tips

Safety: The installation and putting in to operation are only to be executed by qualified, competent and experienced personnel, who are acquainted with installation and mounting as well as the applicable standards.

1.2.9 Prepare Bill of Material (BOM)

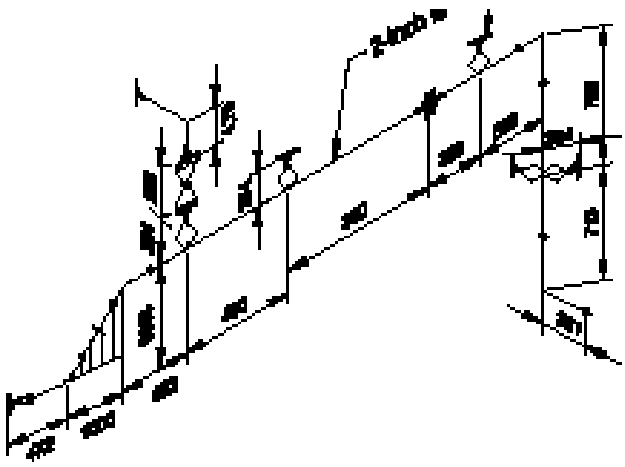
At the end of this exercise, you will be able to:

1. prepare bill of material for piping isometric drawing
2. prepare bill of material for the pipe support drawing.

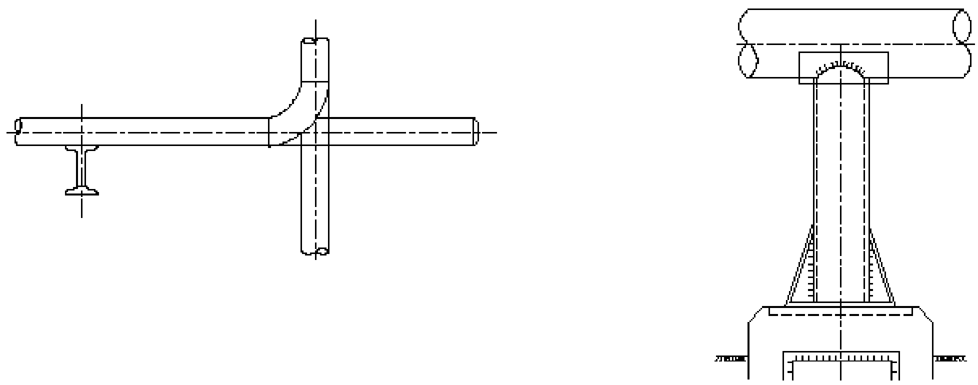
Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Steel rule / Measuring Tape	– 1 No.	Paper	–1No.
Vernier Caliper	– 1 No.	Pen	–1No.
		Isometric drawing (piping)	–1No.
		Isometric drawing (piping support)	–1No.
Equipment/Machines			
Personal Protective Equipment	– 1 Set.		

1. Look at the piping isometric drawing below and prepare BOM (Bill of material).



2. Look at the pipe support drawing below and prepare BOM (Bill of material).



Sl. No.	Material Description	Size	Quantity	Remarks

Exercise

I. Answer the following questions.

1. List out any five uses of Bill of Materials.

----

2. List out any five contents of Bill of Materials.

----

3. Calculate Pipe Outside Diameter (OD) for the pipe of Inside Diameter (ID) 580 mm and Thickness of 15 mm.

----

4. Describe pipe and tube.

----

5. Describe the pipe sizing abbreviations, NPS, NB, DN.

II. State whether the following statements are True or False.

1. For pipe sizes NPS 14 and above, Outside Diameter is the same as NPS.

   True ☐ False ☐

2. Referring to B36.10 thickness table, 10"NB -sch 60 wall thickness is 12.07 mm.

   True ☐ False ☐

3. Bill of Material contains material price / rate.

   True ☐ False ☐

4. DN50 means Nominal Outside Diameter 50mm.

   True ☐ False ☐

5. In general nominal pipe thickness specified as "STD" for carbon steel piping, it will be identical to sch 40.

   True ☐ False ☐

Notes

1.2.10 Standard Symbols of Piping Drawings – Welding Symbols

At the end of this topic, you will be able to:

1. read and interpret weld symbols
2. prepare weld joint surfaces / edges as denoted by the weld symbol
3. perform pipe fitting works to the required weld joint configuration as represented by the weld symbol.

Introduction

Piping / pipeline system includes pipe, flanges, elbows, tees, gaskets, bolts, nuts, support plates, valves, standard supports, lining pads, pressure gauges, temperature indicating gauges, etc. These shall be drawn with lines and standard symbols. Pipe fitter shall have adequate knowledge about various piping, welding, fittings, instruments, standard symbols, etc., to read and interpret the drawings easily.

Fig. 1.2.24 Fillet weld symbol information

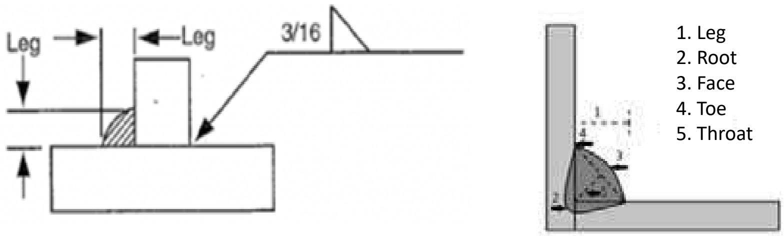


Fig. 1.2.25 Basic Welding Symbols-AWS

Complete Joint Penetration

Since many applications require welds providing complete joint penetration (CJP), there are several ways to specify this condition. One way is to use an arrow, a reference line, and add CJP in the tail of the symbol. A second way to specify the complete joint penetration is to include a single groove-weld symbol or double groove-weld symbols (must be the same weld symbol on both sides of the reference line).

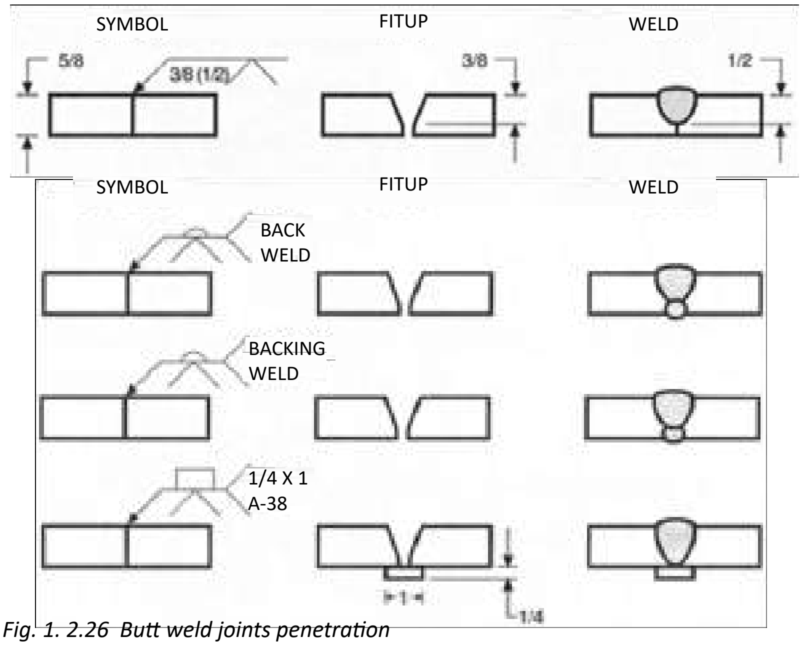


Fig. 1. 2.26 Butt weld joints penetration

Butt Joints Edge Preparation and Weld Type

Important butt joints weld preparation grooves / edge preparation with respect to weld type is as given in Fig. 1.2.28. Important weld symbols, associated joint / edge preparations and respective weld illustrations are also given.

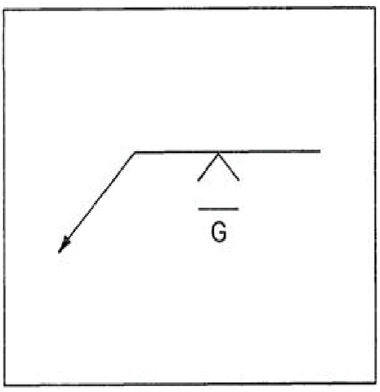


Fig. 1.2.27.-Finish and contour symbols.

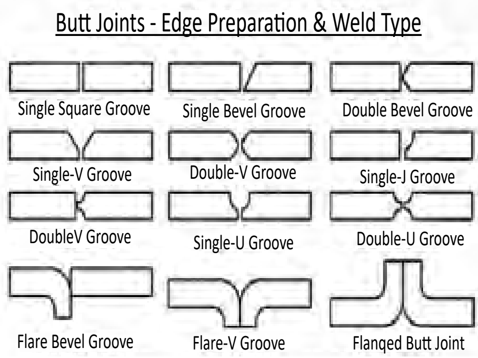


Fig. 1.2.28 Butt Joints- Edge preparation and Weld Type

Exercise

I. Answer the following questions.

1. Draw any four complete joint penetration weld symbols and draw the required edge preparations.

----

2. What is the information conveyed through weld symbols?

----

3. Draw a weld symbol for welding 6 inch NB 12.7 mm thickness pipe to be welded all around a field with a dummy plate of 200 mm square 16 mm thickness. Complete joint penetration weld with 45 degree single bevel 9 mm depth, to be welded from the pipe outside.

Notes

1.2.11 Standard Symbols of Piping Drawings

At the end of this topic, you will be able to:

1. read and interpret piping symbols
2. list the type of instruments to be installed and prepare components accordingly.

Line Symbols

The process lines are the lines where the process media actually flows through. They are represented by different types of lines. On a complete P & ID, each line will be labelled with a line number. Process lines are bolder than other lines such as those that represent electric, pneumatic or data signals. Important line symbols used to prepare drawing, are as given below:

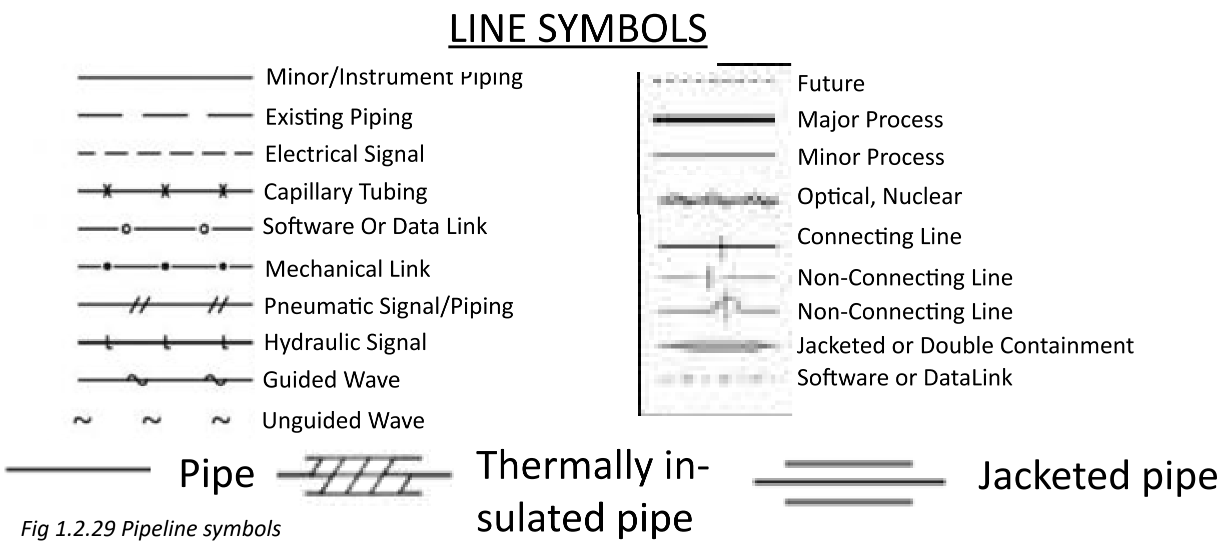


Fig 1.2.29 Pipeline symbols

To indicate pipes crossing that are not physically connected on drawings, a small "hump" to show one going "over" the other, or break one of the lines very near the other to show it going under it is used. This is not a physical representation of the actual pipes. In fact, they may not even cross in the actual system. It is merely a method to keep the lines separate when they must cross in the drawing.

Piping Isometric Symbols

The general piping symbol is always shown as the darkest line on the drawing. For example, a section of piping with a reducer or other fitting would be shown with the piping drawn darkest and the fitting represented by a lighter line.

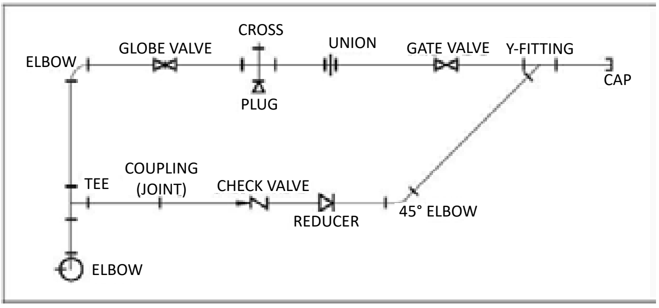


Fig. 1.2.30 Sample piping drawing with standard symbols

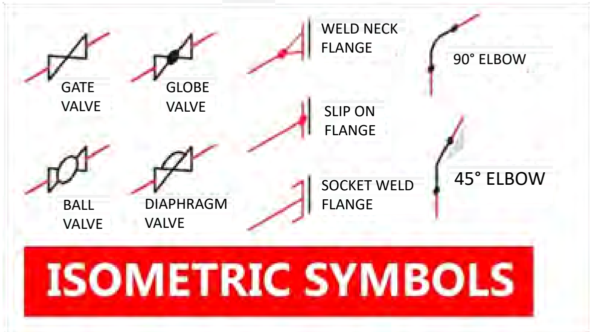


Fig. 1.2.31 Sample Isometric symbols

a. All piping drawings indicate the direction of flow with an arrow. Sample piping drawing and sample isometric symbols are shown in Fig 1.2.30 and 1.2.31.

b. Flange symbols and corrosponding images are depicted in Fig 1.2.32.

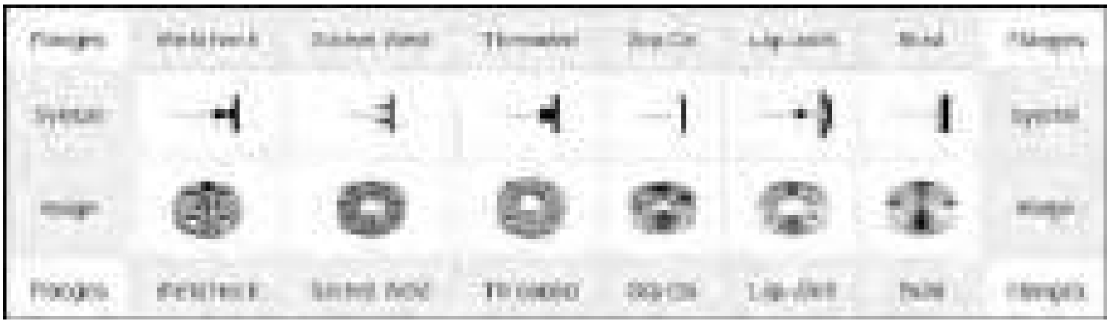


Fig. 1.2.32 T Flanges symbols and Images

c. Isometric symbol representation of various valves based on mode / method of operation and function, have been illustrated in Fig. 1.2.33.

d. Summary of valve symbols are as shown in the following Fig. 1.2.34.

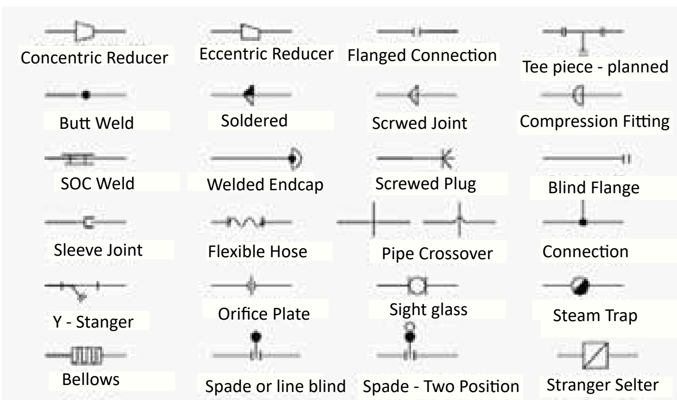


Fig. 1.2.33 – Line fittings symbols

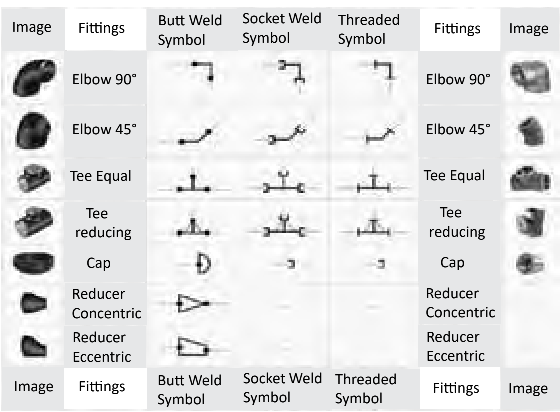


Fig. 1.2.34 Piping fittings illustration

Fig. 1.2.35 Valves Illustration

e. Isometric symbols of line fittings are shown in Fig. 1.2.35.

f. Isometric symbol representation of various fittings based on type of connections such as butt welding, socket welded or threaded connections have been illustrated along with images.

g. Piping Instruments Symbols for Isometrics, are as given below.

Fig. 1.2.36 Piping Instrument Symbols for Isometrics

Exercise

I. Answer the following questions.

1. Draw any five "line symbols" used in drawings, with name / description of each line.

----

2. Draw the isometric representation (symbol) of concentric reducer.

----

3. Draw the isometric symbol for globe valve.

----

4. Draw the isometric symbol for ball valve.

----

5. Draw the symbol of weld neck and slip on flanges.

----

6. Draw the elbow and Tee butt weld symbols.

----

7. Draw the simple free hand sketches of eccentric reducer.

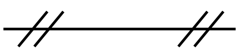
II. State whether the following statements are True or False.

1. In piping instrument symbols for isometrics, TT stands for Temperature Transducer.

   True ☐ False ☐

2. In Piping isometric drawings, flow controller is demmoted by FC into the circle.

   True ☐ False ☐

3. The line symbol for pneumatic signal / piping is 

   True ☐ False ☐

Notes

1.2.12 Hangers and Pipe Support Drawings

At the end of this topic, you will be able to:

1. define and classify different types of pipe supports
2. read and interpret pipe supports drawings
3. explain the purpose of pipe supports and their applications.

Introduction

Piping shall be fixed, supported, anchored or guided to prevent undue line deflection, excessive vibration and to protect piping and connected equipment from excessive loading and expansion stress.Pipe support location and identification numbers shall be marked on the piping drawings. Type of pipe supports include

Hangers (Rod type), Hangers (Spring type), Anchors, Saddles, Rollers, and Sliding supports, Guided type pipe supports.

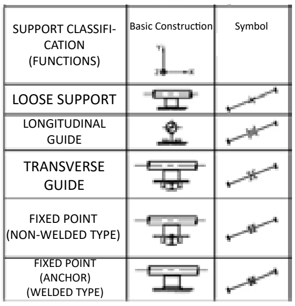


Fig. 1.2.37 Pipe support symbols (Typical)

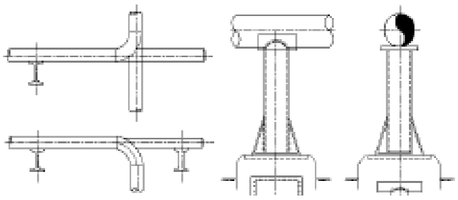


Fig. 1.2.38 Different type of pipe supports

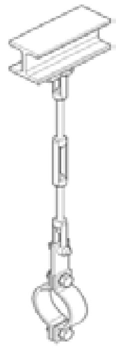


Fig. 1.2.39 Typical rod hanger

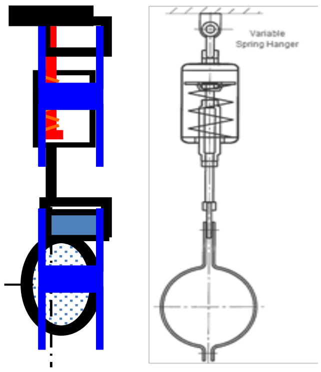


Fig. 1.2.40 Constant &Variable spring hanger and supports

Pipe supports symbols (typical) of isometric drawings are as given in fig 1.2.38. In general, pipe supports are grouped based on the type of pipe supports and single drawings are prepared duly tabulating different sizes.

Pipe support – Hanger Type

Based on the nominal pipe size, pipe fitter shall get all details and dimensions from the pipe support drawings duly reading and effectively interpreting drawings. Major pipe support types are illustrated and briefed in the next subsection.

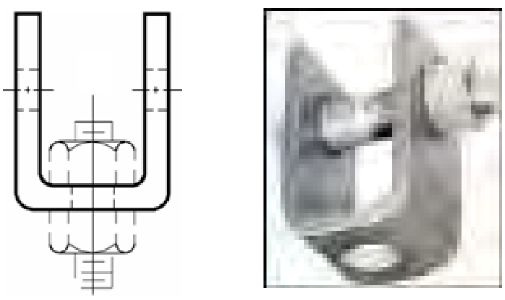


Fig 1.2.41 Lug type welded attachment

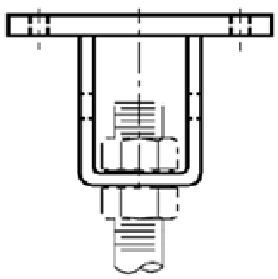


Fig 1.2.42 Plate lug

1. Hanger Rods Type

Hanger is a vertical pipe support with clamp, vertical rod and bolting. It may be a rigid, variable spring or constant support hanger. Refer Fig 1.2.41.

Rod hangers or pipe hangers are attached to the pipe by a U bolt, a clevis, a pipe clamp, etc., to structural steel located above the piping. (Refer Fig 1.2.43 and Fig 1.2.44)

The rod hanger provides support in the vertical direction and allows limited motion in the horizontal direction. Adjustment in the vertical direction can be accomplished by threads or a turnbuckle.

2. Constant Spring Hanger

In constant spring hanger, the load remains constant throughout its travel range. But in variable spring hanger, the load varies with displacement. Spring hangers are used when thermal displacements are upwards and piping system is lifted off from the support position.

3. Variable spring hangers and supports

1. Anchors

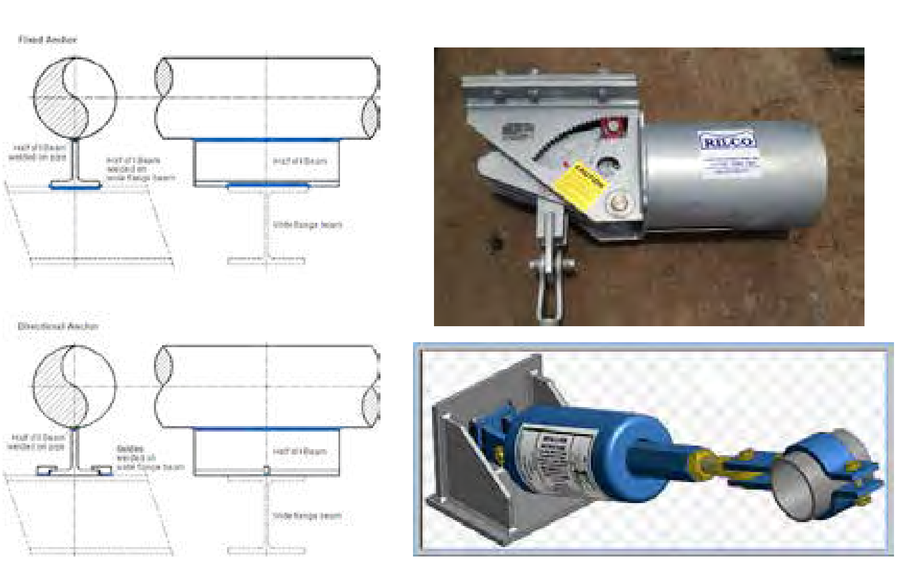


Fig. 1.2.43 Fixed and Directional Anchors

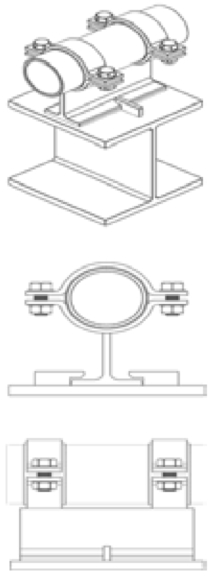


Fig. 1.2.44 Typical Pipe Shoe

Anchor is a rigid support that restricts movement in all three orthogonal directions and all three rotational directions. This is usually welded stanchion, that is welded or bolted to steel or concrete. Two types of anchors exist: fixed and directional. Refer Fig 1.2.45. Fixed anchors are used in locations where all movement of a line must be prevented. The most common way to anchor a pipe is to weld the pipe directly to a support or structural member. If the pipe to be anchored is insulated, first a pipe shoe is welded to the pipe and then the shoe is welded to the steel structure.

2. Stanchion/Pipe Shoe

A pipe shoe is a structure consisting of a saddle and integral base that is used to support the pipe by transmitting the load or forces to the adjacent structure. It can be simply fixed on steel structures.

3. Dummy leg supports

A dummy leg is an extension piece welded to an elbow to support a pipe line, and rests or anchors on some steel member. (Refer Fig 1.2.45)

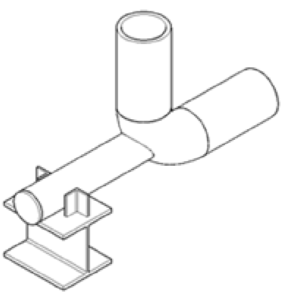


Fig. 1.2.45 Typical dummy leg / Trunnion pipe support

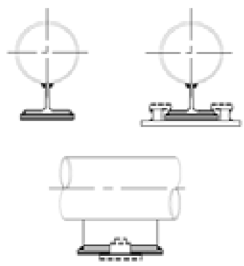


Fig. 1.2.46 Pipe Guides

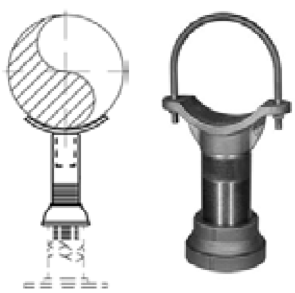


Fig. 1.2.47 Adjustable pipe support

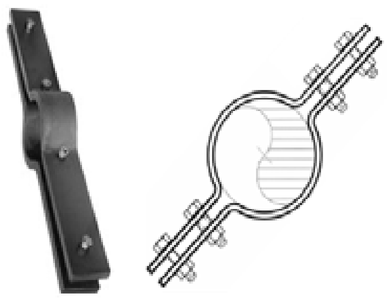


Fig 1.2.48 Extension pipe or riser clamp

4. **Guides**

   When total restriction of pipe movement is not required, pipe guides are used. (Refer Fig. 1.2.46). Pipe guides confine movement along the pipe's linea axis. Pipe guides are used, primarily, to maintain proper line spacing in a pipe rack and they prevent lateral or sideway movements. The guide allows the pipe to slide lengthwise between two angle shapes. When the pipe is supported on shoes, the angle shapes are positioned on either side of the shoe.

5. Miscellaneous pipe support devices are shown in Fig. 1.2.49 to 1.2.51.

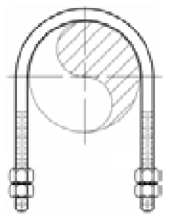


Fig. 1.2.49 Round bend U-bolt

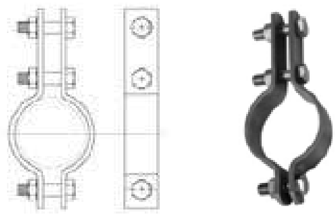


Fig. 1.2.50 Double side bolting pipe clamp

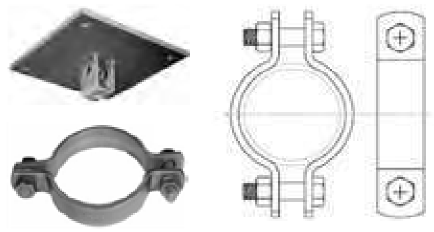


Fig. 1.2.51 Piping clamping and bolting support

Exercise

I. Answer the following questions.

1. Name any four types of pipe supports used in the piping system.

2. Name the type of pipe supports used in insulated piping system.

3. Explain fixed anchors and directional anchors.

4. Differentiate constant spring hanger and variable spring hanger supports.

II. State whether the following statements are True or False.

1. Anchor is a rigid support that does not restrict any piping movement.

   True ☐ False ☐

2. Pipe supports are devices which transfer the load from the pipe to the supporting structures.

   True ☐ False ☐

3. Spring hanger pipe supports are used to compensate for slight vertical movement in the piping system

   True ☐ False ☐

4. Fixed anchors are used in locations where movement of a piping line must be prevented.

   True ☐ False ☐

Notes

Unit: 1.3 Mathematical Skills for Pipe Fitting

Unit Objectives

At the end of this unit, you will be able to:

1. recognise mathematical applications in pipe fitting
2. apply mathematical skills with respect to pipe fitting during fabrication, laying, stringing, etc.
3. carryout calculations related to piping system such as cones, elbows / bends

1.3.1. Piping Mathematical Applications

At the end of this topic, you will be able to:

1. perform unit conversions
2. recognise basic arithmetic, algebra and geometry for pipe fitting
3. calculate area, volume, angles and length.

1. Metric System

Most countries use the metric system. The metric system uses the meter and linear units based on the meter, gram as its standards of measurement and prefixed by kilo, centi and milli, etc . All multiplies and subdivisions of the meter are directly related to the meter by a factor of ten. The more often used abbreviations for linear measurement are the Centimeter "cm" and Millimeter "mm".

Tips

a. Kilometer (km), 1 km = 1,000 meter
b. Meter (m), 1 m = 10 dm = 100 cm = 1,000 mm
c. Centimeter (cm), 1 cm = 10 mm

2. Inch System (Imperial System) Units

Inch system is mostly used in where things are measured in feet, inches and pounds. The smallest linear measurement unit in the Inch System is the inch "in". 1/1000 of inch is called 'Thou'. Other units are the feet "ft" and the yard "yd".

Tips

a. 1 yd = 3 ft = 36 in
b. 1 ft = 12 in
c. 1 m = 39.37 inches

3. Conversion of units

Inch to Inch Fraction conversion: 1/16" = 1 divided by 16 = 0.0625"

Inch Fraction to mm conversion : 0.0625" x 25.4 mm = 1.58 mm

1000 litre = 1 m^3

1 yd = 0.9144 m

1 ft = 0.30480 m

1 in = 25.4 mm

Arithmetic and its Applications

Knowledge of arithmetical calculation is needed in all areas of pipe fitting works. Fitter shall be able to perform arithmetic calculations related to piping system. Piping system requires to calculate length, diameter, perimeter (circumference), bending angles, elevation, coordinates, etc. Sometimes, pipes and cones may be required to be fabricated from plates. Hence fitter shall be able to mark the required development sizes in the plate so as to cut and roll the pipe or cones. The four basic arithmetic operations to be performed in piping works are addition, subtraction, multiplication, and division. If Pipe outside diameter (OD) and inside diameter (ID) are given, then pipe thickness will be

½ (OD-ID). If pipe OD and Thickness (t) are given , then pipe ID will be OD- 2t.

For example, if Pipe OD is 508 mm and pipe ID is 480 mm, then pipe thickness is ½ (OD-ID) = ½ (508-480) = 14 mm

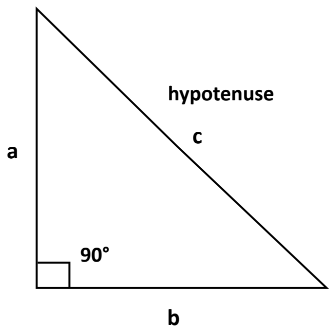
For example, if pipe OD is 610 mm and wall thickness is 20 mm, then pipe ID will be OD- 2t = 610-40 = 570 mm.

Algebra and its Applications

Basic Algebraic formulas applicable for piping include:

- $a^2 - b^2 = (a - b)(a + b)$
- $(a+b)^2 = a2 + 2ab + b^2$

The above formulae will be applicable while calculating coordinates and elevations and third side of right angled triangle. In a right angled triangle, if one side 'b' and hypotenuse 'c' dimensions are given, the other side dimension can be calculated.



a. $a^2 + b^2 = c^2$

b. $a^2 = c^2 - b^2$

c. $a^2 = (c+b)(c-b)$

d. $a = \sqrt{(c+b)(c-b)}$

Fig. 1.3.1 Right Angle Triangle - side dimension calculation

For example, in the above triangle, the dimension of the hypotenuse is 13 cm and that of one side is 5 cm, calculate the dimension of the other side.

By applying the above formula $a = \sqrt{(c+b)(c-b)}$,

$$a = \sqrt{(18x8)} = \sqrt{144} = 12$$

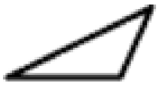
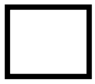
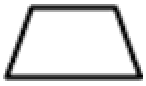
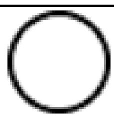
The dimension of the other side is 12 cm.

Knowledge, of geometry is essential for the pipe fitter to perform piping fabrication and installation.

A circle is a geometric form of which every point on the outside of the circle is the same distance away from the center. The distance around the edge of the circle is called the circumference. The distance from one side of the circle to the other, going through the center of the circle, is the diameter. Two times the radius is the diameter of the circle.

1. Formulae for calculating the area circumference

Important formulas for area and circle circumference calculations are as tabulated below:

Shape	Formulas for Area (A) and Circle Circumference (C)
Triangle 	A = ½bh = ½ x base x height
Square 	A = a x a = a^2 Where 'a' is side dimension of the Square
Rectangle 	A = lw = length x width
Trapezoid 	A = ½ (b_1 + b_2)h = ½ x sum of bases x height
Parallelogram 	A = bh = base x height
Circle 	(A = π value is 3.1416 or 3.142) A = πr^2 = π X Square of radius C = 2πr = 2 π radius C = πd = π X radius ('π' value is 3.1416 or 3.142)

For example 3.4: Calculate the area of trapezium shaped pipeline trench when bottom width of the trench is 400 mm, top width trench is 600 mm and the trench height is 350 mm.

Formula for trapezium area is A = ½ (b_1 + b_2)h = ½ x sum of bases x height

Applying the given values, trench area is ½ (400 + 600) x 350 =175 000 mm^2 = 0.175 m^2

2. Perimeter / Circumference Calculation

a. Perimeter of a square: s + s + s + s, where 's' is length / size of one side

b. Perimeter of a rectangle: l + w + l + w, where 'l' is length &'w' is width

c. Perimeter of a triangle: a + b + c, a, b, and c are size / lengths of the 3 sides

3. Volume Calculation:

a. Volume of a cube: s × s × s where 's' is length / size of one side (All sides are equal in cube)

b. Volume of a rectangular box: l × w × h, where 'l' is length & 'w' is width and 'h' is dimension of height

c. Volume of a sphere: (4/3) × π × r^3, where 'r' is radius of sphere and π value is 3.1416

d. Volume of a cylinder: π × r^2 × h, where 'r' is radius of the circle of the base and 'h' is height of the cylinder.

Note: For calculation of pipe volume, inside diameter of the pipe shall be taken into account.

For example, if inside radius of pipe is 200 mm and pipelength is 1500 mm, calculate the volume of the pipe in m^3.

Formula for calculating volume of cylinder is π × r^2 × h

Applying the given values, volume of pipe is 3.1416 x 0.2^2 x 1.5= 0.1884 m^3.

4. Sector Arc length and Area Calculation

i. Length of an arc: The length of the arc is just the radius "r" times the angle "θ" where the angle is measured in radians. To convert from degrees to radians, multiply the number of degrees by π/180.

ii. Area of a sector: The area of the sector is half the square of the radius ‘r’ times the angle ‘θ‘ where the angle is measured in radians.

For example, if radius of segment is 750 mm and angle is 70˚, Calculate the arc length and sector area.

i. Formula to calculate, Length of Arc = rθ

Cube

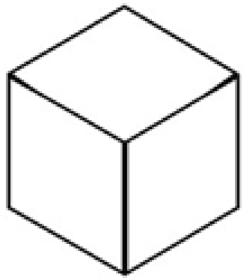


Fig. 1.3.2 Cube

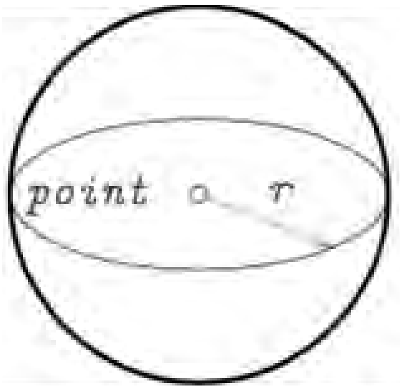


Fig. 1.3.3 Sphere

Cylinder

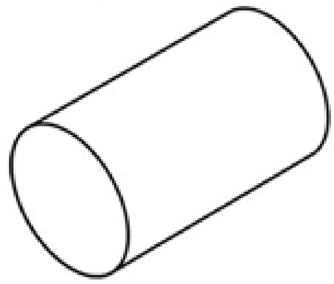


Fig. 1. 3.4 Cylinder

Substituting given values, Length of Arc = 750 x 70 x 3.1416 /180 = 916.3 mm

ii. Formula to calculate sector area = $\frac{1}{2} r^2 \theta$

Substituting values, sector area is = $\frac{1}{2} \times 750^2 \times 3.1416 \times 70 / 180 = 343612.5\ mm^2 = 0.3436\ m^2$

5. Angles calculation

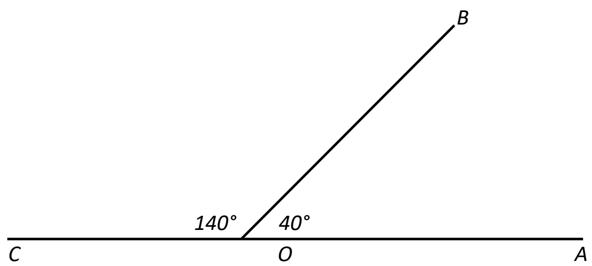
The more familiar unit of angle measurement is “degrees”. A circle is divided into 360 equal degrees, so that a right angle is 90°.

Adjacent Angles: Angles that lie on either side of a common arm are said to be “adjacent”.

For example, ∠AOB and ∠BOC have the arm BO in common. So, ∠AOB and ∠BOC are adjacent angles.

The sum of adjacent angles forming a straight line is 180º. Two such angles are also known as supplementary adjacent angles.

The sum of the three angles of triangle is 180º.



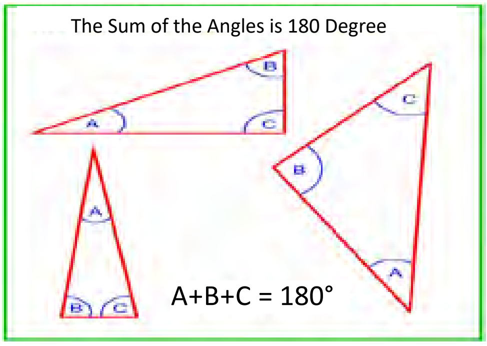


Fig. 1.3.5 Triangles- Sum of the Angles explanation

6. Trigonometry and Formulae for Right Angled Triangles

Trigonometry is the study of relationships that deal with angles, lengths and heights of triangles and relations between different parts of circles and other geometrical figures. Applications of trigonometry are also found in engineering and piping / pipeline installation.

Right-angled triangles have Hypotenuse, Base and Perpendicular. The longest side is known as the hypotenuse, the other side which is opposite to the angle is Perpendicular and the third side is Base. The six trigonometric functions are sine, cosine, secant, cosecant, tangent and cotangent. All the trigonometric ratios are based on the dimensions of the sides of the triangle and the angle of the triangle.

The most important formulae in trigonometry are those for a right triangle. If θ is one of the acute angles in a triangle, then the sine of theta is the ratio of the opposite side to the hypotenuse, the cosine is the ratio of the adjacent side to the hypotenuse, and the tangent is the ratio of the opposite side to the adjacent side.

i. The sine of the angle, $\text{Sin } \theta = \dfrac{\text{the length of the opposite side}}{\text{the length of the hypotenuse}}$

ii. The cosine of the angle, $\text{Cos } \theta = \dfrac{\text{the length of the adjacent side}}{\text{the length of the hypotenuse}}$

iii. The tangent of the angle, $\text{Tan } \theta = \dfrac{\text{the length of the opposite side}}{\text{the length of the adjacent side}}$

When angles of right angled triangle are 90 degree and 45 degree, then the ratio of the sides are 1:1: $\sqrt{2}$

When the angles of right angled triangle are 30 degree, 60 degree and 90 degree, then the ratio of the sides are 1: $\sqrt{3:2}$

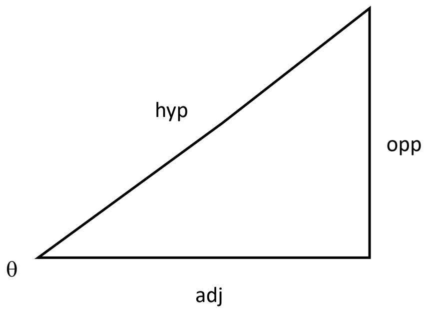


Fig. 1.3.6- Right Angle triangles Trigonometry

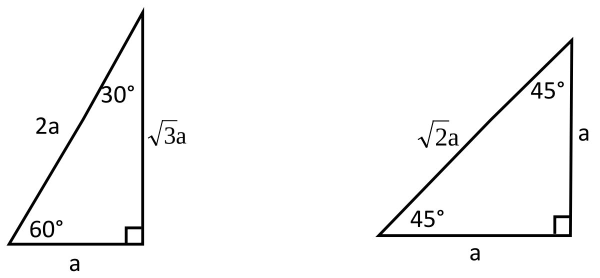


Fig. 1.3.7 Easy way of calculating the sides dimensions of 45˚ and 60˚ right angle triangle

Besides the above, there's important Pythagorean formula that says that the square of the hypotenuse is equal to the sum of the squares of the other two sides.

Exercise

I. Answer the following questions.

1. The base dimension of a triangle is 200 mm and height is 120 mm, what is the area of triangle? (Ans 12000 mm^2)

----

2. In right angled triangle, dimension of the hypotenuse is 20 meter and that of one side is 12 meter, what is the dimension of the third / other side?

----

3. A trapezoidal trench has been constructed for pipeline installation with bottom base as 500 mm and top base as 800 mm with a height of 400 mm. What is the cross–sectional area of the trench? (Ans 260000 mm^2)

----

4. Convert 2552.7mm into inch.

----

5. Convert 36 inch into millimetre.

----

6. What is the formula for calculating the volume of a sphere?

II. State whether the following statements are True or False.

1.Knowledge of geometing is not essential for pipe fitter to perform piping fabrication.

True ☐ False ☐

2. Length of an arc is the radius r times the angle θ where the angle is measured in radians.

True ☐ False ☐

3. The sum of the three angles of a triangle is 180˚.

True ☐ False ☐

4. 1 km = 1,00000 milli meter.

True ☐ False ☐

Notes

1.3.2 Piping System – Calculation Dimemsions

At the end of this topic, you will be able to:

1. able to calculate pipe diameter using both metric system and English system
2. calculate pipe bend radius and other dimensions.

Calculation of Length and Diameter of the piping system

1. Calculation of pipe diameter from pipe circumference

The constant pi, designated by the Greek letter π, is the ratio of the circumference to the diameter of a circle. Circumference equals pi times the diameter of a circle.

Pipe circumference can be measured using measuring tape. Measuring tapes are available in inch units and millimetre units. Pipe circumference can be measured using available tape and then converted to the required unit by unit conversion section.

Dividing circumference by 'π' value 3.1416, the pipe diameter can be obtained.

For example, calculate the plate size (developed length & width) required in both metric and English system to fabricate a pipe to have 1800 mm inside diameter, 16 mm wall thickness and 3000 mm length.

Pipe ID = 1800 mm

Pipe TK = 16 mm

Pipe length = 3000 mm

To calculate the required length and width of the plate

Pipe mean diameter = Pipe ID + TK

= 1800 + 16

= 1816 mm

$$\frac{1816}{25.4} = 71.5 \text{ inches.}$$

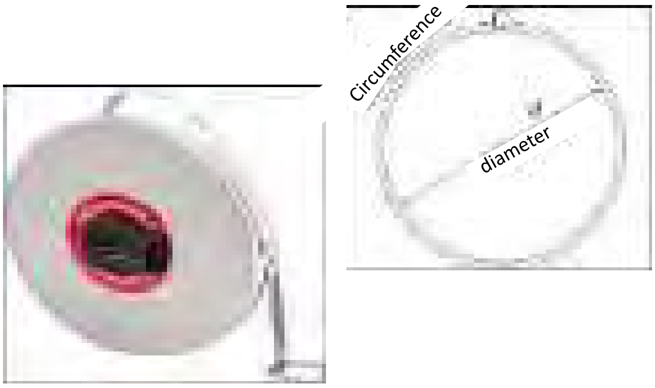


Fig. 1.3.8 Circumference measurement using measuring tape

Tips

Instructor has to explain how to read "tapes and measuring scales"

Pipe mean circumference = 3.1416 x 1816

= 5705 mm

$$\frac{5705}{25.4} = 224.6 \text{ inches}$$

Pipe mean circumference = required plate length

Pipe long = 3000 mm = (118.1 inches) = required plate width

Hence, the required plate size in mm = 5705 x 3000 x 16 mm.

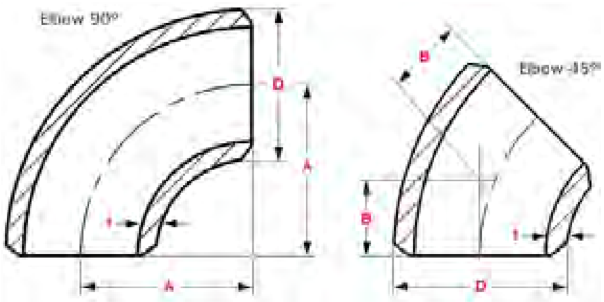
Hence, the required plate size in inches = 224.6 x 118 x 0.63 inches.

Calculation of Pipe Bends Dimensions in Piping

Dimensions of bends shall be calculated based on mean radius and bend angle. General formula for calculation of circumference for parts of Circles: C = π d x segment angle /360.

1. Standard Elbows

Standard Elbows are manufactured mostly by forging and are readily available in the market. In case of forged fitting which is referred to as elbow, the sizes are standardised as 1D, 1.25D or 1.5D . These size elbows are the most widely used.



A. Radius of standard bend

t. Thickness of standard bend

B. Mean size of standard bend

D. Outside diameter of standard bend

Fig. 1.3.9. 90° and 45° standard elbow fittings

2. Straight Pipe length calculation for 90° Bends

The length of pipe (arc) in any bend depends on the following:

degrees in angle of bend

length of bending radius

The length of arc in a pipe bend is measured along the center line of the pipe. The radius is also measured as extending to the centerline.

Length of Arc, when radius of Bend is R, L = R*2*π * θ /360.

This formula can be used for any size of bend angle. There may be a difference of few millimeters in the finished dimension due to elongation depending on the wall thickness and the method of bending including hot / induction bending. Typical pipeline has 90° bend.

a. In figure 3.11 dimension 'D' is the mean radius of bend. 'F' is the straight length at one of the bend and 'G' is the straight length of the other side of the bend. 'B' is outside diameter and 'C' is inside diameter of the pipe.

b. Length of pipe required is = G + (2 x π x D x 90) ÷ 360 + F

For example, calculate the pipe length required if mean radius of bend is 500 mm, straight length at one of bend is 200mm and the straight length of other side of bend is 250 mm.

Length of straight pipe required is =200 + (2 x π x 500 x 90) ÷ 360 + 250 = 200 +785+250 = 1235 mm.

3. Determining the pipe length for 45˚ single offset cold bends

With reference to the figure 1.3.12, the total length shall be computed as below:

T = X1 + L + Y1 = 237.9 + 117.8 + 256.1 = 611.8

This is applicable when the bend is made from pipe material.

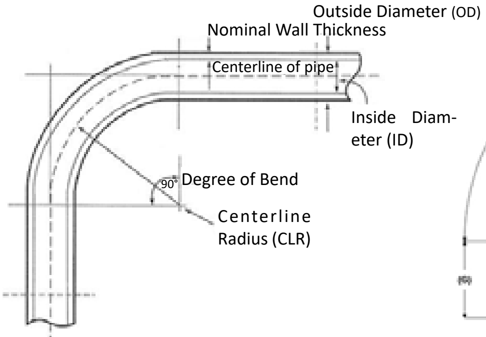


Fig. 1.3.10 Illustration of 90° pipe bend

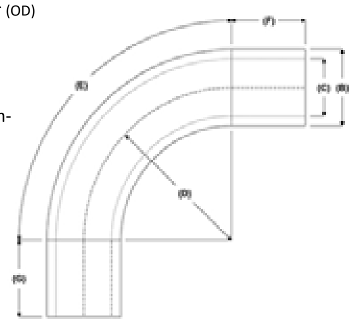


Fig. 1.3.11. Calculation of straight pipe length for making bends

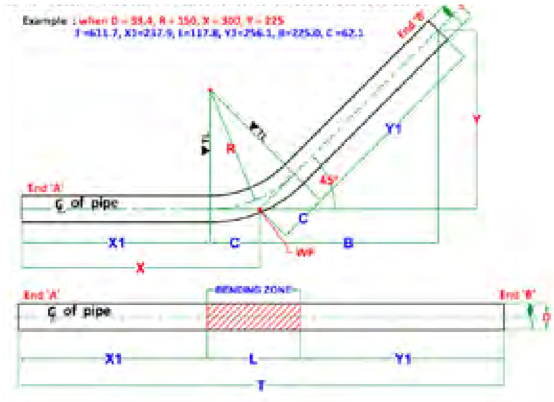


Fig 1.3.12 Determining straight length pipe requirement for 45° single offset cold bends

4. Determining the pipe length of a piping system having rolling offset

In a piping system, when a pipe direction changes in both the horizontal and vertical planes, it is called rolling offset. To visualize the travel of the pipe, imagine a three dimensional box with the pipe entering at one corner and exiting at the farthest diagonal corner. The nomenclatures in fig 1.3.13 are self-explanatory.

Step 1 Calculating the true offset

"True offset" is found using Pythagoras theorem. The "offset squared" plus the "rise squared" will equal the "true offset squared". Then take the square root of the result to get the true offset.

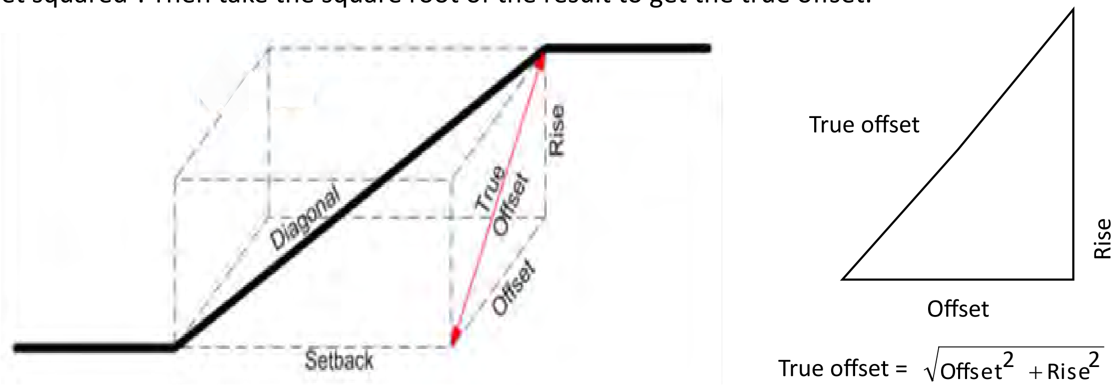


Fig. 1.3.13 Straight length pipe requirement for pipe having rolling offset in vertical and horizontal plan

Step 2 Finding the set back and diagonal

Once true offset is known, determine the setback and diagonal center to center measurements. See the table below for the most common fitting constants.

Fitting angle	60˚	45˚	22.5˚
Diagonal = true offset X	1.155	1.414	2.613
Setback = true offset X	0.577	1.000	2.414

V. Branch Connections

a. The Right Angled equal Tee: To develop the pattern for the branch pipe which is forms a right angled tee joint is to draw the semicircle at the end of the branch pipe, which represents half the circumference or girth of the pipe. Divide the semicircle into six equal parts and name the points 1 to 7. From these points project lines perpendicularly upto the end of the pipe, and on the line ABC joint. Then, set off the base line in the pattern and mark off the parts 1’2’3’4’5’6’7’.....1”, equal to the parts those around the semicircle. From these are marked points on the base line. Now, from the points on the joint line ABC draw horizontal lines into the pattern to cut the perpendiculars from the baseline. The curves drawn through these points in the pattern A’B’C’B”A” diagram should give the true form of the joint line. The full outline of the pattern is now completed.

The shape of the hole in the cross pipe can be developed by projecting the points on the joint line ABC in the elevation. Extend the lines upwards at right angles to the centre line TL. On the middle line, mark off equal distances to those on the semi-circle as at 1’,2’,3’,4’,5’,6’ and 7’. Through these points, draw lines at right angles to those drawn upwards and draw the curves through the points of meeting as shown in the diagram. Similarly, if the curve B’C’B” in the pattern can be repeated on the opposite side of the line B’B”, a contour similar to the hole will be obtained.

b. Right Angled Tee of unequal diameter pipes: To develop the pattern, describe semicircles on the bases of the front elevation and the end elevations and divide each of them into six equal parts, and number them as in the front elevation, from 1 to 7. It can be observed that the outside point numbered 1 in the front elevation will become the middle point in the end elevation. From these points on the semi-circles scribe lines perpendicular to the bases and produce them to cut the major pipe above. From the points where they cut the circle of the major pipe, from D to B, in the end elevation, horizontally project lines to meet the corresponding perpendicular lines in the front elevation. The curve drawn through the meeting points, as from A to B to C, will give the line of intersection. To “unroll” the pattern, horizontally project the base line, and mark off twelve equal parts as from 1’ to 1” equal to those round the semi-circles. Next project the points on the major pipe circle from D to B into the pattern horizontally. From these points 1’,2’,3’,4’,5’,6’,7’...1”, on the base line in the pattern, erect lines of perpendiculars to meet those horizontally projected from the major pipe circles. The curve drawn through these points A’,B’,C’,D’,A”, will give the contour of the intersection line in the pattern.

For the hole contour in the major pipe, produce the perpendicular lines in the front elevation, as shown in the diagram above the major pipe. Take the spaces round the curve from D to B in the end elevation, and then mark them off along the centre line above the front elevation. Through the points thus marked, draw lines horizontally to cut the perpendicular lines from the base. A curve drawn through the points of intersection will give the contour of the hole. Here, in this case the hole is slightly elliptical.

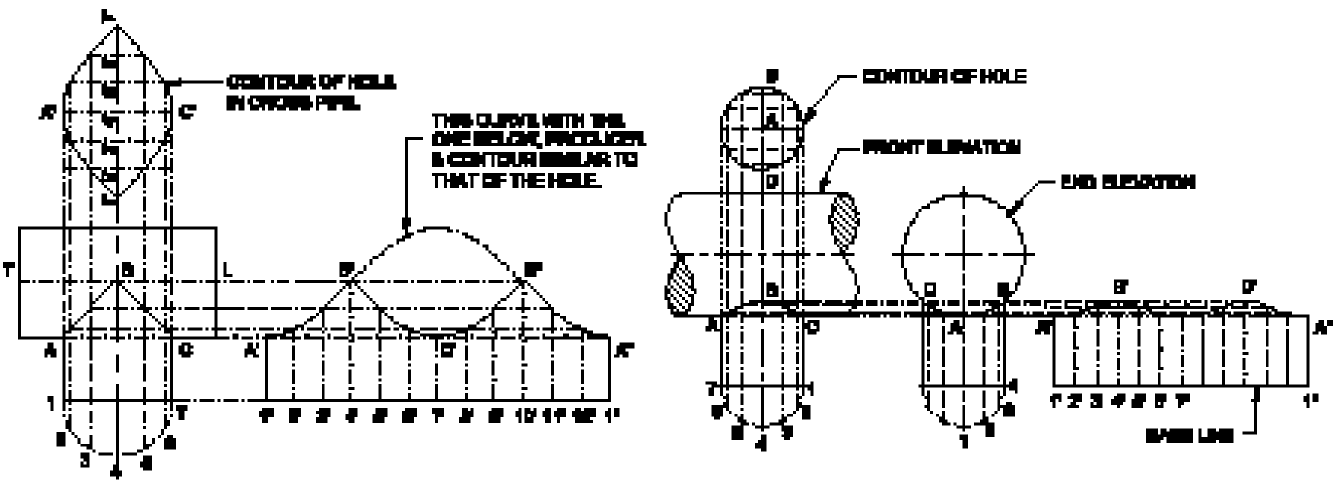


Fig. 1.3.14 Tees of equal diameter pipes

Exercise

I. Answer the following questions.

1. If the circumference of the pipe was measured as 2873 mm, what is the diameter of the pipe? (Ans 914.5 mm)

----

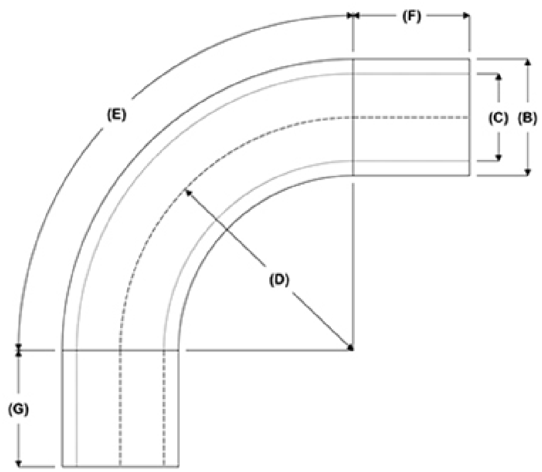
2. If the pipe inside diameter is 290 mm and pipe length is 6 meter, what is the volume of the pipe? (Ans 0.3963 m^3)

----

3. If the pipe outside diameter is 36 inch, thickness is half inch and pipe length 20 feet, what is the volume of the pipe? (133.63 ft^3)

----

4. Referring the figure given below, calculate the pipe length required if dimension mean radius of bend is 700 mm, straight length at one side of bend is 350mm and the straight length of other side of bend is 450 mm.



II. State whether the following statements are True or False.

1. Dimensions of bends shall be calculated based on mean radius and bend angle.

   True ☐ False ☐

2. Standard forged pipe bend fittings manufactured with bend radius - 1D,1.5D where D is pipe dia.

   True ☐ False ☐

3. The length of arc in a pipe bend is measured along the outer radius of the pipe

   True ☐ False ☐

4. Circumference equals π (pi) times the diameter of a circle.

   True ☐ False ☐

Notes

UNIT 1.4 Different Types of Materials Used in Pipe Fitting

Unit Objectives

At the end of this unit, you will be able to:

1. describe property and behaviour of fluids, liquids and gases
2. identify various oil and gas piping materials
3. list properties of different pipe materials and their workability
4. explain hydraulic and pneumatic system.

1.4.1 Properties and Behaviour of Fluids- Liquids& Gases

At the end of this unit, you will be able to:

1. describe property and behaviour of fluids, liquids and gases
2. identify various units of pressure, temperature, velocity and flow rate
3. recognise and explain hydraulic and pneumatic system.

Introduction

1. Pipeline materials selection depends on:
- chemical properties of process fluids
- design and operating temperatures and pressure
- required physical and mechanical properties / strengths.
2. Oil and gas piping may be made either seamless, welded or fabricated from plates depending on process requirements. Proper selection of steel pipe material is critical depending on:
- strength and durability required for application
- ductility and workability required to form into piping and join it.
3. The selected pipe must withstand the conditions of use, especially pressure, temperature and corrosion conditions. Based on flow rate, volume of fluid, working pressure, temperature and atmospheric conditions, material quality, material grade nominal pipe size and wall thickness are specified.
4. Piping pressure rating for steel pipe at different temperatures is calculated according to the applicable design code.
5. All piping and pipeline materials quality are to be given in the drawing and bill of materials. Fitter shall read the drawings carefully and confirm that the materials issued conform to the drawing requirements.

Property and behaviour of fluids, liquids and gases

The term fluid includes both liquid and gases. The main difference between a liquid and a gas is that the volume of a liquid remains definite, because it takes the shape of the surface on or in which it comes into contact with, whereas a gas occupies the complete space available in the container in which it is kept. Process fluids piping in oil and gas industry are mainly classified as:

- hydrocarbon services piping, starting from crude oils to final process / processed fluids

- gas related piping such as propane, butane, helium, hydrogen, nitrogen, oxygen, instrument air, etc., for operations
- chemicals related piping for chemical dozing, such as chlorine, anti – corrosion liquid, etc.

1. Mass Density

Mass Density is the mass per unit volume of a fluid. In other words, it is the ratio between mass (m) and volume (V) of a fluid. Density is denoted by the symbol 'ρ'. Its unit is kg/m^3.

a) Volume = $\frac{\text{Mass}}{\text{Density}}$

b) Mass = Density X Volume

c) Desity = $\frac{\text{Mass}}{\text{Volume}}$

Density, ρ = $\frac{\text{Mass}}{\text{Density}}$ $\frac{\text{Kg}}{\text{m3}}$

In general, density of a fluid decreases with increase in temperature. Density increases with increase in pressure.

Tips

The density of standard liquid (water) is 1000 kg/m3.

2. Viscosity

Viscosity is the property of fluids which defines the interaction between the moving particles of the fluid. It is the measure of resistance to the flow of fluids. Fluids with high viscosity deform slowly. In a liquid, viscosity decreases with increase in temperature.

3. Temperature:

It is the property that determines the degree of hotness or coldness or the level of heat intensity of a fluid. Temperature is measured using temperature scales. There are 3 commonly used temperature scales. They are:

a. Celsius (or centigrade) scale

b. Fahrenheit scale

c. Kelvin scale (or absolute temperature scale)

Kelvin scale is widely used in engineering. This is because, this scale is independent of properties of a substance. Kelvin to Celsius conversion formula – The temperature T in degrees Celsius (°C) is equal to the temperature T in Kelvin (K) minus 273.

T(°C) = T(K) - 273

For Example 2; converting 300 Kelvin to degrees Celsius: T (°C) = 300K - 273 = 27 °C

4. Pressure

Pressure of a fluid is the force per unit area of the fluid. In other words, it is the ratio of force on a fluid to the area of the fluid, held perpendicular to the direction of the force. Pressure is denoted by the letter 'P'. Its units are N/m2, Kg/cm^2, etc., depending upon the measuring system and range.

5. Specific Volume

Specific volume is the volume of a fluid (V) occupied per unit mass (m). It is the reciprocal of density. Specific volume is denoted by the symbol 'v'. Its unit is m3/kg.

6. Specific Weight

Specific weight is the weight possessed by unit volume of a fluid. It is denoted by 'w'. Its unit is N/m3 or kg/m^3.

7. Specific Gravity

Specific Volume, $v = \frac{V}{m} \quad \frac{m3}{Kg}$

Specific gravity is the ratio of specific weight of the given fluid to the specific weight of standard fluid. It is denoted by the letter 'S'. It has no unit.

Specific Volume, $w = \frac{\text{Weight}}{\text{Volume}} \quad \frac{N}{m^3}$

Specific gravity may also be defined as the ratio between density of the given fluid to the density of standard fluid.

$$\text{Specific Gravity, } S = \frac{\text{Specific Weight of Given Fluid}}{\text{Specific Weight of Standard Fluid}}$$

Awareness on Hydraulic System and Pneumatic System

1. Fluid Power

Liquid or Gas is referred to as a fluid. Fluid power is the method of using pressurized fluid to transmit energy.

$$S = \frac{\rho \text{ given fluid}}{\rho \text{ standrad fluid}}$$

Accordingly, there are two branches of fluid power – Pneumatics, and Hydraulics. Any media (liquid or gas) that flows naturally or can be forced to flow could be used to transmit energy in a fluid power system. The earliest fluid used was water. Hence, the name hydraulics was applied to systems using liquids. Oil hydraulic system employs pressurized liquid petroleum oils and synthetic oils. Pneumatic system employs compressed air that is released to the atmosphere after performing the work.

2. Hydraulic System

Hydraulic systems use the ability of a fluid to distribute an applied force to a desired location. Hydraulic systems use liquid to transfer force from one point to another. Hydraulic power is used in oil and gas transportation cross country pipelines, offshore oil rigs, pumping stations and water injection lifts in oil and gas industries. Liquid is incompressible. When a "squeezing" force is applied to an object, it does not change to a smaller size. Liquid, for example hydraulic fluid, possesses this physical property. Resistance to flow causes pressure. Head pressure can have an adverse effect on a hydraulic system.

Pressure: When a force (F) is applied on an area (A) of an enclosed liquid, a pressure (P) is produced. Pressure is the distribution of a given force over a certain area. Pressure can be quoted in bar, pounds per square inch (PSI) or Pascal (Pa) or kg/cm².

Pressure= Force ÷ area

Where force is in Newtons (N) and area is in square meters (m^2).

1 Pascal (Pa) =1 N/m², 1 bar= 100,000 Pa= 105 Pa. 10 bar= 1 MPa (mega Pascals)

In hydraulic systems, the force is in Newtons and the area in square millimeters. 1 N/mm2 = 1 MPa = 10 bar. To convert from N/mm² to bar, multiply by 10, and to convert from bar to N/mm², divide by 10.

For Example, a cylinder is supplied with 50 bar pressure. Its effective piston surface is equal to 350 mm². Find the maximum force which can be attained.

P= 50 bar = 50/10= 05 N/mm². A= 350 mm². F= P x A= 05X350= 1750 N

b. Pascal's Law

Pascal's Law is one of the basic laws of fluid power. According to the law, pressure in a confined body of fluid acts equally in all directions and at right angles to the containing surfaces. Accordingly, the pressure at any point in a body of fluid is same in any direction.

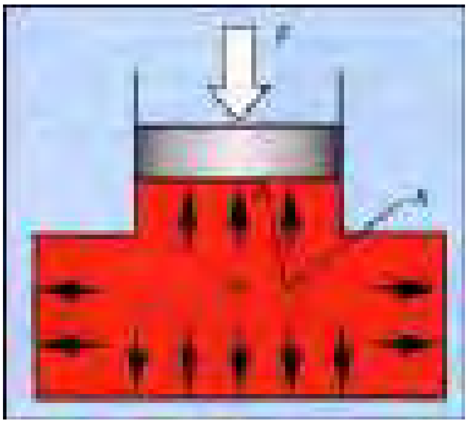


Fig. 1. 4.1. Pascals law explanation

c. Flow rate versus flow velocity

The flow rate is the volume of fluid that moves through the system in a given period of time.

Flow rate, Q = V x A

Where Q= flow rate (m^3 / Sec)

V= flow velocity (m / Sec)

A= area (m^2)

1) Pipe Diameter = $\sqrt{\dfrac{4 - \text{flow rate}}{\pi - \text{velocity}}}$

2) Velocity = $\dfrac{4 - \text{flow rate}}{\pi \sqrt{-} (\text{pipe diameter})^2}$

3) Flow Rate = $\frac{1}{4}\pi$ - (pipe diameter)2-velocity

A fluid flows at a velocity of 4 m/s through a pipe with a diameter of 0.2 m. Determine the flow rate.

d. Continuity equation

Hydraulic systems commonly produces a constant flow rate. If we assume that the fluid is incompressible (oil), this situation is referred to as steady flow. This simply means that whatever volume of fluid flows through one section of the system must also flow through any other section. Flow is constant and the diameter varies.

$$Q = 0.0663\ m^3 / s\ X\ \frac{1000\ L / s}{1\ m^3 / s}$$

The following equation applies in this system:

Q1 = Q2

A1 x V1 =A2 x V2

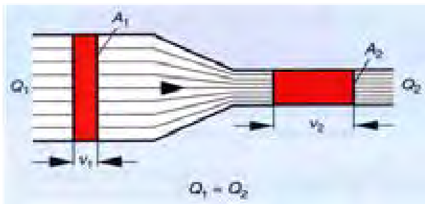


Fig. 1.4.2. Continuity equation explanation

e. Work and power

Work is the measure of a force traversing through a distance. Work = Force X Distance. When work is done in a certain time, it is called power. {Power = (Force X Distance) / Time.} A common measure of power is horsepower.

3. Pneumatic systems

Pneumatic systems are similar to hydraulic systems. In these systems, compressed air is used in place of hydraulic fluid. Pneumatic systems use air to transfer force from one point to another. Air is compressible. This describes if it is possible to force an object into a smaller space than it normally occupies. For example, a sponge is compressible because it can be squeezed into a smaller size.

A pneumatic system is a system that uses compressed air to transmit and control energy. Pneumatic systems are used extensively in various industries. Most pneumatic systems rely on a constant supply of compressed air to make them work. This is provided by an air compressor. This compressed air is then supplied to the system through a series of pipes and valves. Compressed air is the air from the atmosphere which is reduced in volume by compression thus increasing its pressure. A basic pneumatic system consists of the following two main sections:

- compressed air production, transportation, and distribution system
- compressed air consuming system

Pneumatic power is used to create/operate complex instruments and for gas lift operations in oil and gas industries.

Exercise

I. Answer the following questions.

1. What are the main differences between liquids and gases?

----

2. Define Mass Density.

----

3. Define Pressure.

----

4. State Pascal's Law.

----

5. Define flow rate.

II. State whether the following statements are True or False.

1. The term 'fluid' comprises – liquid and air.

   True ☐ False ☐

2. Liquid is compressible.

   True ☐ False ☐

3. 1 Pascal (Pa) =1 N/m^2.

   True ☐ False ☐

Notes

1.4.2 Properties of Different Pipe Materials

At the end of this topic, you shall be able to:

1. list the different process conditions and basis for material selection
2. describe on different material compositions and alloying elements
3. describe mechanical and chemical properties of various metallic materials
4. identify various pipe materials categorization and types of pipes
5. explain on different types of stainless steel.

Process Conditions and Materials Selection

1. Piping / pipeline construction materials depends on process and service conditions such as

i. Nature of Fluid – corrosiveness, toxicity, flammability, viscosity.

ii. Service conditions – pressure and temperature.

iii. Environmental condition – desert, hills, atmospheric temperate, marine, earthquake, etc.

2. Process condition that will impact the selection of material is

a. Type of fluid to be transported: For corrosive fluids, higher corrosion resistance material shall be selected as compared to non-corrosive ones. Corrosive fluids such as crude oil, sea water, ammonia, acids, etc., H_2S require high corrosion resistance material. On the other hand, normal carbon steel is enough for non-corrosive fluids such as – Lube oil, air, nitrogen, etc.

b. Temperatures of fluids to be handled are

Cryogenic, Low temperature, Medium temperature and High temperature. Increase or decrease in the service fluid temperature will greatly affect mechanical properties of the pipe material such as - impact resistance, elongation and tensile strength. Hence, special material is required for both high temperature cryogenic services.

Properties of and different pipe materials

1. Material properties

Considering both process fluid and material properties, piping material are selected from a variety of materials available in the market. Piping material is broadly classified into three categories namely, metal, non-metal, and composite, which is a combination of metal and and metal or metal and non-metal. Metals are broadly classified as ferrous (steel, cast iron) and non-ferrous (aluminium alloy, copper alloy, nickel alloy, magnesium, etc).

Non – metal pipes are broadly classified as – PVC, CPVC, PE, HDPE, GRP/GRE & Cement, etc./ MDPE.

2. Mechanical properties

The mechanical properties of a material are those which affect the mechanical strength and ability of a material. Fig 1.4.3 is the stressstrain diagram which depicts various physical properties relationships. Some of the mechanical properties are

- Ultimate Tensile Strength which is the capacity of a material to withstand when subject to tension. It defines the limit to which any further addition of load under constant strain would arrest the specimen elongation or thinning and would result in failure.
- Yield Strength is the load at which plastic deformation / permanent deformation starts. It defines the transition from elastic to plastic phase and it establishes the limiting value at which this transition occurs.
- Elasticity Elastic range is the ability of a material to resume its normal shape after the load is removed just like rubber.
- Modulus of Elasticity (Young's Modulus) is ratio of stress to strain and measured using tension tests.
- Elastic range is a range in which the material returns to its original shape after the load is released.
- Plastic range is a range in which the material is permanently deformed even after the load is released.
- Ductility is expressed in elongation of a specimen and its reduction in cross – sectional area before it's failure. It is established by measuring specimen length before elongation and minimum diameter before failure.
- Percentage Elongation is a measure of ductility.
- Hardness is the ability of a material to resist plastic deformation. Hardness is tested by Brinell or Rockwell Hardness tests, both of which are indentation type tests.
- Toughness is the ability of a material to absorb energy before fracture.
- Brittle fracture is sudden and rapid failure of a metal due to application of energy with hardly any deformation.

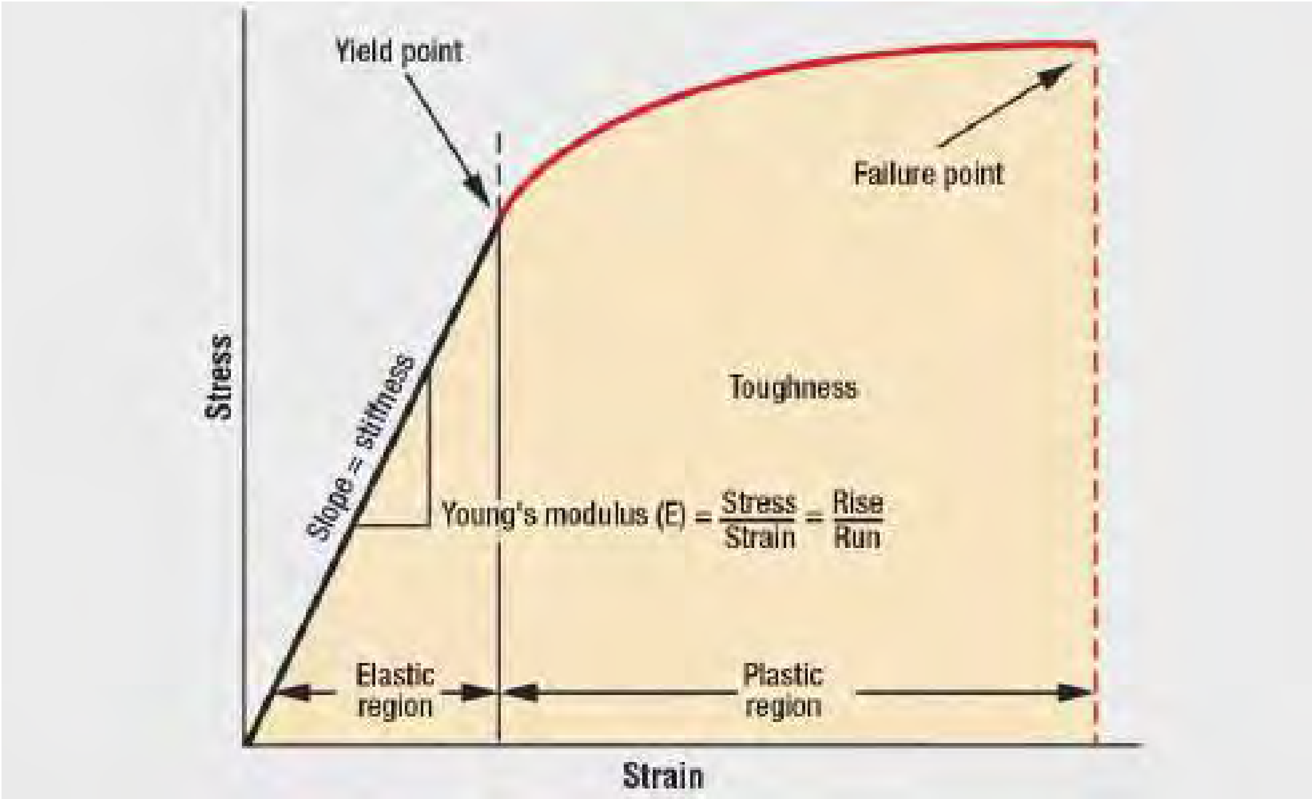


Fig. 1.4.3. Physical properties of material while performing tensile test- Stress – Strain Diagram

3. Chemical composition – Alloying elements

Some of the chemical properties of engineering materials are chemical composition, atomic bonding, corrosion resistance, acidity or alkalinity. The chemical composition of engineering material indicates the elements which are combined together to form that material. The strength, hardness, ductility, brittleness, corrosion resistance, weldability, etc., depend on chemical composition of materials. Hence, knowledge of chemical composition of engineering materials is essential. Addition of alloying elements to prevent carbon-chromium precipitation and formation of carbides, which reduces corrosion at higher temperature is called stabilization. Stabilization process can be employed to reduce corrosion.

Steel materials categorization

Steel materials are broadly categorized into four basic groups based on their chemical composition. They are carbon steel , alloy steel, stainless steel and duplex stainless steel.

1. **Carbon steel:** Carbon steel is the most utilized steel in the oil and gas industries. Based on the carbon content, carbon steels are further classified into three groups – low carbon steel/mild steel, medium carbon steel and high carbon steel.
2. **Alloy Steel:** Metls rarely used in their purest form as they have low mechanical strength. In order to achieve the desired (improved) properties such as weldability, ductility, machinability, strength, hardenability and corrosion resistance, etc., alloy steel with varying proportions of alloying elements is manufactured. Alloy steels are broadly classified into low alloy steels and high alloy steels. Low alloy steels have alloying elements less than 5%. High alloy steels have alloying elements more than 5%.
3. **Stainless Steel:** Stainless Steel is an alloy steel with alloying elements as – chromium, nickel, molybdenum etc. Stainless steel exhibits corrosion resistance due to formation of a very thin layer of (chromium Cr_2O_3 Oxide) on the surface. This layer is also known as passive layer. Increasing the amount of chromium will further increase the corrosion resistance of the material. Stainless steel also contains carbon, silicon and manganese. There are different types of stainless steel used in piping. After carbon steel, stainless Steel is the most widely used material in process industries because of its excellent corrosion resistance property and good ductility.

a. **Types of stainless steels:** There are different types of stainless steel used in industries. Based on microstructure, stainless steels are further classified as austenitic stainless steels, ferritic stainless steels, martensitic stainless steels, duplex stainless steel.

i. Austenitic Stainless Steel

- Austenitic Stainless Steel includes alloys of Cr, Ni, Fe.
- This is non-magnetic and can not be hardened by heat-treatment.
- This has excellent formability and weldability.
- This has high corrosion resistance and possess high impact strength at low temparature.
- Low-carbon stainless steels such as 316L or 304L are used to avoid corrosion problems caused by welding. "L" means that the carbon content of the alloy is below 0.03%, which prevents sensitization (precipitation of chromium carbides at grain boundaries) caused by the high temperatures involved in welding.

ii. Ferritic Stainless Steel

- Ferritic stainless steels possess a ferrite microstructure like carbon steel.
- Ferritic steels consists of Iron-Chromium alloys with molybdenum.
- These are generally magnetic and contain comparatively high carbon. Ferritic steels cannot be hardened by heat treatment.

iii. Martensitic stainless steel

- Martensitic stainless steel have higher strength and are comparatively tougher. But they are not as corrosion-resistant as the other two classes of steel.
- Mark this type of steel. These steels are machinable, magnetic and heat-treatable.

iv. Duplex stainless steels

- Duplex stainless steel consists of a two-phase microstructure consisting of grains of ferritic and austenitic stainless steel. Ferrite + Austenite mix is as 50/50 ratio. Commercial alloys ratio may vary in the range 40/60.
- Duplex stainless steel materials are characterized by high chromium (19–32%) and molybdenum (up to 5%) and lower nickel contents than austenitic stainless steels.
- This material has higher yield strength and superior resistance to stress corrosion cracking.
- It has good resistance to pitting and crevice corrosion.

Oil and gas pipes and pipe fitting materials

Piping components are mechanical elements suitable for joining or assembling into a pressure tight fluid containing piping systems. Components include pipes, tubes, fittings, flanges, gaskets, bolt-nuts, valves, expansion joints, hose pipes, traps, strainers, separators, control valves, safety valves, blind flanges, spectacle blinds and drip rings, etc.

1. Types of pipe and pipe fitting materials

The pipe is a straight pressure tight cylindrical hollow, used in the piping system to transport liquid, gas and sometimes solids. Piping class or pipe class is a document that specifies the type of components such as a type of pipe, s chedule, material, flange ratings, branch types, valve types and valve trim material, gasket and all the other component specific requirements, to be used for different fluids under different operating conditions in a plant. pipe class is developed considering operating pressure, temperature and corrosive environment.

a. Cast iron (CI)

Cast iron/ductile iron/malleable iron – are brittle, low strength material used for normal temperature applications and basic utilities like sewage system, air, water, drains, etc. Cast iron is also affected by corrosion caused by the by action of a solution of carbonic acid and acid. It is heavy and, if treated roughly, the pipe and fittings can crack. CI shall not be used on severe cyclic condition services, excessive heat, thermal shock applications, etc.

b. Galvanized steel

Normally, galvanized piping connections are threaded and screwed to avoid damage to galvanizing due to welding. Galvanized steels use is limited to about 200° F or 93° C for basic utilities like water, air, nitrogen.

c. Carbon steel pipes

Carbon steel pipes are widely used in oil and gas industries.

d. Pipeline materials:

Various pipeline materials are available. Normally, pipeline materials are classified as metallic (such as carbon steel, stainless steel), non-metallic (poly ethylene, HDPE, PVC, etc.), carbon steel pipes with cement lined. Pipeline materials are selected and used based on corrosive services like acids, caustic, process limited services, etc. Carbon steel cement lined pipe is normally used in sea / deep river water applications.

e. Stainless steel piping

Stainless piping is made of different alloys. It is commonly installed in process industries, chemical plants or in the food processing industry. Some types are highly acid resistant. Delivery length is normally 6 m.

f. Non – ferrous piping

Copper piping is used for water supply pipe. Flexible copper tubing is used in water heaters, refrigerators, etc. Flexible copper is not recommended for exterior use. Copper and copper alloys are for special usage within oil and gas operations. These materials are often used for valves and seals. This is due to properties like electrical and thermal conductivity that help to transfer heat and cold without warping, cracking, or failing otherwise.

g. Duplex stainless steel (DSS) pipelines

In oil and gas offshore facilities, duplex stainless steel pipelines are installed as DSS are corrossion resistant. At deep water exploration of offshore oil, duplex and super duplex stainless steel pipes are installed as they withstand greater pressure in severe corrosive environments. The main pipes used in the offshore oil and gas industry are duplex 2205 (22% chromium, 5% nickel) and 2507 (25% chromium, 7% nickel); and super duplex 2507 which has a higher corrosion resistance. Duplex steel is also highly resistant to chloride-induced stress corrosion cracking and has the strength to resist pressure at extreme depths.

h. PVC – Polyvinyl Chloride Pipes

PVC Pipes are made from polyvinyl chloride. PVC pipes are mostly used in plumbing, drain and vent lines. PVC pipe has been a very big deal in the plumbing industry in the last few decades, because it is lighter and easier to work with than traditional galvanized steel pipes.

i. CPVC pipes are

Chlorinated polyvinyl chloride (higher strength at moderately elevated temperature than PVC) tough and exceptionally resistant to chemical attack. PVC / CPVC requires protection from ultraviolet exposure, if installed outdoor as they start softening when subjected to high pressure.

j. GRE/GRP piping

GRP piping installations are associated with oil and gas industry processing and utility service applications in onshore and offshore. Installation of glass-reinforced plastics (GRP) piping is performed with installations associated with offshore applications on both fixed and floating topsides facilities for oil and gas industry production and processing.

K. PE / MDPE / HDPE (High Density Poly-Ethelene) pipe is used for a variety of applications, including distribution of pressurized natural gas, pipelines carrying petroleum and petroleum products and chemicals, underground loops for geothermal heating and cooling systems, distribution of compressed gases and air, potable water mains and service lines, and sanitary and storm sewer systems.

High-density polyethylene pipe is strong, durable, flexible and light weight. When fused together, HDPE offers a zero leak rate due to the seamless nature of the pipe system. HDPE pipe offers a more environmentally sustainable footprint because it is non-toxic, corrosion and chemical resistant, has a long lifespan, and is suitable for trenchless installation methods. HDPE pipe will not rust, corrode, tuberculate or support biological scale or growth, and has superb chemical resistance when compared to traditional pipe materials.

Fig. 1.4.4. Socket & Spigot Ends of pipes -non-metallic piping / pipeline such as PVC, GRE / GRP / MDPE / HDPE

Exercise

I. Answer the following questions.

1. Name any four corrosive fluids.

   ----

2. What are the mechanical and chemical properties that will directly influence the choice of material?

   ----

3. What do you understand about the terms 'Yield Strength' and 'Ultimate Tensile Strength'?

   ----

4. Draw stress–strain diagram duly illustrating mechanical properties nomenclatures.

   ----

5. What are different types of stainless steels?

II. State whether the following statements are True or False.

1. Pipe service conditions include process pressure and temperature.

   True ☐ False ☐

2. Decrease in the service fluid temperature will not affect mechanical properties.

   Ture ☐ False ☐

3. Martensitic stainless steel is magnetic.

   True ☐ False ☐

4. Galvanized pipes are generally available in the threaded form.

   Ture ☐ False ☐

5. Percentage elongation is a measure of yield strength.

   Ture ☐ False ☐

Notes

1.4.3 Metallic Piping and Pipe Fitting Materials Standards / Specifications and Applications

At the end of this topic, you shall be able to:

1. classify pipes based on manufacturing process
2. describe piping identification and traceability requirements
3. recognise different piping materials standards / specifications and applications.

Pipe materials classification based on manufacturing process

Based on manufacturing process, metallic pipes are classified into seamless and welded. Welded pipes are further classified as ERW (Electrical Resistance Weld) / EFW (Electrical Fusion Welded) and SAW (Submerge Arc Welded). SAW pipes are further classified as straight seam or Helical / Spiral SAW. Seamless pipes are stronger than other pipes. Welded pipes are manufactured from plates / coil sheets.

Fig. 1.4.5. Pipe with threaded end

Fig. 1.4.6. Pipe with plain ends

Pipes are supplied with plain, bevelled or threaded ends as required. Pipes and pipe fittings are supplied with or without heat treatment as required by product standard or specification or purchase order. Generally, hot finished fittings require heat treatment. Cold drawn / finished fittings require heat treatment.

Piping materials identification marking

Piping materials are normally marked with (by painting, hard punching or by both), material specification, material grade, heat number / cast number, size, thickness / schedule, length , manufacturer logo, etc., as required by respective material specification / purchase order. In general, no hard punching is permitted for piping material thickness less than 6 mm. For critical materials, if stamping is essential for identification and traceability, low stress stamps shall be used. Stainless steel pipes are marked by engraving or stencilling. Additionally, flanges are stamped with service pressure rating class and heat treatment marking such as 'N' for normalised, 'QT' for Quenched and Tempered. Flanges are, generally, stamped at the outer periphery / thickness area.

1. Pipes and pipe fittings are manufactured to various piping materials standards / specifications such as ASTM, API standards. Commonly used piping and pipe fitting materials are listed in Table 1.

1. ASTM A-53

Piping Materials Standards / Specification / Applications

Table 1

Sl.No	Material Specification	Material Description
1	ASTM A-53	Welded and Seamless Steel Pipe
2	ASTM A-106	Seamless Carbon Steel Pipe for High-Temperature Service. This piping is mainly used for Process piping. ASTM A 106 pipe material grades are Grade A, B and C, with maximum carbon content 0.25, 0.3 and 0.35 respectively. Bending ability decreases from grade A to C.

3	ASTM A-312	Seamless and Welded Austenitic Stainless Steel Pipe
4	ASTM A-333	Seamless and Welded Steel Pipe for Low Temperature Service. This carbon and alloy steel pipes are available both in seamless and welded without addition of filler metal in welding operation, intended for use at low temperatures. Several grades are available from Grade 1 to Grade 11.
5	ASTM A-335	Seamless Ferritic Alloy Steel Pipe for High-Temperature Service
6	API-5L	Specification for Line Pipe. In the oil and natural gas industries, API 5L steel pipes are mostly used to transport oil and gas.
7	ASTMA 234	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
8	ASTM A 420	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service
9	ASTM A 105	Standard Specification for Carbon Steel Forgings for Piping Applications
10	ASTM A 182	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
11	ASTM A 193	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications
12	ASTM A 194	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
13	ASTM B 16.5	Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
14	ASTM B 16.9	Factory-Made Wrought Butt Welding Fittings
15	ASTM B16.11	Forged Fittings, Socket-Welding and threaded
16	ASTM B16.34	Valves- Flanged, threaded, and welding end.
17	ASTM B16.47	Large Diameter Steel Flanges NPS 26 Through NPS 60 Metric/Inch Standard

Exercise

I. Answer the following questions.

1. What is meant by material yield strength?

   ----

2. What is the advantage of adding molybdenum as one of the chemical elements in material composition?

   ----

3. What does the letter "L' stand for in stainless steel material designation 316L?

   ----

4. What is the definition for LTCS?

Notes

1.5. Preparation of Piping and Pipeline

Unit Objectives

At the end of this unit, you will be able to:

1. identify of different flanges, bends, elbows, shapes, joints, etc., used to fabricate pipes
2. identify and distinguish different types of nuts, bolts, screws, clamps, fixtures, etc., used in piping
3. recognise on different packing materials, adhesives, gaskets, o ring, ropes, etc.
4. cut gaskets using a cutting machine
5. install various valves, instruments and piping accessories
6. perform valve functional test.

1.5.1. Pipe Flanges, Pressure Rating and Their Applicability

At the end of this topic, you will be able to:

1. describe different types of flanges and materials
2. recognise with flange ratings and dimensions.

Pipe flange and purpose

A flange is a piping object made by forging or cutting steel plates used for connecting pipes, valves, pumps and other equipment to form a piping system. Flange joints are made by bolting together two flanges with a gasket between them to provide effective seal. Flange joints can be dismantled easily to provide easy access for cleaning, maintenance, inspection or modification. Flanges are usually, welded or screwed with pipe.

II. Types of flanges

1. The following flange types are mainly used in Oil and Gas industry – weld neck flange, slip on Flange, socket weld flange, lap joint flange, threaded flange, spade and spectacle flanges, blind flange.

2. Special Flanges

Apart from the above standard flanges, there are number of special flanges for specific applications, such as orifice flanges, long weld neck flanges, weld flange / nipoflange, Expander flange, reducing flange.

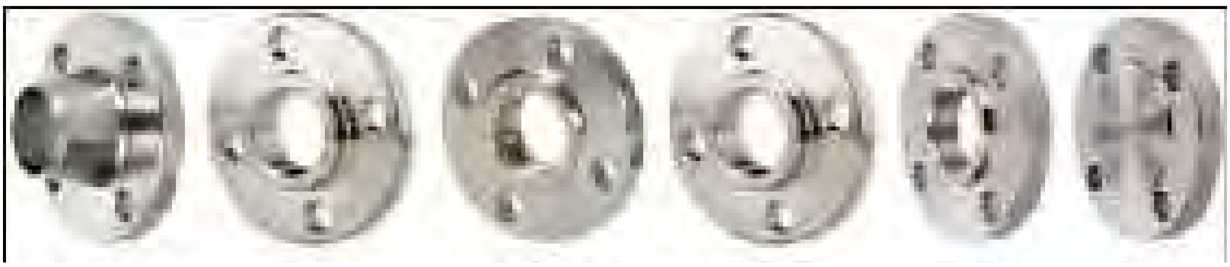


Fig. 1.5.1 Various types of flanges

Materials for flanges

Pipe flanges are manufactured from different materials like carbon steel, alloy steels, stainless steel, cast iron, etc. In general, the material of flange and pipeline are of same or equivalent grade / specification. Flanges are available in various types and standards. ASME / ASTM standard flanges are widely used. ASME B16.5 describes dimensions, dimensional tolerances, etc.

Dimensions of flanges

Flanges have number of standard (unique) dimensions. Flange outside diameter is abbreviated as “OD”. Pitch Circle Diameter is abbreviated as “PCD”. It is also called ‘bolt circle’.

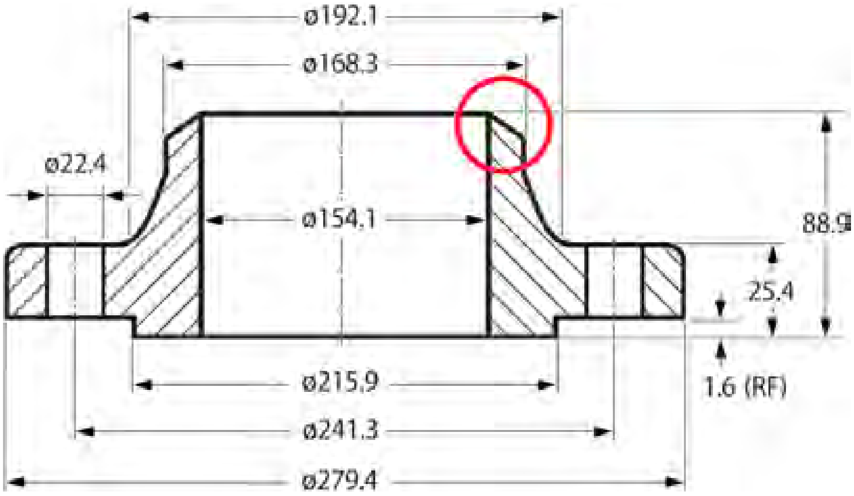


Fig. 1.5.2 Weld neck flange NPS 6, class 150, schedule 40, ASME B16.5

The above flange has 8 bolt holes, and a welding bevel of 37.5 degrees. All given dimensions are in millimeters. Pipe fitter shall measure and cross check all the above flange dimensions before commencing flange assembly.

Pressure rating of flanges and its significance

The pressure rating is the maximum allowable working pressure (MAWP) at the specific temperature for given material of a pipe, fitting or valve that if should be capable of withstanding in normal conditions. Each flange material has different pressure ratings. Flange pressure class /rating is given in pounds. Different names are used to indicate a Pressure Class. For example, 150 Lb or 150 Lbs or 150. “Class 150”, means that safe working pressure for this flange at rated temperature for given material is “150 pound per square inch”. Forged steel flanges, according to ASME B16.5, are made in seven primary Pressure Classes: 150, 300,400 600, 900, 1500, 2500. Inner diameter and diameter of the raised face are all the same for all ratings. But outside diameter, bolt circle and diameter of bolt holes become larger in each higher pressure class.

1.5.2. Type of Flanges

At the end of this exercise, you will be able to:

1. identify the types of flanges
2. draw a freehand sketch of a pipe flange weld neck type.

Practical

Requirements		
Tools/Instruments		**Materials/Components**
Measuring Tape	– 1 No.	Paper
Steel Rule	– 1 No.	Pencil, Marker
Vernier Caliper	– 1 Set	Different type of flanges 2” diameter
Equipment/Machines		
Personal Protective Equipment	– 1 No.	

Tips

Instructor may provide different types of flanges and explain to trainees about how to identify the flange type.

1. Look at the picture below and write the types of flanges in Table 1.

1 2 3 4 5 6

Table 1

Sl. No.	Name of the Flange type	Sl. No.	Name of the Flange type
1		4	
2		5	
3		6	

2. Draw a free hand sketch of a pipe flange - Weld Neck Type

Exercise

I. Answer the following questions.

1. Name any five types of flanges.

----

2. What is meant by flange pressure rating?

----

3. What are the different materials used for manufacturing flanges?

----

4. What are the purposes of flange connections?

----

5. What are the different flange dimensions to be cross checked by the pipe fitter prior to flange assembly?

II. State whether the following statements are True or False.

1. "Weld Neck" is a term used to describe a type of pipe

   True ☐ False ☐

2. Lap joint flange does not have raised face.

   True ☐ False ☐

3. The flange material grade shall be higher than that of the pipe.

   True ☐ False ☐

4. The abbreviation 'PCD' stands for 'Pitch Circle Diameter'.

   True ☐ False ☐

5. As the temperature increases, flange rating decreases.

   True ☐ False ☐

6. Diameter of "raised face" will be the same for all different ratings of NPS 6 flanges.

   True ☐ False ☐

Notes

1.5.3 Flanges Classification based on Pipe Attachment

At the end of this topic, you will be able to:

1. classify and distinguish flanges based on pipe attachment
2. perform a socket weld joint fitup
3. list the applications of different types of flanges.

Based on type of attachment with pipe, flanges are classified as slip on flange, socket weld flange, threaded / screwed flanges, lap joint flanges, weld neck flanges, blind flange, reducing flanges, integral flange, spade & spectacle blind flange, orifice flange, etc.

Weld Neck Flanges are easy to recognize by long tapered hub with smooth transition that goes gradually from flange thickness to pipe or fitting wall thickness. The long tapered hub provides additional reinforcement and reduces stress concentration. Weld neck flanges are attached to the pipe or fitting with full penetration weld (Butt weld) Fig. 1.5.4. These are used mainly for high pressure/ critical services and for sub-zero and / or elevated temperatures.

Slip on flange Slip on flanges are flanges slip over pipe and are also called as "SO Flange". The slip on type flanges are attached by fillet welding inside as well as outside. In general, these flanges are manufactured by forging. Details of slip on flanges are given in Fig. 1.5.5

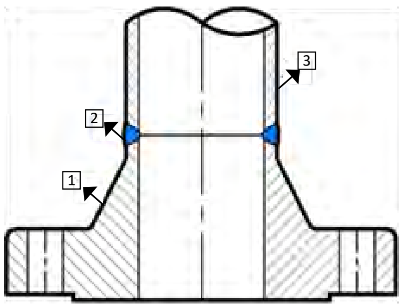


Fig. 1.5.3 Weld Neck Flanges

1. Weld Neck flange
2. Butt Weld
3. Pipe or Fitting

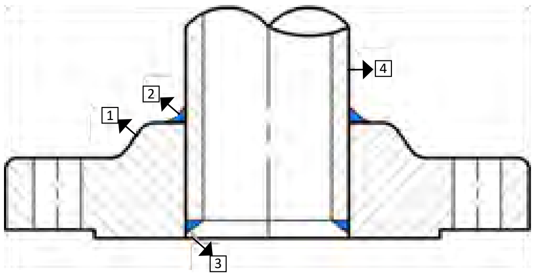


Fig. 1.5.4 Slip On Flange

1. Slip On flange
2. Fillet weld outside
3. Fillet weld inside
4. Pipe

Socket weld flange Socket weld flange has a female socket in which the pipe is fitted. This flange is mostly used for small bore lines. The connection with the pipe is done by fillet weld, at the outside of the flange. During fitup before welding, the pipe or tube shall be inserted into the socket to the maximum depth and then withdrawn approximately 1/16" (1.6 mm) away from contact between the end of the pipe and the shoulder of the socket to create a space between flange or fitting and pipe. (Refer dimension 'X' in Fig. 1.5.6. The purpose of the clearance in a socket weld is usually to reduce the residual stress at the root of the weld that could occur during solidification of the weld metal.

Threaded / screwed flanges Threaded flange has threads inside the flange bore which fits on the pipe with matching male thread on the pipe. Refer Fig. 1.5.7. Screwed fittings are made in carbon / stainless steel and duplex stainless steel and up to 4inches diameter in instrument air galvanised piping system. Threaded / screwed on flanges are used on smaller piping such as instrument air, utility air / water services ,and galvanized steel, where welding cannot be carried out. Threaded flanges are used for special uses with their main advantage being that they can be attached to the pipe without welding. Sometimes, a seal weld is also performed in conjunction with the threaded connection. A threaded flange or fitting is not suitable for a pipe system with thin wall thickness, because cutting thread on the thin pipe is very difficult.

Lap joint flange A stub is end always used with a lap joint flange, as a backing flange. The stub ends are welded with pipes and flanges and kept loose over the same (Refer Fig. 1.5.8.). Lap joint flanges are of same common dimensions as any other flange. However, it does not have a raised face. These flanges are nearly identical to a slip on flange with the exception of a radius at the intersection of the flange face and the bore to accommodate the flanged portion of the stub end.

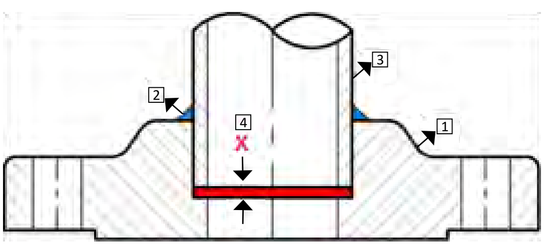


Fig. 1.5.5 Socket weld flange assembly

1. Slip On flange
2. Fillet weld outside
3. Fillet weld inside
4. Pipe

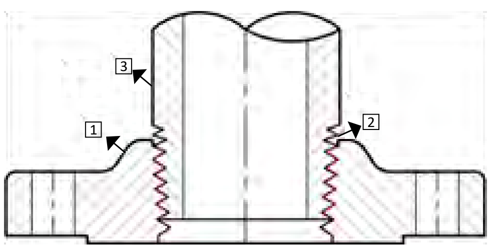
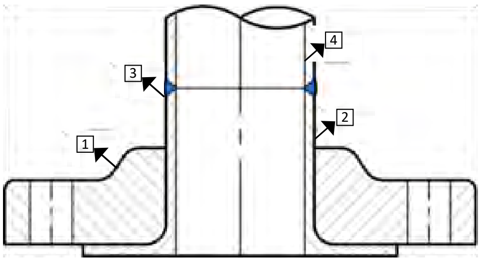


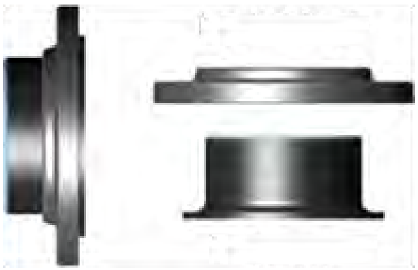
Fig.1.5.6 Threaded Flange Connection

1. Threaded flange
2. Thread
3. Pipe or Fitting

Blind flanges Blind flanges are manufactured without a bore, drilled with all relevant bolt holes and used to close / blank off the ends of piping, valves and pressure vessel openings, etc. (Refer Fig. 1.5.9).

Reducing flanges Reducing flanges are used to connect between larger and smaller sizes without using a reducer. In case of reducing flanges, the thickness of flange should be that of the higher diameter (Refer Fig. 1.5.10). A reducing flange consists of a flange with one specified diameter and has a bore of a different and smaller diameter. Except for the bore and hub dimensions, the flange will have dimensions of the larger pipe. There are several types of reducing flanges including weld neck reducing flanges, slip on reducing flanges and threaded reducing flanges.





Stubend

Lap Joint Flange

1. Lap Joint flange
2. Stub End
3. Butt weld
4. Pipe or Fitting

Fig. 1.5.7 Lap joint flange with stub end connection

1. Blind flange
2. Stud Bolt
3. Gasket
4. Other flange

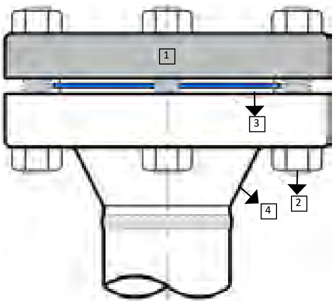


Fig. 1.5.8 Blind Flanges (plain &bolted)

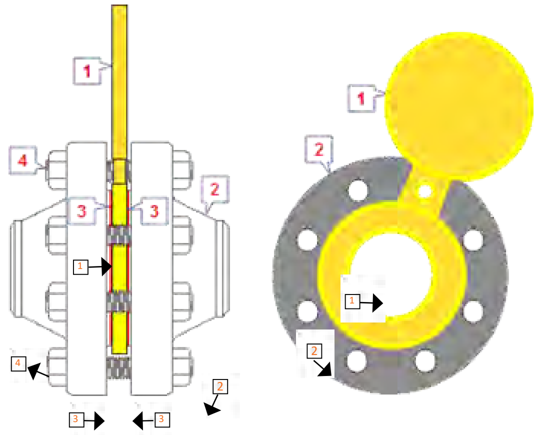
Integral Flange Integral flanges are those, which are cast along with the piping component or equipment (Fig. 1.5.11). Integral flange also called "long weld neck flange (LWN flange)", is used for very high pressure situations. In this case, the weld is far from the ring to avoid bending stresses and weld stress being combined.

Spade & Spectacle blind flanges Spade and spectacle comprise combination of spade and blind together. Spade fits into the space between two flanges and gives flow through the spade (Fig. 1.5.12 and 1.5.14). A spectacle blind is a steel plate cut into two discs of a certain thickness. The two discs are attached to each other by section of steel similar to the nose piece of a pair of glasses. One of the discs is a solid plate, and the other is a ring, whose inside diameter is equal to that of a flange Fig. 1.5.13 & 1.5.14). Spectacle blinds are, generally, applied to permanently separating pipe systems and or just to connect with each other. Spectacle blinds are installed in systems which need to be separated from other installations from time to time when need arises in situations like maintenance / isolation.

Spades and ring spacers Spades and ring spacers are basically the same as spectacle blinds, except that both are not attached to each other. Spades and spacers are installed in systems where frequent closing / opening is not necessary. Depending on the flange size and the pressure class, spades can weigh high. To prevent unnecessary weight to flange connections, two separate parts of spades and ring spacers are considered.

Fig. 1.5.9 Integral Flange (Long Weld Neck Flange)

Fig. 1.5.10 Reducing Flanges



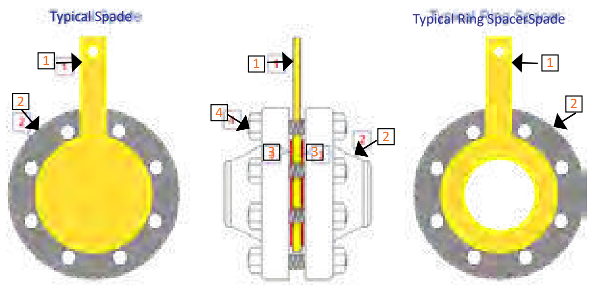
1. Spectacle Blade
2. Flanges
3. Gasket
4. Stud Bolts

Fig. 1.5.11 Spade and Spectacle blinds

Fig. 1.5.12 Spectacle blind flange -open

Fig. 1.5.13 Spectacle blind flange – closed

1. Spade 3. Gasket
2. Flanges 4. Stud Bolts



1. Ring spacer 3. Gasket
2. Flanges 4. Stud Bolts

Fig. 1.5.14 Spade and Ring Spacer

Orifice flanges Orifice flanges are used with orifice meters for the purpose of measuring the flow rate of either liquids or gases in the respective pipeline (Refer Fig. 1.5.15). Pairs of pressure "Tappings", mostly on 2 sides, directly opposite each other, are machined into the orifice flange. When installing the orifice plate flange, the pressure taps need to be at the same elevation to each other. Orifice flanges are installed where orifice plate or flow nozzle needs to be installed. Orifice flanges, generally, come with either raised faces or RTJ (Ring Type Joint) mostly in weld neck configuration.

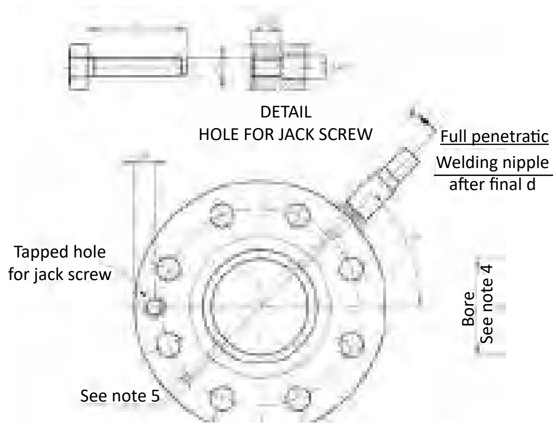


Fig. 1.5.15 Orifice flanges

1.5.4 Marking, Drilling and Reaming of Flange

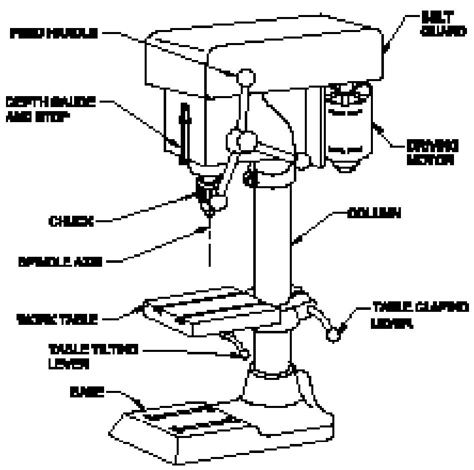
At the end of this exercise, you will be able to:

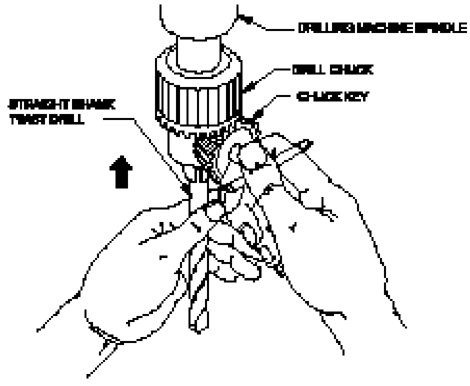
1. perform marking and punching
2. carryout drilling and reaming
3. verify PCD of flange (Pitch Centre Diameter).

Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Dot punch	– 1 No.	CS- Flange # 150 rating	– 1 No.
Round File	– 1 No.	**Equipment/Machines**	
Divider	– 1 No.	AG-Grinding Machine	- 1 No.
Measuring Tape	– 1 No.	Drilling Equipment	- 1 No.
Steel rule	– 1 No.	Drill Chowk with 12mm	- 1 No.
Vernier Caliper	– 1 No.	Drill bit Q12mm	- 1 No.
Try square	– 1 No.		
Ball peen hammer	– 1 No.		
Drill bit	– 10mm.		
Scriber	– 1 No.		

- check and select CS/MS – material according to the drawing
- grind and file to size 10mm x 153mm
- check the thickness and diameter of the flange using vernier caliper
- make the PCD axis x,y
- mark the hole centres for the drill hole by using scriber and dot punch centre punch
- then using the same radius, from the entre of the axis hole, draw a arc on
  PCD on either side of both axes of hole centre
- make a punch mark intersection of the PCD circle and the radious arc
- fix the job/flange on the machine vice
- fix the 12mm drill in drill chuck
- set the spindle speed for 12mm drill
- use coolent while drilling
- finish the job and deburr all corners so that you get equally spaced six holes
- check the drilled hole size using vernier caliper
- apply thin coat of oil and preserve it for evaluation





Tips

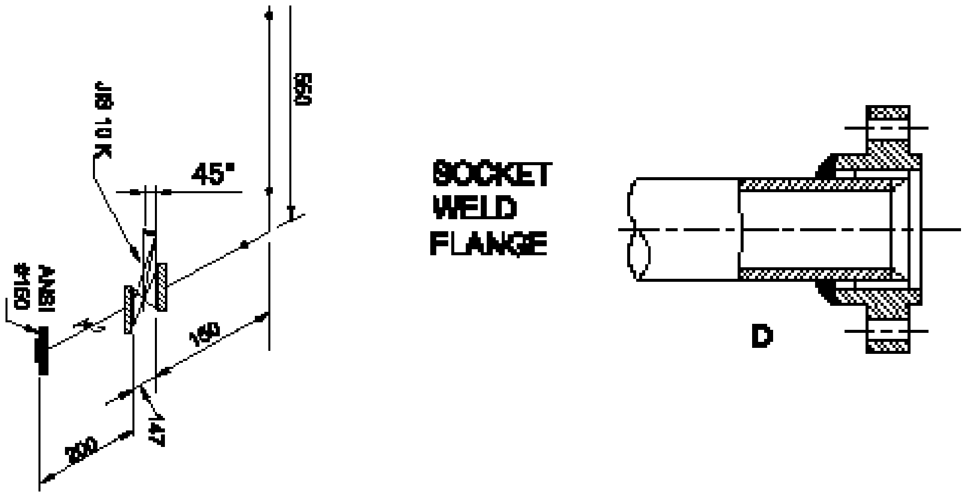
Safety

Use appropriate PPE.

Do not remove burr/chips with bare hands.

Do not try to change the drill bit while the drilling machine main switch is ON. Instructor or may explain with step by step instruction, how to carryout pipe to flange "socket weld" fit up

1. Look at the isometric drawing below and carryout pipe to socket weld flange fitup and alignment.



Tips

1. All dimensions are in millimetre.
2. With the given materials, candidate is required to fit up pipe to socket weld flange.
3. Candidate is to check the tool items according to the tools list provided.

Exercise

I. Answer the following questions.

1. Name any five flanges classified based on pipe attachment type.

----

2. How is socket weld joint fitting performed?

----

3. Explain the construction of lap joint flange connection.

----

4. What are the applications of spades and spectacle blinds?

----

5. What are the installation requirements for orifice flanges?

----

6. Draw a free handsketch of spectacle and blind flange assembled condition.

II. State whether the following statements are True or False.

1. The long tapered hub of weld neck flange increases stress concentration.

   True ☐ False ☐

2. Weld neck flanges are attached with pipe either by fillet weld or by butt weld.

   True ☐ False ☐

3. Normally slip on flanges are welded with pipe by full penetration butt welding.

   True ☐ False ☐

4. Threaded piping /flange is used in airlines instruments.

   True ☐ False ☐

5. Threaded pipe can be attached with pipe without welding.

   True ☐ False ☐

Notes

1.5.5 Flanges Classification Based On Facing and Face Finish

At the end of this topic, you will be able to:

1. classify and distinguish flanges based on flange face and finish
2. describe ring type joint flanges
3. describe the significance of flange face finishes.

Flanges classification based on facing

Different types of flange faces are used as contact surfaces to seat the sealing gasket material. ASME B16.5 and B16.47 address various types of flange facings, including the raised face, flat face, ring type joint groove, etc.

i. Flat face (FF)

The flat face flange has a gasket surface in the same plane as the bolting circle face. Flat face flanges are never to be bolted to a raised face flange.

ii. Raised face (RF)

The Raised Face flange is the most common type used in oil and gas piping applications. It is referred to as a raised face because the gasket surfaces are raised above the bolting circle face. Pressure rating of the flange determines the height of the raised face. This face type allows the use of a wide combination of gasket designs including flat ring sheet types and metallic composites such as spiral wound and double jacketed types.

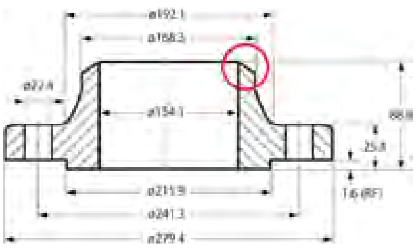


Fig. 1.5.16 Flange – Flat Face

Fig. 1.5.17 Raised Face Flanges image and dimensional details

iii. Ring type joint flanges

A ring type joint (RTJ) flange is a type of flange that uses a metal ring that sits in a groove as a gasket to seal the flange pair. RTJ flanges are usually manufactured in blind, slip on, threaded and weld neck as needed. RTJ flanges are typically used in high pressure (class 600 and higher rating) and/or high temperature services above 800°F (427°C) and in offshore piping systems. The flanges seal, when bolts are tightened, duly compressing the gasket between the flanges into the grooves. Raised face in RTJ flange does not serve as any part of the sealing means.

Fig. 1.5.18 Ring Type Joint Flange & Ring Gasket

iv. Tongue and groove (T&G) flanges

The tongue and groove faces of flanges must be matched. One flange face has a raised ring (Tongue) machined onto the flange face while the mating flange has a matching depression (Groove) machined into is face. Tongue and groove facings are standardized in both large and small types. They differ from male and female in that the inside diameters of the tongue and groove do not extend into the flange base. Thus they retain the gasket on the inner and outer diameter. These are commonly found on pump covers and valve bonnets.

Types of flange face surface finishes

The flange face finish concept refers to the type of roughness of the flange face. The ASME B16.5 code requires that the flange face (raised face and flat face) shall have a specific roughness to ensure that this surface is compatible with the gasket and provides a high quality seal. Depending on the type of gasket used in the connection, different flange surface finishes are used to optimize gasket performance. The common flange face finishes are stock finish, concentric serrated, spiral serrated and smooth finish.

Fig. 1.5.19 Tongue-and-Groove (T&G)

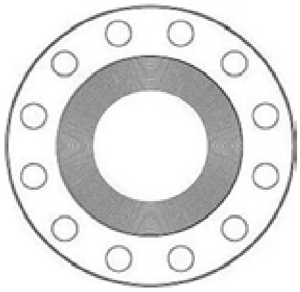


Fig. 1.5.20 – Flange with serrated finish face

a. Stock finish

This is a continuous spiral or phonographic groove, suitable for practically all general services. Stock finish is a widely used flange surface finish, which is practically suitable for all ordinary service conditions. Under compression, the soft face of gasket will embed into this finish, which helps to create a seal between the mating surfaces.

b. Serrated finish

Serrated finish flange is required when non-metallic gasket is to be installed. The serration on flanges is specified by the number, which is the arithmetic average roughness height (AARH). There are two types of serrations namely concentric and spiral (phonographic). The serration is generated by 90 degree tool, which creates "V" geometry groove with 45 degree angled serration.

i. Spiral serrated

This is also a continuous or phonographic spiral groove. It differs from the stock finish in that the groove is typically generated using a 90 deg tool which creates a “V” geometry with 45° angled serration.

ii. Concentric serrated

As the name suggests, this finish is prepared with concentric grooves. A 90° tool is used and the serrations are spaced evenly across the face.

c. Smooth Finish

Flange faces with a smooth finish should show no apparent sign of tool markings when viewed with naked eye. Smooth finish are typically made for gaskets with metal facings such as double jacketed, flat steel and corrugated metal. Flange face roughness will be between Ra 3.2 and 6.3 micrometers (125 - 250 micro inch).

Fig. 1.5.21 Flange face finish configuration and their roughness

d. Surface finish notation AARH

AARH stands for arithmetic average roughness height. It is used to measure the roughness (rather smoothness) of surfaces. Sometimes AARH is referred also as RA which stands for roughness Average and means the same. 125 AARH means 125 micro inches will be the average height of the ups and downs of the surface. 63 AARH is specified for Ring Type Joints. 125-250 AARH (it is called smooth finish) is specified for spiral wound gaskets.

1.5.6 Flanges Face and Finish

At the end of this exercise, you will be able to:

1. identify type of flange face and finish.

Practical

Requirements		
Tools/Instruments		**Materials/Components**
Measuring Tape	– 1 No.	Paper
Try Square	– 1 No.	Pencil
Steel rule	– 1 No.	Flange chart or different type of flanges 2”.
Equipment/Machines		
Personal Protective equipment	– 1 Set	

Tips

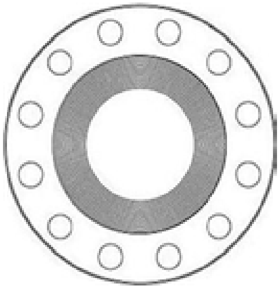
Instructor may provide different types of flanges with various finished surfaces, and explain to trainees about the method of identification.

Look at the picture below and write the type of flange surface finish conditions in Table 2.

1

2

3



4

5

Table 2

Sl. No.	Type of flange surface finish condition
1	
2	
3	
4	
5	

Exercise

I. Answer the following questions.

1. Name any three flange types that are classified based on flanges facing.

2. What are the applications of raised face flanges?

3. What are the different types of flange face serrations and how are they formed?

4. Explain the significance of RTJ flanges.

5. Describe the surface finish notation AARH.

II. State whether the following statements are True or False.

1. Flat face flange can be bolted to flat face or raised face flange.

   True ☐ False ☐

2. Raised face height is same on pressure rating flanges of the same size.

   True ☐ False ☐

3. The purpose of raised face is to decrease the pressure containment capability of the joint.

   True ☐ False ☐

4. Ring type joints shall not be used in offshore piping systems.

   True ☐ False ☐

5. The raised face of the ring type joint flange does not serve any part of sealing means.

   True ☐ False ☐

6. AARH refers to "Arithmetic Average Roughness Height".

   True ☐ False ☐

7. RA refers to "Raised Face Area".

   True ☐ False ☐

Notes

1.5.7 Types of Pipe Bends, Elbows and Shapes

At the end of this topic, you will be able to:

1. classify and distinguish different types of pipe fittings
2. identify applications of pipe fittings
3. describe the significance of pipe fittings.

Pipe fittings classifications

1. A pipe fitting is a constituent part used in a piping system for
   - making connections
   - changing direction,
   - branching or for change of pipe diameter, which is mechanically joined to the system
   - changing the pipe specification from one material to another.
2. Pipe fittings classification based on end connections are butt weld fittings, socket weld fittings, screwed, Flanged, spigot socket fittings.
3. Fittings classifications by name is
   - bend angles (90° and 45° elbows)
   - reducing elbows
   - short and long radius bends
   - equal and unequal tees
   - concentric and eccentric reducers
   - stub ends / end caps.

Fig. 1.5.22 Various Pipe Fittings

1. Elbow 90° long radius
2. Elbow 45°
3. Elbow 90° short radius
4. Elbow 180° long radius
5. Elbow 180° short radius
6. Tee straight
7. Tee reducing
8. Reducer concentric
9. Reducer eccentric
10. End cap
11. Lap joint Stub End

Pipe fittings details

1. Butt weld fittings

Butt weld pipe fittings are the most commonly available ones in carbon steel, stainless steel, nickel alloy, aluminum and high yield strength material. Butt weld fittings are available as elbows, tees, caps, reducer and outlets (olets). These fittings are the most common type of welded pipe fitting and are specified by nominal pipe size and pipe schedule. Butt weld fittings are made from seamless or welded pipe and are forged (through multiple process) to get the shape of elbows, tees and reducers, etc.

2. Elbows & bends

The function of an elbow is to change direction or flow in a piping system. Elbows are split into two groups, namely long radius and short radius. Comparatively, small pressure drop will occur in long radius bend whereas, high pressure drops will occur in short radius bends. There are 5 standard elbows: 45°, 90° and 180° elbows all these three are long radius version, and in addition, the 90° and 180° elbows both in the short radius version. The center to face distance is equivalent to the radius through which the elbow is bent. The center to face distance for a long radius elbow, abbreviated as LR always is "1½ x nominal pipe size (NPS) (1½D)", while the center to face distance for a short radius elbow, abbreviated as SR is equivalent to nominal pipe size.

a. 90˚Elbow

Butt weld long radius 90 degree elbow is used for 90 degree turn on piping in butt weld piping system. Long radius elbows are preferred due to their low pressure drop. They can also be cut at lesser degree, if required in piping layout. Their center line radius is 1.5 times the nominal pipe diameter. Butt weld short radius 90 degree elbows are used where space is limited. They are available only in 90 degrees but they can be cut to lesser degree, if required as per piping layout. Center line radius of short radius elbows is same as nominal pipe diameter.

3D elbows as an example, are calculated with:

3(D) x 2(NPS) x 25.4

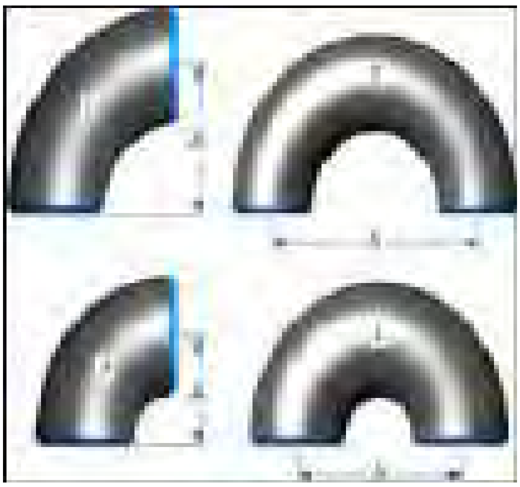


Fig. 1.5.23 Types of standard elbows

b. 45° Elbow

The function of a 45° elbow is the same as a 90° elbow, but the measurement of dimensions is different from that of the 90° elbow. Butt weld long radius 45 degree elbow is used for 45 degree turn on piping in butt weld piping system. Long radius elbows are preferred due to their low pressure drop. They can also be cut at lesser degree, if required in piping layout. Their center line radius is 1.5 times the nominal pipe diameter. Only long radius 45 degree elbows are available. The radius of a 45° elbow is same as the radius of the 90° LR (1½D). However, the center to face dimension is not equivalent to the radius as in 90° LR elbows. This is measured from each face to the point of intersection of the center lines perpendicular to each other, distances **"B"** on the image Fig 1.5.24. This is due to the smaller degree of bend. Short radius 45° elbows are not available.

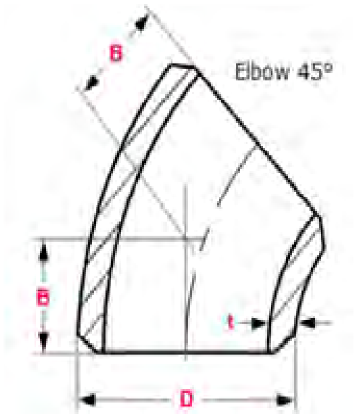


Fig. 1.5.24 45˚Elbow Dimensioning

Fig. 1.5.25 Reducing Elbows

c. Reducing elbows

Reducing Elbow is an elbow with different diameters on the ends Fig 1.5.25.

3. Tees straight and reducing

The primary purpose of a Tee is to make a 90° branch from the main run of pipe. There are two types namely the equal tee and reducing tee. The equal tee (or straight tee) branch has the same diameter as the runpipe. A straight or equal butt welding tee is available for all common diameters Fig 1.5.26. Butt weld straight tees are used for branch connection of same size that of headers. Butt weld reducing tees are used for branch connection of smaller size than that of header. Dimensions and Standards of Tee connections are if a tee specified NPS 3, it is equal or straight tee. If a tee specified as NPS 3 x 2, it is a reducing tee, intended for different sizes.

4. Butt weld concentric reducers

Concentric reducers are used preferably in vertical piping Fig 1.5.27.

5. Butt weld eccentric reducers

These are mostly preferred in horizontal piping, as they keep bottom of pipe unchanged Fig 1.5.28.

6. WeldOlet, Threadolet And SockOlet

These are basically self-reinforced fittings Fig 1.5.29. Weldolet is used for butt weld branch connection where standard tee is not available due to size restrictions and the piping is of critical / high-pressure service. A threadolet is the same basic design as a weldolet. Weldolet is used when welding a pipe or fitting directly to the branch fitting and a threadolet is used when thread is required to install threaded pipe or fitting. Sockolet is used for socket welding branch connection.

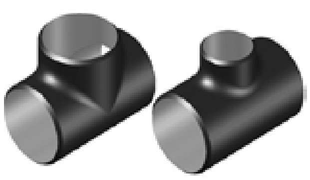


Fig. 1.5.26 Straight and Reducing Tees

Fig. 1.5.27 Butt Weld Concentric Reducer

Fig. 1.5.28 Butt Weld Eccentric Reducer

Fig. 1.5.29 WeldOlet, Threadolet and SockOlet

1.5.8 Type of Pipe Fittings and Dimensions

At the end of this exercise, you will be able to:

1. identify the type of fittings
2. check the dimensions of fittings.

Practical

Requirements	
Tools/Instruments Measuring Tape – 1 No. Steel rule – 1 No. Wire brush – 1 No. Try Square – 1 No. Spirit level – 1 No. **Equipment/Machines** Personal Protective equipment (PPE) 1 complete set	**Materials/Components** Paper Pencil 2" ϕ – 90° Elbow long radius – 1 No. 2" ϕ – 45° Elbow – 1 No. 2" ϕ – Tee Straight – 1 No. 3" X 2"– Reducer concentric – 1 No.

Tips

Instructor may provide different types and sizes of pipe fittings and explain to trainees about how to identify and measure the size of fittings.

Look at the picture and write the name of fittings, measurement and document fittings dimension.

Sl. No.	Name of the fittings	Size	
		NB. Dia (ϕ)	Length in mm
1.			
2.			
3.			
4.			
5.			

Exercise

I. Answer the following questions.

1. What are the purposes and applications of pipe fittings in piping systems?.

----

2. What are the major classifications of pipe fittings?

----

3. What are the advantages of butt weld fittings?

----

4. Differentiate long radius elbow and short radius elbow.

----

5. Differentiate – weldolets, sockolets and threadolets.

II. State whether the following statements are True or False.

1. Pipe fittings can be used in piping works, for changing direction flow.

   True ☐ False ☐

2. If the piping system requires changes in pipe diameter, pipe fitting shall not be used.

   True ☐ False ☐

3. Butt weld fittings are made from seamless or welded pipe.

   True ☐ False ☐

4. Long radius pipe bend makes high pressure drop than low radius bend.

   True ☐ False ☐

5. Reducing elbow will have different diameter at both ends.

   True ☐ False ☐

6. Pipe fitting "Equal Tee" is used for same diameter of run pipe (header) and different diameter of branch connection.

   True ☐ False ☐

Notes

1.5.9 Types of Pipe Joints / Joining Methods

At the end of this topic, you will be able to:

1. describe features of different fabrication joint types
2. choose and employ appropriate jointing methods
3. perform appropriate joints preparation.

Piping fabrication joint types

Piping fabrication and installation is made with different joint types based on material and process conditions. Following are the different piping joint types being employed in oil and gas industry and associated miscellaneous services. welding, bolting, bonding, screwing / threaded.

Types of welding joints.

a. **Butt joints**: Item to be welded is kept in the same plane and are joined at the edges. Unless otherwise specified, these types of butt joints are considered to be groove welds with full penetration.

b. **Tee joints:** one part is perpendicular to the other in the approximate shape of the letter ''T".

c. **Lap joints**: consists of two overlapping parts.

d. **Corner joints:** parts in a corner joint form a right angle and are joined in the corner.

Fig. 1.5.30 shows different types of weld joints. Each type of welding joint has different parameters to meet different requirements.

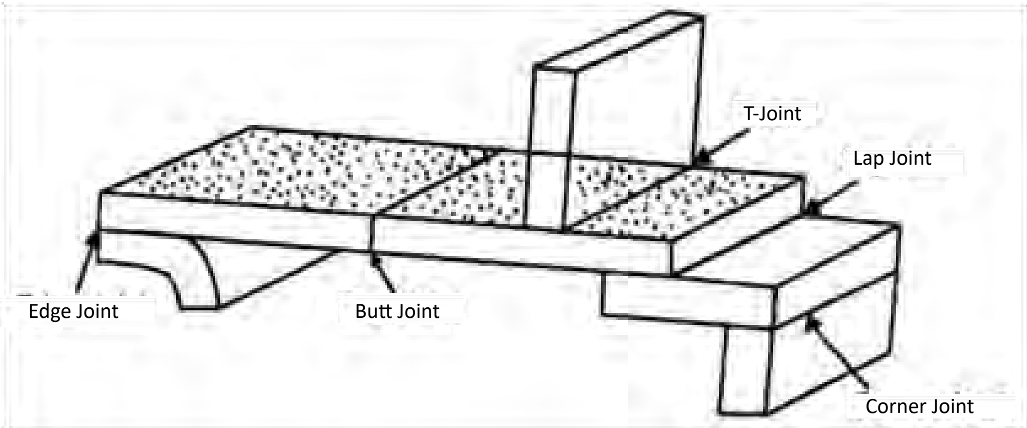


Fig. 1. 5. 30 Basic types of Welded Joints

f. **Most employed pipe welds:** Two major types of welds used to join metallic piping materials are, butt weld and fillet weld.

i. **Butt welded joints groove preparation**

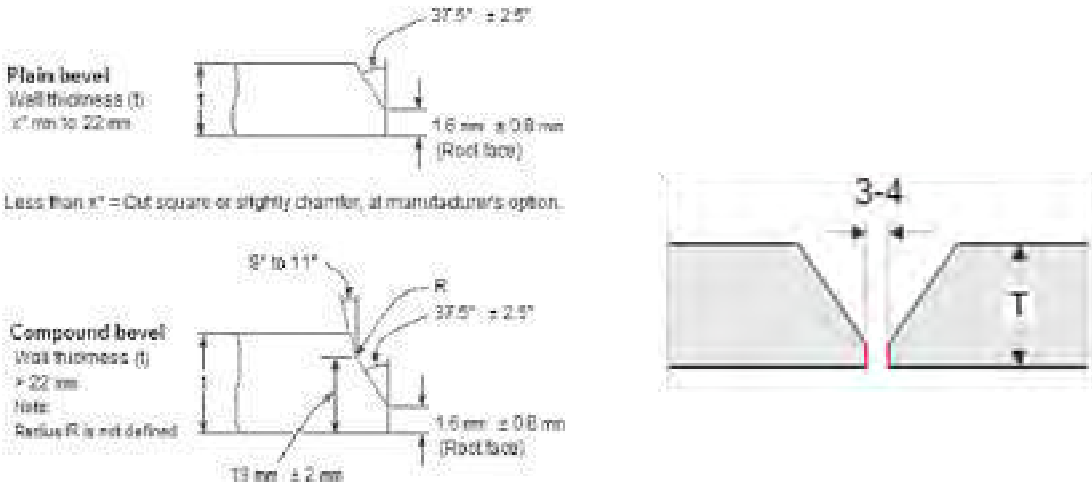


Fig. 1.5.31 Butt Weld Grooves Preparation

This is groove type weld used to join two metal pieces that are positioned next / adjacent to each other, by duly fusioning and melting the joining faces and edges with or without addition of filler metal. A butt joint is the most universally used method of joining pipe to itself, fittings, flanges, valves, and other equipment. When the material to be welded exceeds 5" in thickness, the ends of pipes, fittings and flanges must be chamfered / edge prepared at approximately 37.5°, flared on a small upright side (Root face) to form welding bevel. The most used bevels are the plain bevel of wall thicknesses (t) 4 to 22.5 mm, and the compound bevel of wall thicknesses above 22 mm. During joining pipe to pipe or pipe to elbow, a gap of approximately. 3-4 mm should be created for higher thicknesses, to obtain a proper weld penetration. If filler metal diameter is less, then the root gap can be reduced accordingly. Based on the groove formation, the different types of butt welds are:

square butt weld, bevel groove weld, V-groove weld, J-groove weld, U-groove weld, flare-V-groove weld, flare-bevel-groove butt weld.

ii. Joining by fillet welds

This is not a type of joint. It is fillet-type weld (Tee joint, lap joint, corner joint, etc).

Fillet welding refers to the process of joining two pieces of metal together whether they are perpendicular or at an angle. Fillet weld is aesthetically triangular in shape and may have a concave, flat or convex surface depending on the welder's technique. These welds are commonly referred to as

a) Tee joints when two pieces of metal are fitted perpendicular to each other;

b) Lap joints where two pieces of metal overlap and are welded at the edges.

c) If two metal pieces are joined at edges and perpendicular to each other, it is called corner fillet weld.

Fillet welded joints such as tee, lap and corner joints are the most common connection in welded fabrication. Bevel preparation is not needed. However, surface preparation to sound metal is needed for proper fusion. Fillet weld assemblies are simple to make. In piping system, slip on flanges welding, seal welding of threaded joints (if required), socket weld of piping and pipe supports welding are normally welded by fillet weld.

Bolted joint connections

Bolted joints are extensively used in piping industry. A bolted flange connection may be made with flange, bolts / studs, gaskets, washer, etc. The correct placement of gasket and proper tightening of bolts in a flanged joint will ensure a leak – free joint. Piping bolted connections are mostly made either by studs bolts or hexagonal head bolts.

Bonding joints

Bonded joints are very common in many piping and pipeline systems, in which the bond behaviour of the joint interface and degree of surface preparations are of crucial importance. Permanent bonding joints are made using adhesives / resins. Adhesives / resins are added in the joining surfaces at controlled environment and temperature as recommended by the manufacturer and cured. Different types of bonding joints include lamination joints, bell and spigot joints. Dissimilar metals, composite metals and PVC, GRE / GRP metals can be joined by bonding process.

Threaded / screwing joints

a. Threaded joints are detachable joints of two or more component parts either directly connected with each other or by standardized fasteners like bolts, nuts and screws. Threaded joint in piping means, pipes are connected by screwing with the help of threads provided for each pipe, having internal threads in one pipe and the other having threads externally.

b. Types of threads: There are two types of threads namely, straight thread and tapered threads. Threaded joints in process piping may be made by tapered threads. Pipe thread "NPT" (National Pipe Thread) is mostly used with sealant.

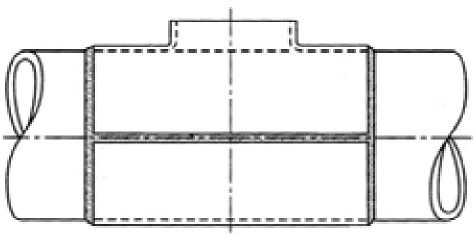


Fig. 1.5.32 Fillet welding of pipe sleeve ends

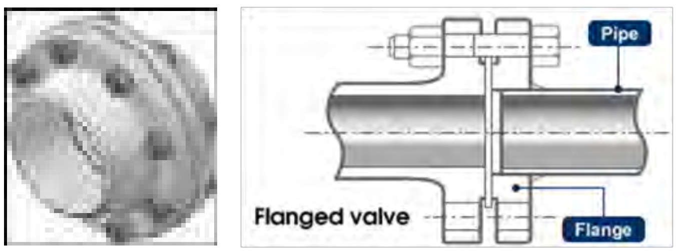


Fig. 1.5.33 Bolted Joints

c. Types of threaded joints

Different types of threaded joints are as discussed here.

Direct joints

The component parts to be joined have internal or external thread and are directly screwed together. No additional fastening elements are needed. This types of joints are performed in plant piping, airlines instrument etc.

Indirect joints

The component parts to be joined are held together by standardized components like bolts, screws and nuts. Locking devices and washers may be used additionally.

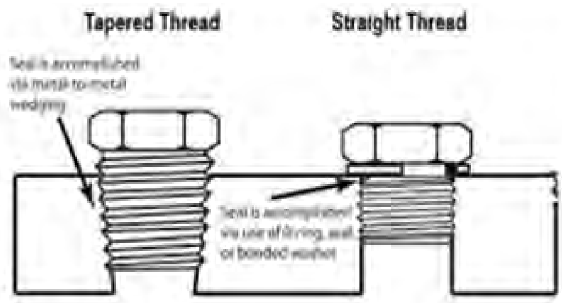


Fig. 1. 5.34 -Type of threads

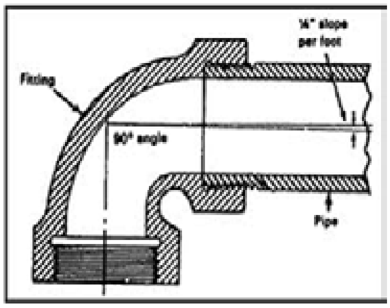


Fig. 1.5.35 Typical threaded joints in piping

Where a component part has a female thread, the joint may be made without a nut. The walls of the workpiece must be sufficiently thick for this kind of joint. This type of joints are performed in skid mounting, pump mounting, etc.

Fastening joints

The component parts are to be joined directly or indirectly only for the purpose of connecting them. The vee-thread, ISO metric vee-thread or Whitworth thread are the preferred types of threads. Both threads are self-retaining.

Adjustable joints

The component parts are joined for the purpose of connecting them and transmitting movements or forces. The preferred types of threads are round threads, ACME standard screw thread or saw-tooth thread. Valve stem and gland joints are of this type. These are less self-retaining – indicates 1 round thread, 2 ACME standard screw thread and 3 saw-tooth thread.

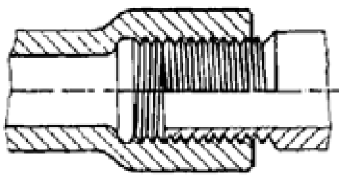


Fig. 1 5.36. Direct joint

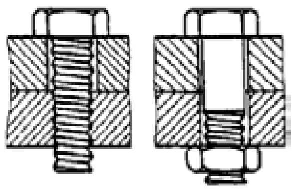


Fig. 1. 5.37 Indirect joint

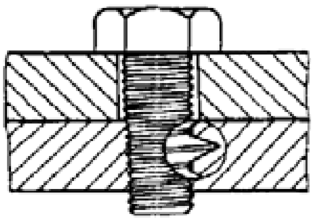


Fig. 1 5.38 Screwed joint fastening

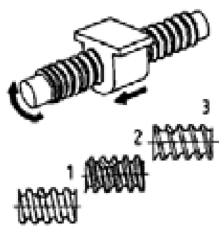


Fig. 1.5.39 Adjustable joint

1.5.10 Edge Preparation and Fitup

At the end of this exercise, you will be able to:

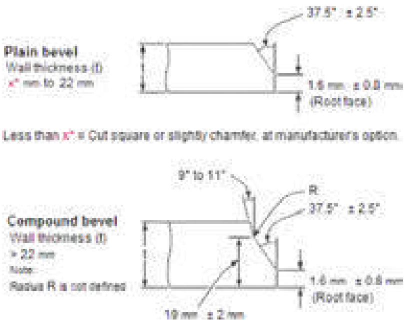
1. prepare pipe to pipe edge beveling and joint fitup
2. prepare plate to plate edge beveling and joint fitup.

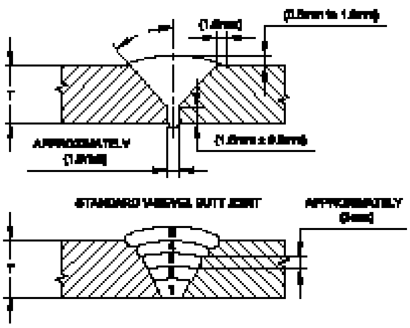
Practical

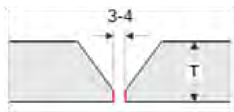
Requirements	
Tools/Instruments Measuring Tape – 1 No. Steel rule – 1 No. Try Square – 1 No. Spirit level – 1 No. Flat file – 1 No. Hack saw – 1 No. **Equipment/Machines** Personal Protective Equipment – 1 No. Grinding Machine – 1 No.	Welding Equipment – 1 No. Oxy-Acetylene Gas cutting – 1 No. **Materials/Components** Paper – 1 No. Scriber – 1 No. Approved shop drawing 2” ϕ –SCH 80 pipe – 400 mm long – 1 No. 10 X 100 X 300 long-plate – 2 No.

Tips

The instructor will guide the trainee on how to select suitable tools and equipment for use in pipe fitting works, and demonstrate how to prepare pipe and plate beveling, (edge preparation).







Exercise

I. Answer the following questions.

1. Name any four type of joints normally used in piping.

----

2. List out different type of weld joints

----

3. Draw the sketches for the following weld joints fit-up:

----

i. Two Numbers of 20 mm thick plates joining full penetration butt weld with double V groove

ii. Two Numbers of 16 mm thick plates joined together to perform full penetration butt weld “T” joint with single bevel

4. List out different type of butt welds.

____

5. Describe bonding joints and their applications.

____

6. What are all the items can be welded by fillet welds, in piping system, provided if mentioned in the drawing?

____

II. State whether the following statements are True or False.

1. "Bonding" is one type of pipe joining method.

   True ☐ False ☐

2. In piping works, butt joints are made with partial penetration welds.

   True ☐ False ☐

3. Edge type joints comes under the category of "Groove type weld".

   True ☐ False ☐

4. Fillet weld is one type of joint.

   True ☐ False ☐

5. Lap and corners joints can be welded by fillet welding.

   True ☐ False ☐

6. In general, Slip on Flanges are welded by "Butt welding".

   True ☐ False ☐

7.. 'NPT' is the abbreviation for 'Nominal Pipe Thread".

   True ☐ False ☐

Notes

1.5.11 Types of Bolts, Nuts and Screws - Pipe Clamps & Fixtures

At the end of this topic, you will be able to:

1. explain different pipe fasteners and differentiate the same
2. describe features of different pipe joint clamps
3. choose appropriate pipe clamps for pipe joint fitup.

Types of bolts, nuts and screws – pipe fasteners

In piping, Bolting is a term used to perform flange joints connection using appropriate fasteners. Stud bolt, nuts, machine bolts and washers are known as bolting material or fastener. In oil and gas industry, stud Bolts and hex Bolts are mostly used for flange connections. The stud Bolt is a threaded rod with 2 heavy hexagon nuts, while the hex Bolt has integral head with one nut. Fasteners are coated to increase the wear resistance, prevent damages and avoid field coating / painting of fasteners.

Fig. 1 5.40 Coated Fasteners

a. Studs (stud bolt)

Stud has a thread on full lengths or at both ends. While joining flanges, the length of stud bolt should be enough to cover entire nut plus 1.5 to 3 threads exposed either side. Long studs must be avoided as it increases the chance of corrosion and other damage to the exposed threads, which would make subsequent removal difficult. Length of the stud depends on the flange thickness, type of gasket, nuts size and the maximum exposed thread requirements.

Fig. 1.5.41 Stud bolts (threads – full length and at both ends)

Fig. 1.5.42 Machined bolt with nuts & washer

b. Machine bolts / hexagonal bolts

Bolts have a thread at one end and hexagonal head on another end as shown in fig 5.50.

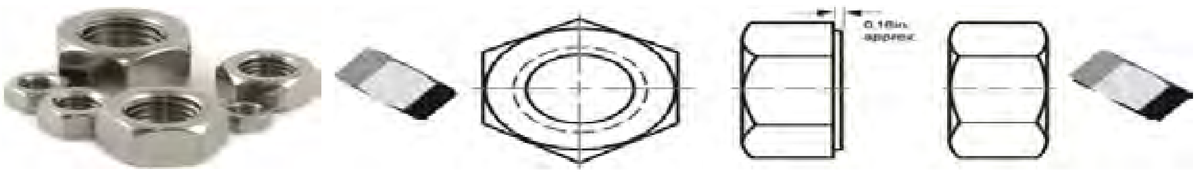


Fig 5.43 Hexagonal Nuts

c. Hex N uts

Commonly, hexagonal heavy series nuts are used with studs and bolts. The non-bearing face of a nut is chamfered, while load bearing face is finished with a washer face or may be chamfered. In general, the height of a nut for a stud bolt is the same as the diameter of the thread rod.

d. Washers

i. A washer is a thin, mostly circular sheet / plate material with a hole at the center. Standard washers purposes to distribute the load / pressure evenly over the flange surface, so that the flange is not damaged.

ii. Different types of washers are used such as flat / plain, splits washer (helical spring washer), and conical springs (bellevelle spring washer).

- Plain washers, which spread a load and prevent damage to the surface being fixed or provide some sort of insulation such as electrical insulation.

- spring washers / conical washers, which have axial flexibility and are used to prevent fastening or loosening due to vibrations
- locking washers, which prevent fastening or loosening by preventing unscrewing rotation of the fastening device, usually, locking washers are also spring washers.

Fig. 1.5.44 Flat and spring washers

Fig. 1.5.45 Conical washer

e. Screws

Screws are not normally used in piping / pipeline works. It is used only in miscellaneous secondary structures of process plants.

g. Materials for stud / bolts

Bolting material can be divided into three groups – high strength, intermediate strength and low Strength. The material qualities for studs and bolts are specified in ASME / ASTM standards with grades. Frequently used grades are A193 / A320 / A307 for bolts / studs and A194 for the nuts.

Fig. 1.5.46 Types of screws with different head formations

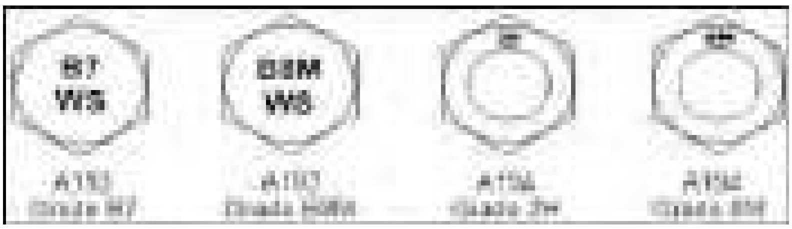


Fig. 1.5.47 Identification marking in bolts and nuts

h. Marking of stud / bolts / nuts

ASTM material Standard A193 and A320 specify marking requirements for stud and bolt. Marking is to be done at the ends of the stud or on the bolt head. In the case of hex head bolt, both the symbols are marked on the bolt head. For nuts, marking should be done on the nut's non-load bearing face. Due to limited space, only manufacturer's identification mark and material grade / class are marked with a unique identifier on stud and bolt.

II. Various pipe fitting fixtures and clamps

1. Rigid clamps

Rigid clamps are usually made from hard iron or steel which makes these clamps suitable for pipe clamping and allows fast locking and unlocking. Pipes can easily be inserted into these clamps and locked to an accurate position.

2. Adjustable clamps

Steel, aluminum and plastic often comprise the base material for these clamps. The main advantage of adjustable clamps is that they can be used for a wide range of pipe sizes. The size of the clamp can be changed easily in accordance to the diameter of the pipe by tightening or loosening the screw attached to the clamp. This allows the clamp to be reused for another pipe which has a different diameter.

3. **C-clamp**

   The popular C-clamp is the standard go-to clamp for many occasions. Its simplicity and availability are unmatched. Every clamp collection starts with a few sizes of C-clamps.

Fig. 1.5.48 Adjustable Clamp fixing

Fig. 1.5.49 C Clamp

Fig. 1.5.50 Simple Clamping

Fig. 1.5.51 F Clamp

Fig. 1.5.52 Pipe clamp fixture

4. **F- clamps**

   The F-clamp is designed for various pipe diameter fixtures. The F-clamp has a slider bar that allows the opening capacity to be easily adjusted to accommodate a wide range of diameters. This has made the F-clamp another very popular clamp and is used when a C-Clamp's opening capacity is too small.

5. **Pipe clamp fixture**

   The pipe clamp fixture is similar to the F-clamp, except instead of using a sliding bar it uses to a sliding pipe. This allows for the pipe clamp to fit any opening capacity as needed to suit appropriately the pipe size.

6. **Chain type clamps**

   Chain type clamps align and reform pipe diameters as small as 1 in. (25 mm) and as large as 20 ft (6 m). The inside or outside of the pipe can be aligned with these clamps. Chain clamps allow pipe, elbow, tee, flange, and other fittings to be held safely and securely in place during the alignment and welding process.

7. **Cage clamps**

   Cage Clamps are available for pipe sizes 2 to 60 in. (51 to 1524 mm) as shown in fig 5.62. These rigid frame clamps are designed for rapidly aligning the outside diameter and come in two basic styles. The tack type cage clamp is used to align pipes for tack welding. The no-tack type allows the joint to be completely welded without removal of the clamp. These clamps are designed to align only one pipe size per clamp. The clamps are available in hand lever, ratchet, and hydraulic models. Full-circle steel-type clamps are available for pipe sizes 6 to 72 in. (152 to 1829 mm) and have multiple contact points to handle aligning, reforming or rounding applications. These clamps are designed to put pressure on the high point of the pipe or shell and bring them into alignment. The welder is able to do a 100% weld and grind without removal of this type of clamp.

9. **Internal hydraulic and pneumatic alignment clamps** are used mainly for pipeline applications and are available for pipe sizes 6 to 60 in. (152 to 1524 mm). These clamps cover a range of one to six pipe sizes,

Fig. 1 5.53 Chain type clamping

Fig. 1.5.54 Cage clamps

Fig. 1.5.55 Frame type clamping

Fig. 1.5.56 Internal alignment clamps

depending upon the make and model. These clamps allow to complete full circle weld without obstruction. An automated welding system in conjunction with the clamp, increases productivity and lowers weld rejects. Wherever possible, internal clamps shall be used due to the following reasons:

a. The internal clamp gives smoother alignment for both pipe joint ends and leads to better weld root.

b. The internal clamp use the pushing technique, reduce the need of additional or temporary tack welds.

c. Internal clamps increase the production rate and yields better quality fitting.

1.5.12 Different Type of Fasteners and its Dimension

At the end of this exercise, you will be able to:

1. identify the different types of fasteners and measure the dimensions
2. record the names and grade of fasteners
3. identify the different type of washers.

Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Measuring Tape	– 1 No.	Paper	
Steel rule	– 1 No.	Pencil	
Thread gauge	– 1 No.	Marker pen	
Wire brush	– 1 No.	M12, M16, M20–studs-	–1 EA
Equipment/Machines		M12, M16, M20–nuts-	–1 EA
Personal Protective Equipment	– 1 No.	Plain washer's 14/20	–4 Nos.
		Spring washers 18mmID	–2 Nos.

Tips

The instructor should provide a chart for the different sizes and grades of bolt, nuts, washers and explain how to identify the type, size and grade of fasteners.

Identify the fastener size and record in Table 4.

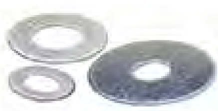

1


2


3


4

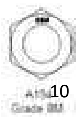

5


6

7

8

9


10


11


12

Table 4

Sl. No.	Name of the fasteners used in piping	Size of the fastener's	Sl. No.	Name of the fasteners used in piping	Size of the fastener's
1.			7.		
2.			8.		
3.			9.		
4.			10.		
5.			11.		
6.			12.		

1.5.13 Pipe Edge Preparation and Alignment

At the end of this exercise, you will be able to:

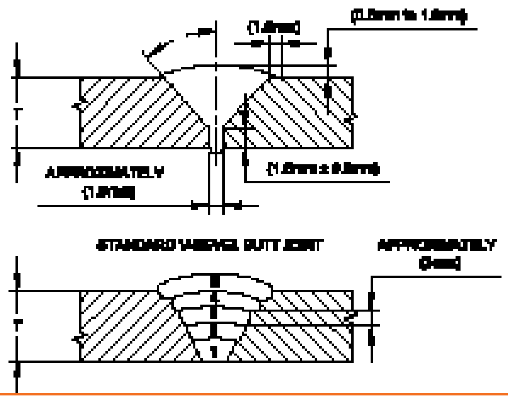
1. perpare pipe edge beveling and check the bevel angle
2. assemble pipe to pipe fit up, using F-Clamp for alignment.

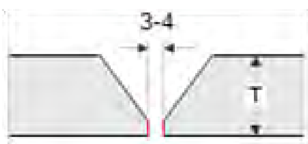
Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Measuring Tape	– 1 No.	Paper	
Try Square	– 1 No.	Pencil	
Spirit level	– 1 No.	Marker pen	
Welding hand shield	– 1 No.	Welding electrode	– 2 Nos.
Wire brush	– 1 No.	4" ϕ – Carbon steel pipe 600 mm long	– 1 No.
Scriber	– 1 No.	**Equipment/Machines**	
F.Clamp	– 1 No.	Personal Protective Equipment (PPE)	- 1 Set.
Spacer wire	– 1 No.	Welding equipment with accessories	- 1 No.
Bevel protractor	– 1 No.	Grinding machine with accessories	- 1 No.
Hi-Low gauge	– 1 No.		

Tips

The instructor should demonstrate pipe end beveling and guide the trainee about how to use grinding machine for beveling, and how to check bevel angle.





Exercise

I. Answer the following questions.

1. What are the fasteners used in oil and gas industry piping works?

----

2. What are the different coating / plating performed for fasteners to prevent corrosion and improve wear resistance?

----

3. What is the difference between stud bolt and hexagonal bolt?

----

4. Describe different types of washers and their applications.

----

5. What are the advantages of internal alignment clamps?

Notes

1.5.14 Pipe Joining Packing Materials - O-Ring, Ropes and Adhesives

At the end of this topic, you will be able to:

1. define packing materials related to piping
2. describe features of different pipe joint clamps
3. choose appropriate pipe clamps for pipe joint fitup.

O ring is a mechanical packing gasket. It is a loop of elastomer with a round crosssection (in some applications – square / rectangular), designed to be seated in a groove and compressed during assembly between two or more parts, creating a seal at the interface. O ring seals prevent fluids from escaping through the gaps in mating surfaces. Because the material is soft, the O ring is mechanically squeezed to plug any gap between the two mating hardware pieces. The flexible nature of O ring materials accommodates minor imperfections in the mounting parts. But, it is still important to maintain good surface finish of those mating parts.

Fig. 1.5.57. O rings

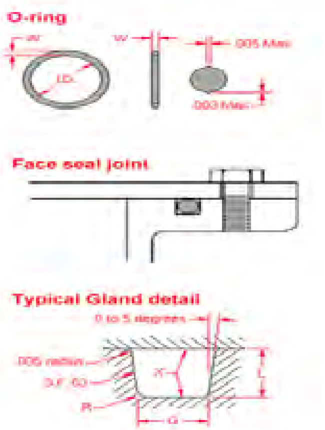


Fig. 1.5.58 Typical O ring sizing and sealing arrangements

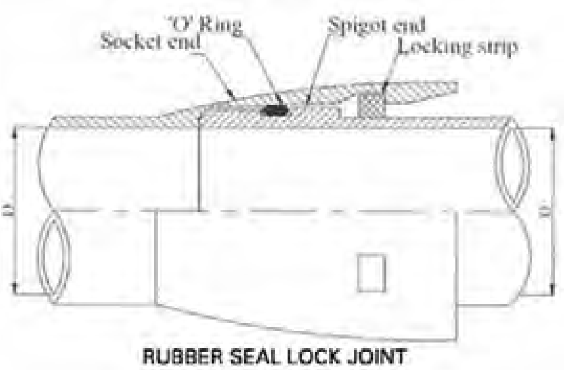


Fig. 1.5.59 O ring positioning in Spigot joint

b. O ring materials

O Rings can be made from plastic or metal. O rings are made from different materials as listed below:

- synthetic rubbers – thermosets
- butadiene rubber (BR)
- butyl rubber (IIR)
- chlorosulfonated polyethylene (CSM)
- epichlorohydrin rubber(ECH, ECO)
- ethylene propylene diene monomer (EPDM)
- eluoroelastomer (FKM)
- nitrile rubber (NBR, HNBR, HSN, Buna-N).

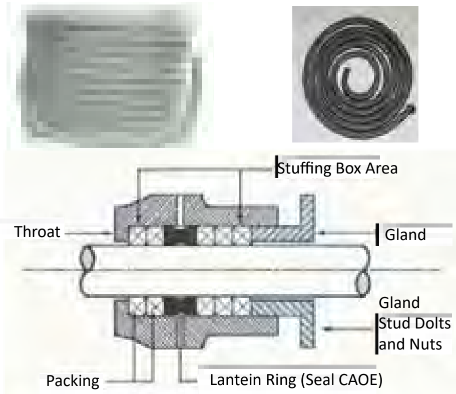


Fig. 1.5.60 Rope packing

Rope packing

Rope packing is made by graphite PTFE. In piping works, ropes are rarely used (such as valve gland / stuffing box stem assembly) where sealing is required on the moving parts. Unless otherwise specified in the drawing, manufacturer recommendations shall be followed for the rope materials selection and installation.

a. Adhesive is a substance that is capable of holding materials together in a functional manner by surface attachment that resists separation. Various joints are made using adhesives. Most of the PVC, GRE/ GRP, PE piping are joined by applying adhesives. An adhesive in the form of a liquid or a tacky solid is placed between the surfaces to be joined, which are then mated and heat or pressure or both applied to accomplish the joint. The best choice of adhesive depends on the materials to be bonded.

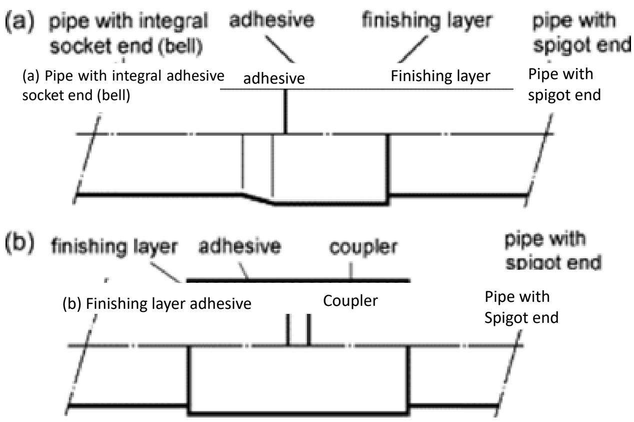


Fig. 1.5.61 Spigot joints made with adhesives

b. Adhesive types: Adhesives can be divided into two broad groups – structural adhesives and non-structural adhesives.

Tips

Note: non-structural adhesives, also known as glues or cements, are used for low load applications.

c. Adhesive shelf life and working life: Adhesives are characterized by their shelf life, which is defined as the time that an adhesive can be stored after manufacture and still remain usable, and by their working life, defined as the time between mixing or making the adhesive and when the adhesive is no longer usable.

d. Structural adhesives

Structural adhesives have high load carrying characteristics. Structural adhesives, developed to produce high strength are generally composed of synthetic resins or combinations of synthetic resins and elastomers. Common synthetic resins used are epoxy, phenol and resorcinol. Structural adhesives like plastics are classified into two groups-Thermoplastic and thermosetting.

i. Thermoplastic adhesive

Thermoplastic adhesives may be re-softened by heating repeatedly at high temperatures, which is decided by their chemical structures. They also lose bond strength due to decomposition. Most commonly used thermoplastic adhesives are the polyamides, vinyls and non-vulcanizing neoprene rubber.

For structural applications, vinyls have proved very versatile. For example, polyvinyl acetate can be used to form strong bonds with metals, glass and porous materials.

ii. Thermosetting adhesives

Thermosetting resins are the most important materials from which metal adhesives are formed. Thermosetting resins are available to give strong, waterproof and heat- resistant joints. There are two general types of thermosetting structural adhesives the phenolic-resin base and the epoxy-resin base adhesives. Epoxy resins are amongst the newest thermosetting resins and are widely acclaimed as they combine the properties of excellent action, low shrinkage, high tensile strength, toughness and chemical inertness. They can be cured at room temperature without any volatile by-products and can develop strengths between 15 to 30 MPa. Amongst the latest arrival on the scene is the oily metal epoxy that bonds directly to oily metals as received with normal protective oil layer on them.

e. Adhesive joints types

The main types of joints employed for adhesive bonding are lap joint and the tongue and groove configuration which can be used for butt, corner or fillet joints.

i. Lap joints

An adhesive joint performs best when loaded in shear as is the case in lap joints – three well-known types of which are shown in Fig. 1.5.63. In thin gauge metal bonds, joint designs can provide large bond areas. Thus, it is possible to produce joints that are as strong as the metal.

ii. Butt joint

A square butt joint performs poorly for adhesive applications because of low effective area and high stress concentration. However, there are several ways by which the contact area between the adhesive and the adherend can be increased. These include scarf edge preparation, double butt lap, single strap, double strap, bevelled double strap and recessed double strap.

iii. Fillet or T-Joint

Like the square butt joint, the common T-joint may not provide adequate bonding area and hence, fillet T joints are not applicable for piping.

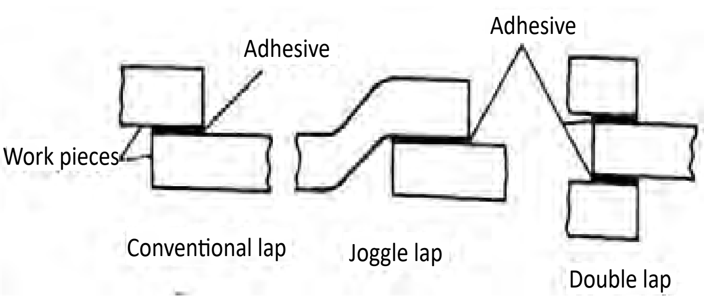


Fig. 1.5.62 Typical lap joints by adhesive bonding

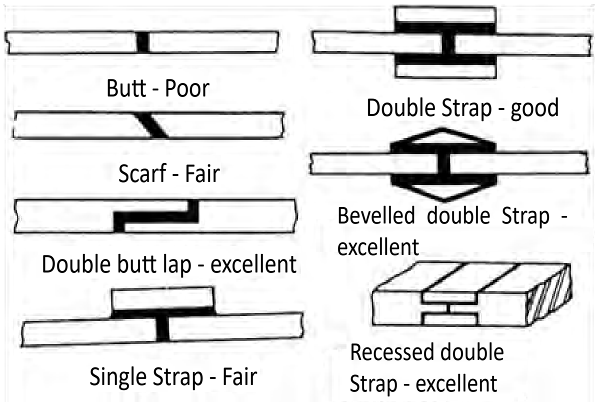


Fig. 1.5.63 Typical butt joints by adhesive bonding

iv. **Corner joints**

The corner joints are subjected to both peel and cleavage stresses and the joint is relatively weak. Hence, this is not applicable for piping.

f. **Tube / pipe joints**

Adhesive bonding is used for tube / pipe joints some of which are shown in Fig. 1.5.64. Large bonded areas give strong joints with clean appearance but processing may be complicated with some while edge preparation may be costly for some others. The strength developed in an adhesive joint depends upon the joint design, type of loading, service temperature, adherend material, etc.

1.5.15 Adhesive Storage and Handling Conditions

At the end of this exercise, you will be able to:

1. check the adhesive storage and handling conditions
2. identify the adhesive shelf life and potlife.

Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Special rubber gloves	– 1 Pair.	Paper	
Special goggles	– 1 No.	Pencil	
Equipment/Machines		Marker pen	
Personal Protective Equipment	– 1 No.	Adhesive pen	– 1No.
		MSDS	– 1No.

Exercise

I. Answer the following questions.

1. Name any four types of O ring materials.

----

2. Describe O ring functions and applications.

----

3. What are the factors that are likely to affect / influence the adhesive joint strength?

----

4. Define adhesive shelf life and work life.

----

5. What is the significances of epoxy resin base thermosetting adhesives?

III. State whether the following statements are True or False.

1. O ring can be used for both static applications and dynamic applications.

   True ☐ False ☐

2. Butadiene rubber can be used for making O ring.

   True ☐ False ☐

3. The strength of joint may be influenced by contact angle between the adhesive and metal.

   True ☐ False ☐

4. Phenolic resin based adhesive is a type of thermoplastic structural adhesive.

   True ☐ False ☐

5. Epoxy resin base adhesives are thermosetting adhesives.

   True ☐ False ☐

Notes

1.5.16 Gaskets

At the end of this topic, you will be able to:

1. describe features and significance of different types of gaskets
2. recognise constituent parts / materials of the gaskets
3. identify the gasket with respect to the manufacturer marking
4. select appropriate type of gaskets for installation
5. cut the gaskets without affecting quality.

Gaskets Purpose

Flange gaskets are used to create a static seal and maintain leakage proof sealing between two flanges faces, at all operating conditions. A gaskets fills the microscopic spaces and irregularities of the flange faces. Then it forms a seal that is designed to keep liquids and gases. Correct installation of damage-free gaskets and damage-free flange faces is essential for a leak-free flange connection.

Gasket Types

a. Three major types of gaskets are used to achieve the leak proof sealing between the flanges of piping works. They are:

- non-Metallic Gaskets that include compressed non-asbestos fibre gasket (CNAF), PTFE and rubber, teflon
- metallic gaskets that include oval ring and octagonal ring-ring type joint
- composite / semi–metallic gaskets that include, spiral wound gaskets, cam profile gaskets and metal jacketed gasket.

Non-metal gaskets are manufactured as long sheets and the required size of gaskets are cut from the sheet. Spiral wound gaskets are made by winding of metal and filler metal. Metallic gaskets are made from forged ring or cut from metal sheet and machined.

b. Based on the type of construction, gaskets are classified as full face, spiral wound metallic, Ring type, Metal jacketed, Inside bolt circle.

Non - metallic gasket

a. Non-metallic gaskets are usually composite sheet materials, used with flat-face and raised-face flanges in low pressure class applications. These gaskets are also known as a soft gasket. In earlier stages, compressed asbestos fibre (CAF) gaskets were mainly used.

b. ASME B16.21 covers types, sizes, materials, dimensions, dimensional tolerances, and markings for non-metallic flat gaskets. Non-metallic gasket is manufactured from flexible materials such as compressed non-asbestos fiber (CNAF), PTFE / teflon, rubber / elastomer, mica / glass fiber, ceramic fiber and graphite.

Advantages and applications of non-metallic gaskets

- Non-Metallic gaskets can be easily compressed with low tension bolting.
- These types of gaskets are used with low-pressure class flanges such as 150 and 300 and also in low temperature. However, graphite gasket can be used up to 500˚ C .
- Rubber and elastomer gaskets are not used in hydrocarbon services, but used in utility lines.
- Non-metallic gaskets are cheapest and easily available.
- Full-face gasket types are suitable for flat-face (FF) flanges. Flat ring gasket types are suitable for use with raised faced (RF) flanges.

The above Fig.1.5.62 shows full face gasket and inside bolt

circle gasket. Full face

gasket can be used only with FF flange and is normally used for utility lines.

Fig. 1.5.64 Non-Metallic gaskets types

Semi-metallic gaskets

Semi-metallic gaskets are composites / combination of metal and non-metallic materials. Different types of combination of materials are possible based on service requirement. Spiral wound, metal lacketed, and cam profile gasket are well known in composite gasket category. Semi-metallic / composite gaskets are used on raised face, male-female and tongue-and-groove flanges.

The metallic portion is intended to offer strength and resiliency, while the non-metallic portion provides conformability and sealability. Often used semi-metallic gaskets are

spiral wound, camprofile, variety of metal-reinforced / jacketed graphite gaskets.

ASME B16.20 covers materials, dimensions, dimensional tolerances, and markings for metallic and semi-metallic gaskets.

Fig. 1.5.65 - CNAF & PTFE Gaskets

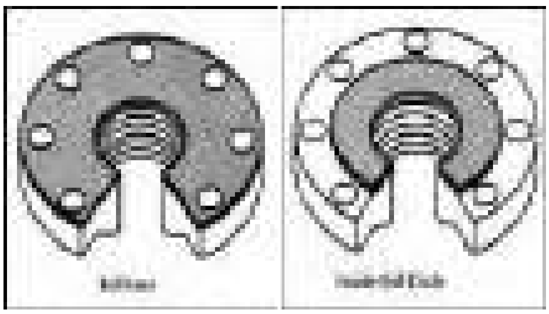


Fig. 1.5.66 – Full Face & Inside Bolt Circle Images

a. Spiral wound gasket

The most widely used composite type gasket is a spiral wound gasket. It is suitable for wide range of pressure and temperature classes. The selection of material of construction for Gasket winding depends upon the:

- corrosive nature and concentration of fluid being carried

- operating temperature of the fluid
- relative cost of alternate winding material.

There are three components in spiral wound gasket, – inner and outer ring, filler material, and winding material. Spiral wound gaskets are available with or without inner ring. The inner ring is used to provide additional support to the winding material. The winding is an alternative layer of filler material and winding material. The filler material is soft material such as graphite and PTFE and winding material is a thin sheet of stainless steel or other exotic material. PTFE is not used for high temperature services. Stainless steel or other exotic material is used as the winding material. Outer ring of spiral wound gasket is mostly manufactured from Carbon steel or stainless steel. The most commonly used material for spiral wound metallic gasket winding are austenitic stainless steel 304 with asbestos filler, austenitic stainless steel 316 with asbestos filler, austenitic stainless steel 321 / 347 with asbestos filler or Exotic material such as monel, titanium. Duplex can also be used as per service requirements. It is customary to select inner ring material to be the same as the metal winding. Depending on the type of metal filler combinations, spiral wound gaskets are suitable for raised face, flat faced and lap joint flanges at pressures up to 7000 kPa (1000 PSI) and temperatures up to 500°C.

b. Gaskets marking

Gasket materials are generally marked with size, pressure class, manufacturer logo, filler and winding material, inner and outer ring material. Spiral wound gaskets are painted in accordance with ASME / ANSI B16.20. Metallic winding material is indicated by solid colour on the cantering ring. Non-metallic filler used between metal winding is indicated by stripped colour. Refer Fig. 1.5.67.

C. Cam profile gaskets

These gaskets are used in applications where high pressures and temperatures are to be maintained and consequently high bolt loads need to be controlled. Cam profile or grooved gaskets are used in all industrial applications. Cam profile gaskets are used in industrial power plants, petro chemical industry. Cam profile gaskets consist of a metal core (generally, stainless Steel) with concentric grooves on either side with sealing materials. The sealing layers (depending on the service duty) can be graphite, PTFE (teflon), CAF or metal (aluminium or silver). The sealing layers protect the flange surfaces from damage in addition to providing an effective seal.

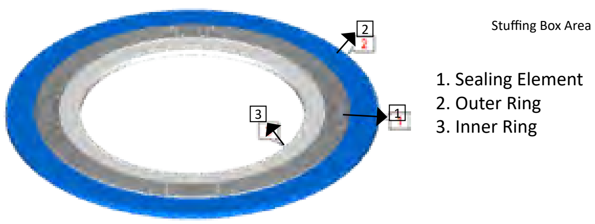


Fig. 1.5.67 Typical Spiral Wound Gasket

Fig. 1.5.68 Spiral wound gasket with cross-sections

d. Metal jacketed gasket

Metal jacketed gasket comprise metallic or non-metallic filler material enclosed by thin sheet of metal jacket / outer shell. The filler material gives the gasket resilience, while the metal jacket protects the filler and resists pressures, temperatures and corrosion. There are different ways to cover filler material as shown in the following Fig 1.5.69. Jacketed gaskets are easily fabricated in a variety of sizes and shapes and are an inexpensive gasket for heat exchangers, shell, channel, and cover flange joints. Metal jacketed gaskets are commonly used in heat exchangers and valve.

Flat jacketed gaskets are used at higher temperatures than plain flat gaskets. They require lower bolt loads than flat metal gaskets. For very high temperature services, graphite filler is used.

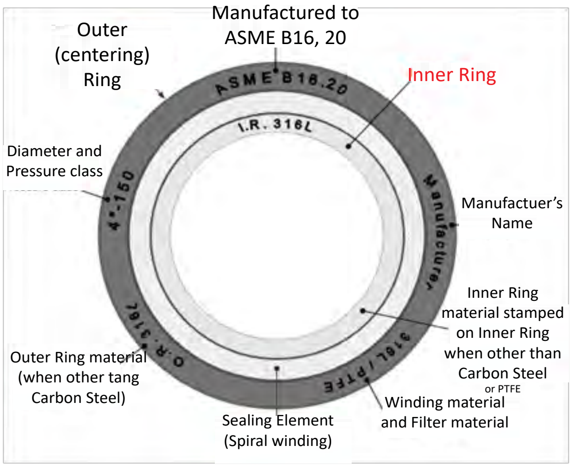


Fig. 1.5.69 Typical identification marking in gasket

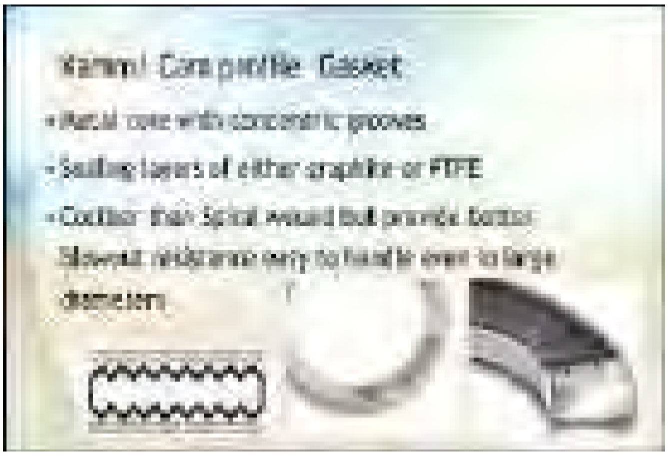


Fig. 1.5.70 Camprofile gasket

V. Metallic gaskets

Metallic gaskets are fabricated from one or a combination of metals to the desired shape and size. Metallic gaskets can be made from forged ring or cut from metal sheet and machined. High tension bolting is required for metallic gaskets. Metallic gaskets are very robust.

a. **Materials of construction:** List of material that can be used for metallic gaskets is given in ASME B16.20. Some of the materials are soft iron, low carbon steel, 4-6% Chrome, ½ Mo, Stainless steel Type 304,316,347,410, Monel, and Inconel.

Metallic gaskets are used in high pressure class flanges and for high temperature. Often used metallic gaskets are ring type joint gaskets (RTJ). They are always applied to special, accompanying flanges which ensure good, reliable sealing with the correct choice of profiles and material.

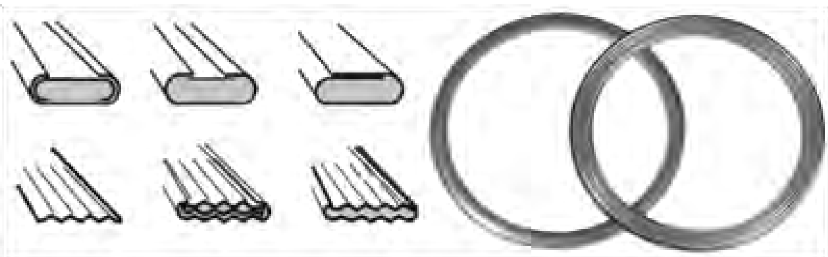


Fig. 1.5.71 Metal jacketed gasket

b. Ring type joint gaskets

Materials of construction are selected to match the flange material and to be resistant to the corrosive and erosive media. In addition, the material hardness of the RTJs is to be less than the hardness of the flanges to ensure the RTJ is deformed and not the flanges when assembled.

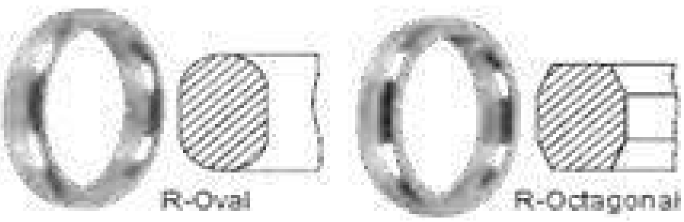


Fig. 1.5.72 Types of RTJ Gaskets

Fig. 1.5.73 Ring Type Joint gasket installation Image

Ring type joint gaskets are designed to seal by initial line contact or wedging action between the mating flange and the gasket. By applying pressure on the seal interface through bolt force, the softer metal of the gasket flows into the micro fine structure of the harder flange material, creating a very tight and efficient seal. It is machined to tight manufacturing tolerances in accordance with the relevant standards, to ensure correct installation.

i. RTJ gasket function

The RTJ gasket fits in a groove machined on the flange face of both mating flanges. Under axial compressive load, ring type joints plastically deform and flow into the irregularities of the flange groove. Since the load bearing area of the ring type joint is relatively small, very high surface stresses result between the sealing faces of the ring type joint and the groove. These stresses are further increased on the style RX and BX rings which allows very high internal pressures to be sealed. The seal is maintained by the action of axial load upon the gasket.

ii. Types of RTJ gaskets:

Two types of the metallic gasket are used with RTJ flange – octagonal and oval. Most applied type is style R ring that is manufactured in accordance with ASME B16.20 used with ASME B16.5 flanges, class 150 to 2500. Style R ring type joints are manufactured in both oval and octagonal configurations. The octagonal cross section has a higher sealing efficiency than the oval and is the preferred gasket. Oval and octagonal RTJs with the same ring size designation can be interchangeable in standard flanges with flat bottomed ring grooves. Oval and octagonal RTJs are designed to seal pressures of up to 6,250 psi in accordance with ASME B16.20 and up to 5,000 psi in accordance with API 6A pressure ratings.

iii. RTJ applications / uses

The hardness of the ring should always be less than the hardness of the flanges. The ring type joint gaskets are used where high integrity seal is essential. They are mainly used in piping and valve assemblies of petroleum industries, refining industries, oil fields, offshore piping, drilling and completion equipment. Ring type joints are also commonly used on pumps, valves and pipe work assemblies along with some high pressure vessel joints in various process plants.

c. Serrated gaskets

Serrated gaskets are flat metal gaskets which have concentric grooves machined into their faces. The reduced surface area provided by the grooves allows an efficient seal at lower bolting loads. They are commonly used with smooth faced flanges where gaskets of soft material would be unsuitable.

d. Insulating gaskets

Gaskets made of non-conductive material together with insulating sleeves around bolts and are used where it is necessary to provide electrical isolation between parts of a line.

Selection of gasket

Hardness of the gasket shall always be less than flange material by at least 50 BHN. If gasket hardness is more than flange, while tightening the flange, the gasket will damage the serration and joint might leak.

Gasket cutting processes

a. General instruction for cutting gasket

- Ensure that gasket material issued for cutting is the correct material to be cut.
- Ensure that cutting area is clean. It shall not have stones and burrs which may damage the gasket.
- Make a template as per the required dimensions and use. If template is already there, check the template dimensions for conformity.
- Mark the locations / positions accordingly.
- Use a hollow punch and hammer to punch out all the bolt and stud holes.
- Cut out the inner part of the gasket.
- Cut the outer perimeter of the gasket.

Fig. 1.5.74 Manual cutting method

b. **Manual cutting methods** are very common and generally performed in plants for jobs that require custom gaskets to be cut in the field. The material can be cut with a utility knife, scissors or shears or even by a battery operated device.

1.5.17 Different Type of Gaskets

At the end of this exercise, you will be able to:

1. identify different types of gaskets
2. draw the sketches of spinal wound gaskets.

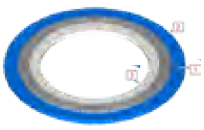
Tips

Instructor should provide the gasket chart and explain methods of identification to trainees.

Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Measuring Tape	– 1 No.	Paper	
Steel rule	– 1 No.	Pencil	
Compass drawing tool box	– 1 No.	Marker pen	–1No.
		Gasket Chart	–1No.
Equipment/Machines			
Personal Protective Equipment	– 1 No.		

a) Identify different types of gaskets



1.

2.

3.

Sl. No.	Name of gaskets used in Piping
1.	
2.	
3.	

b) Draw the sketch of spiral wound gasket and name the constituent parts.

c) Draw the free hand sketch of oval and octogonal gasket duly showing the cross section.

Exercise

I. Answer the following questions.

1. List out major group / types of gaskets with examples for each type.

----

2. Name any four types of non-metallic gaskets.

----

3. Describe the construction of spiral wound gasket.

----

4. Explain the construction of metallic jacket gasket.

----

5. Draw the sketch of spiral wound gasket.

----

6. In general, what are the details that need to be marked on the gasket by the manufacturer?

----

7. Explain the functions and effective sealing principles of ring type joint gaskets.

II. State whether the following statements are True or False.

1. Non-metallic gaskets shall not be used on raised face flanges.

   True ☐ False ☐

2. Full face gasket can be used only with flat face flange.

   True ☐ False ☐

3. Spiral wound gasket is a type of composite gaskets.

   True ☐ False ☐

4. Corrosive nature and fluid concentrations are also a deciding factor of gasket winding material.

   True ☐ False ☐

5. Spiral wound gaskets can be made with or without inner ring.

   True ☐ False ☐

6. PTFE filler metal is not used for high temperature services.

True ☐ False ☐

7. Non–metallic filler used between metal winding is indicated by stripped colour.

True ☐ False ☐

8. Ring type joint gasket material hardness shall be more than the hardness of flange material.

True ☐ False ☐

9. Hexagonal and oval shapes are the two types of RTJ gaskets.

True ☐ False ☐

10. Metallic serrated gaskets have spiral grooves machined in their surfaces.

True ☐ False ☐

Notes

1.5.18 Valves Installation

At the end of this topic, you will be able to:

1. describe different types of valves
2. explain different types of valve functions
3. install different types of valves including pressure relief valves.

Introduction to valves

Valves are mechanical devices that control the flow and pressure within a system or process. Some valves are self-operated while others are operated manually or with an actuator or pneumatic or hydraulic system. valve operations can be controlled by hand-lever, hand-wheel, motor operated, chain operator, gear operator, remote operation etc. Common types of valves are gate valve, globe valve, ball valve, butterfly valve, needle valve, plug valve, diaphragm valve, non-return valve, knife edge valve, drain valve, float valve, flush bottom valve, pinch valve, isolation valve, pen stack valve etc.

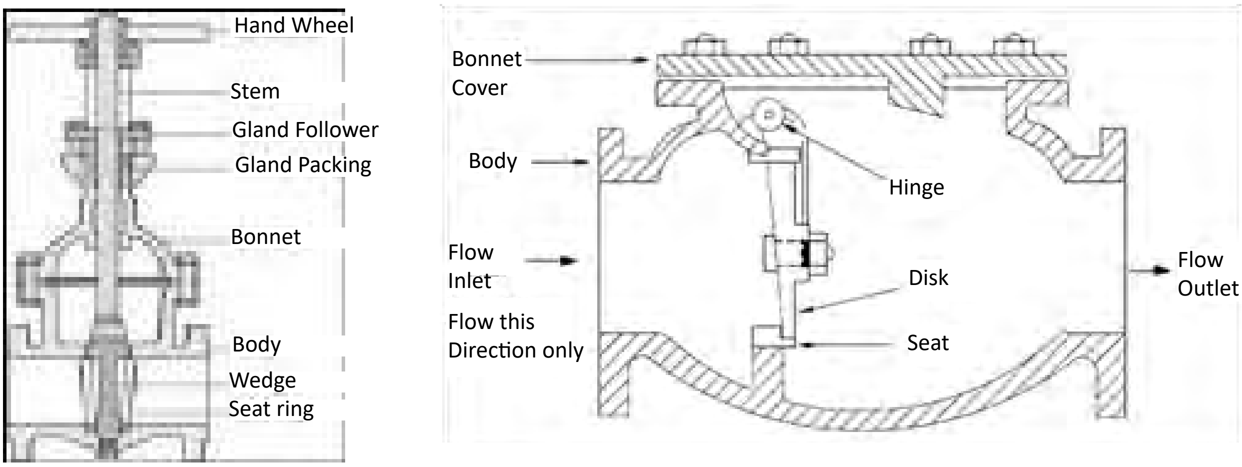


Fig. 1.5.75 Typical Valves with parts details (Left side Butterfly valve & right side – Swing check valve)

Valves classification

The following are some of the commonly used valve classifications, based on mechanical motion:

i. Linear motion valves: The valves in which the closure member as in gate, globe, diaphragm, pinch and lift Check Valves, moves in a straight line to allow, stop, or throttle the flow.

ii. Rotary motion valves: When the valve-closure member travels along an angular or circular path, as in butterfly, ball, plug, eccentric and swing check valves, the valves are called rotary motion valves.

iii. Quarter Turn Valves: Some rotary motion valves require approximately a quarter turn, 0° through 90° motion of the stem to go to fully open from a fully closed position or vice versa for example ball valve, plug valve, butterfly valves.

Functions of valves

Each type of these valves have a number of models with different features and functional capabilities. Based on the functions, the valves are classified as

i. Stopping and starting flow (for example, gate valves, globe valves, ball valve, butterfly valve, etc).

ii. Reduce or increase a flow (for example, globe valve).

iii. Controlling the direction of flow (for example, Check valve, shuttle two way / three way / four way valves, angle-globe valves for a 90-degree change in direction of flow).

iv. Regulating a flow or process pressure (for example, globe, needle, butterfly, diaphragm, piston, punch).

Relieve a pipe system of a certain pressure (PRV, PSV)

Isolation (gate, ball, plug, piston, diaphragm, butterfly, pinch).

Control valve functions: - Control valves are valves used to control conditions such as flow, pressure, and direction of flow.

i. Pressure control valves – A pressure control valve is used to reduce the amount of pressure in a tank or system of pipes.

ii. Flow control valves – Used to control fluid flow.

iii. Directional control valves such as check valves (non – return valve) and directional valves allows flow in the intended direction and stop flow in the reverse direction.

Valve rating

All pipes entering and leaving the process unit shall have a block valve and flanges provided to allow for spading (spades or spectacle blinds) at the boundary of the process unit also called battery limit. Pressure-temperature ratings of valves are designated by class numbers. ASME B16.34 (for valves-flanged, threaded, and welding end) is one of the most widely used valve standards. It defines three types of classes: standard, special, and limited. ASME B16.34 covers Class 150, 300, 400, 600, 900, 1500, 2500, and 4500 valves.

Fig. 1.5.76 Globe valve images

Fig. 1.5.77 Ball Valve Images

Valves installation procedures

Valves will be supplied with manufacturer's instruction for valves installation, operating and maintenance. Fitter shall always follow the manufacturer installation instruction for valves installation. Depending on the type of valve, some valves will have specific and special instructions for installation due to criticality and operating conditions. Valves in horizontal pipes shall be positioned with their stem on or above the horizontal, except as follows:

i. Butterfly valves shall be positioned with the stem horizontal in services where fouling substances could collect in the lower shaft bearing.

ii. Gate valves should be positioned with the stem horizontal in services where fouling substances could collect in the bottom.

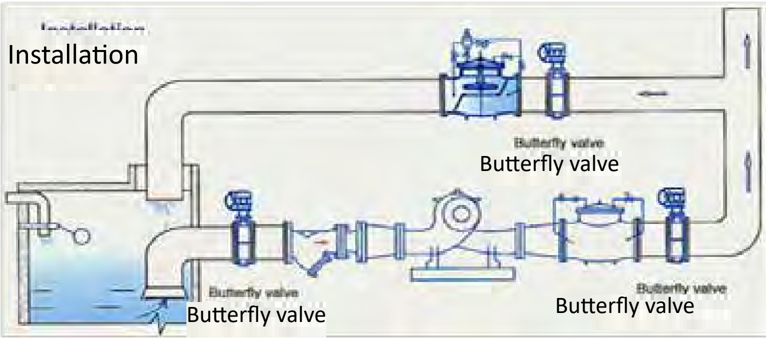


Fig. 1.5.78 Typical Butterfly valves installation

Valves flanges bolt tightening procedures

a. Observe the tightening sequences. Using a torque wrench, tighten each bolt within the required range as per specification / manufacturer recommendation.

b. Loosely install stud bolts. Identify proper bolting sequence and number bolts accordingly. Each bolt should be numbered so that bolt torque sequences can be easily followed.

c. Failure to follow proper bolt torque sequences can result in cocking flanges. Then, regardless of the amount of subsequent torqueing, they cannot be brought back to parallel. This can lead to a leaky joint.

d. Torque the bolts. Bolts should be torqued in a proper bolting sequence, in a minimum of four stages as specified here:

i. Torque the bolts up to a maximum of 30% of the final torque value required following the recommended bolt torque sequence.

ii. Care should be taken not to over tighten the valve onto the pipe, as it is possible to distort the internal parts of the valve.

iii. Repeat Step i, increasing the torque to approximately 60% of the final torque required.

iv. Repeat Step i, increasing the torque to the final torque value.

e. Retorque all studs. All studs should be retorqued using a rotational pattern of retorqueing to the final value of torque until no further rotation of the nuts can be achieved. This may require several retorqueings as torqueing of one stud causes relaxation in adjacent studs. Continue torqueing until equilibrium has been achieved.

Fig. 1.5.79 Typical Gate Valve installation arrangement

Fig. 1.5.80 Typical Globe Valve installation arrangement

Pressure relief valve (PRV) and safety relief valve installation (SRV)

a. Introduction to PRV & SRV

A Pressure relief valve is a safety device designed to protect a pressurized vessel / pipeline or system during an overpressure event. In the piping industry, there are two different names assigned to relief valves:

i. PRV (Pressure Relief Valve) release excessive liquid more than set point. Released fluid may be recirculated. The term PRV is used when dealing with liquids and opens gradually with gradual increase in pressure.

ii. PSV (Pressure Safety Valve) also known as PRV, release pressure more than set point to safeguard the equipment / piping system. The term PSV is used when dealing with incompressible fluids, especially, gas phase where the opening must be spontaneous with the sudden increase in pressure.

Both relief valves are set to open at a predetermined set pressure to protect equipment / piping system from being subjected to pressures that exceed design limits. Relief valves close at reset pressure. Hence, functionally the name PRV and PSV are used interchangeably.

The pressure relief valve must open at a predetermined set pressure, flow a rated capacity at a specified overpressure, and close when the system pressure has returned to a safe level.

b. Spring loaded pressure relief valve

The basic spring loaded Pressure Relief Valve has been developed to meet the need for a simple, reliable, system actuated device to provide overpressure protection. The spring load is adjustable to vary the pressure at which the valve will open. When a pressure relief valve begins to lift, the spring force increases. Thus system pressure must increase if lift is to continue.

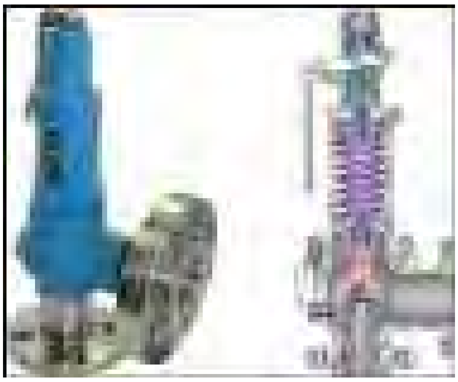


Fig. 1.5.81 Pressure relief valves

1.5.19 Ball Valve Installation

At the end of this exercise, you will be able to:

1. perform any size and type of ball valve installation in piping system.

Practical

Required Tools Instruments:	Required Materials / Components:
Measuring tape Steel rule Spanner set Torque wrench	Required Materials / Components: 1. 2” Ø ball valve - 1 No. 2. 2” Ø pipe spool with flange - 1 No. 3. 2” Ø spiral wound gasket - 2 Nos. 4. M12 stud bolt with two nuts each - 12 set

Work instructions

1. Follow valve manufacturer instruction, if any. Look for special warning tags and identification plate if any, to ensure that the valve is suitable for the intended service.
2. Remove the valve end caps installed by the manufacturer for transporting purpose. Check inside the valve to ensure that any material / shipping blocks used in shipping are removed.
3. Visually check the valve for any damages and cleanliness. Check for any foreign material that should not be inside the valve and remove.
4. Open and close the valve to ensure that no damage has occurred in transporting the valve.
5. Check the valve name plate, valve specification and confirm with the drawing requirements. Be sure the rating of the valve is as specified in the approved drawing.
6. Ensure that all pressure / functional tests of valves have been completed and cleared for installation.
7. Check the flow direction specified in the drawing and if it has been marked on the valve body and follow the same for all installations.
8. Check the valve orientation specified in the drawing as well as if specified in manufacturer instruction.
9. Make sure that piping / pipeline and flange faces are clean. Any foreign material such as metal filings, pipe scale, welding slag, welding rods, etc., can damage the disc or seat.
10. Inspect the valve flange ends to ensure that there are no raised burrs or edges that would not seal properly.
11. Install the gasket according to the manufacturer / approved drawing requirements.
12. Handle the valve only with apparatus that will not damage the valve and adequately support it using safe and proper technique.
13. Pipes shall be supported effectively and rigidly so as to avoid any distortion / damages.
14. Align the pipe work and spread the flanges enough to allow the valve body to be easily inserted between the flanges without contacting the pipe flanges.
15. Insert the valve between the flanges, without damaging the seating faces.
16. Always lift the valve by locating holes or by using a nylon sling on the neck or the body. Never lift the valve by the actuator or operator mounted on the valve.
17. Identify what type of bolts were provided and ensure that it meets the approved drawing requirements.
18. Clean all bolts and nuts with solvent and lint – free cloth. Visually inspect all threads to insure removal of all foreign material, corrosion products, burrs and previous lubrication. Lubricate all thread contact areas and nut facings.
19. Place the valve between the flanges, centre it, insert the bolts and hand-tighten them.

1.5.20 Pressure / Safety Relief Valves Installation

At the end of this exercise, you will be able to:

1. perform any size pressure or safety relief valves installation in piping and equipment system.

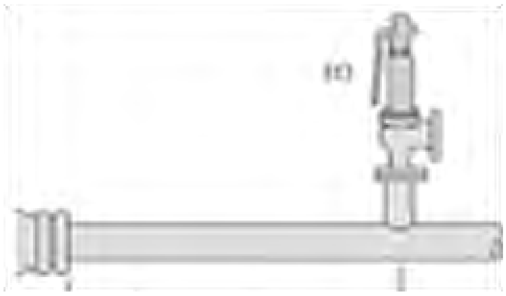
Practical

Required	
Tools / Instruments: Measuring tape Steel rule Spanner set Feeler gauge torque wrench **Required Equipment / Machines:** PPE	**Materials / Components:** 1. 2” Ø pressure relief valv – 1 No. 2. 2” Ø pipe spool – 1 No. 3. 2” Ø spiral wound gasket – 2 No. 4. M12 stud bolt – 12 Nos. 5. M12 nut – 24 Nos.




Work instructions

1. Correlate the valve name plate details with respect to valve requirements specified in the approved drawing.
2. Check the valve for any damage. For flanged valves, use new gaskets and tighten mounting studs evenly.
3. Check and ensure that preset pop up pressure value of the valve pressure is valid. If not , the pop up pressure shall be reset.
4. If calibration is expired, the PRV / SRV shall be calibrated prior to installation.




5. Before installation, flange faces or threaded connections on both the valve inlet and the vessel and/or line on which the valve is mounted must be thoroughly cleaned of all dirt and foreign materials.
6. Because foreign materials that pass into and through safety valves can damage the valve, the systems on which the valves are tested. It has to be finally installed, inspected and cleaned.
7. New systems in particular are prone to contain foreign objects that inadvertently get trapped during construction and will destroy the seating surface when the valve opens. The system should be thoroughly cleaned before the safety valve / pressure relief valve is installed.
8. The gaskets used must be dimensionally correct for the specific flanges. The inside diameters must fully clear the safety valve inlet and outlet openings so that the gasket does not restrict flow.

9. The inlet piping should be short and direct. The inlet should never have a smaller diameter than the valve itself. This will constrict the flow of steam, air or other media.
10. Mount PRVs are designed to function in a vertical position, which means upright and with the spindle vertical. A valve installed in any position other than vertical might not perform correctly.
11. For flanged valves, draw down all connection studs or bolts evenly to avoid possible distortion of the Valve body. Bolt tightening sequence has to be followed (evenly and gradually applying tightening force on opposite bolts).
12. For flanged valves, be sure to draw the bolts down evenly. This is, especially crucial for cast iron valves. If valve flange tighten one side all of the way and then the other, not should it be able to tighten it completely, but crack the valve. Use torque wrench to ensure optimum torque.
13. Avoid overtightening the valve. This can damage both inlet and outlet threads and cause leakage.
14. Do not apply a wrench to the valve body of threaded valve. Use hex flats provided on the inlet bushing.
15. The valve should be mounted vertically in an upright position either directly on a nozzle from the pressure vessel or on a short connection fitting of piping that provides a direct, unobstructed flow between the vessel / pipe and the valve. Installing a safety Valve in other than this recommended position will adversely affect its operation.
16. Never install PRV on a fitting having a smaller inside diameter than the inlet connection of the valve.
17. The discharge piping should always be supported. If it is not supported, it can weigh down and warp the valve, which will cause the valve not seated properly. This can lead to excessive leakage.

Tips

Safety: Under no circumstances should any additional load be applied to the easing lever nor should the valve be gagged in order to increase the seat tightness. This will affect the operating characteristics and can result in the safety valve failing to lift in overpressure conditions.

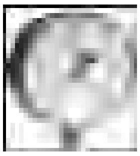
1.5.21 Pressure Gauge Installation

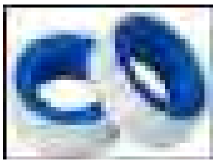
At the end of this exercise, you will be able to:

1. perform any size pressure relief or safety relief valve installation in piping and equipment system
2. install temperature gauge following work instruction.

Practical

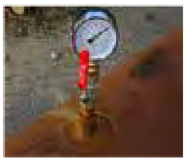
Required	
Tools / Instruments: Thread tape Spanner / Wrench, Pressure Gauge, Temperature Gauge – as required **Required Equipment / Machines:** Personal protective equipments (PPE)	**Materials / Components:** 1. 2” Ø pressure relief valv – 1 No. 2. 2” Ø pipe spool – 1 No. 3. 2” Ø spiral wound gasket – 2 Nos. 4. M12 stud bolt – 12 Nos. 5. M12 nut – 24 Nos.

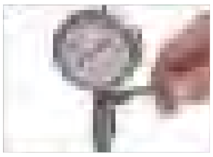
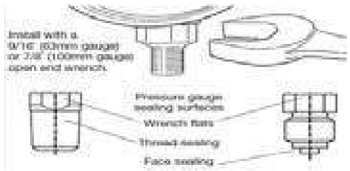





Work instructions

1. First make sure you have the right type of gauge for the application. Ideally, select a gauge where its normal operation will be around 50% to 60% of full scale.
2. Always follow manufacturer instruction, if any.
3. Check the gauge and ensure that there is no damage and that the leading needle is at zero.
4. Check the calibration validity of the pressure gauge before installation. If calibration has expired, arrange for recalibration.
5. Pay attention to how you screw the gauge in. Do not turn the case by hand to tighten. Use open end or adjustable wrench always flats of the gauge socket to tighten the gauge into the fitting or pipe.
6. Apply sufficient torque to prevent leaks.
7. Notice the type of threads on the gauge before you seal it. If the gauge has parallel threads, seal it using rings, washers or suitable profile seals.
8. If the gauge has tapered threads, additional sealing means, PTFE tape are recommended. This is standard practice for any pipe fitter because tapered threads do not provide complete sealing on their own.
9. Thread seal tape will not only prevent leakage past the thread, but will allow you to have the gauge facing in a good direction.
10. Install in such a way that pressure indicators are visible either from grade, permanent ladder or platform.



Tips

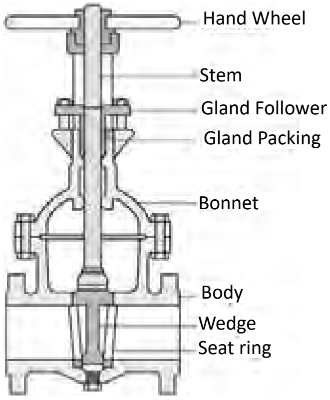
Safety: Torque applied to a diaphragm seal or its attached gauge, tends to loosen one relative to the other, can cause loss of fill and subsequent inaccurate readings. Always apply torque only to the wrench flats on the lower seal housing when installing filled, diaphragm seal assemblies or removing the same from process lines.

1.5.22 Different Type of Gaskets

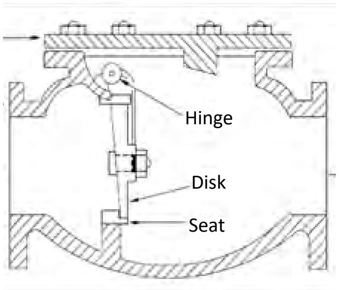
At the end of this exercise, you will be able to:

1. identify the different type of valves
2. perform 2" ϕ ball valve installation with piping spool assembly
3. perform 2" ϕ check valve installation with piping spool assembly.

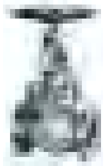
Requirements			
Tools/Instruments		**Materials/Components**	
Measuring Tape	– 1 No.	2" ϕ Ball valve	– 1 No.
Steel rule	– 1 No.	2" ϕ Piping spool with flanged assembly	– 4 No.
Spanner sets	– 1 No.	2" ϕ Spiral wound Gasket	– 2 No.
Torque wrench	– 1 No.	100mm X M12	– 16 No.
Equipment/Machines		2" ϕ Check valve studs and nuts	– 1 No.
Personal Protective Equipment	– 1 No.		



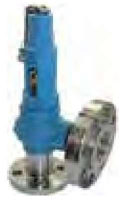
1



2


3


4


5


6

a) Identification of valve type

Sl. No.	Name of the valves used in piping
1.	
2.	
3.	
4.	
5.	
6.	

Tips

Instructor should provide different types of valve chart and explain to trainee of the method of identification.

b. Perform the installation of 4” ϕ inch dia ball valve with flanged piping spool assembly.
c. Perform the installation of 4” inch diameter check valve with flange piping spool assembly.

Exercise

I. Answer the following questions.

1. Name any six types of valves normally installed in piping systems.

   ----

2. Name any four valves meant for stopping and starting flow.

   ----

3. Write down the general instructions for valves installation.

   ----

4. What are all the specific requirements for butterfly valves installation?

   ----

5. What are the specific requirements for check valves installation?

   ----

6. Describe valve flanges bolt installation and tightening procedure.

   ----

7. What are the specific requirements for PRV-Installation?

II. State whether the following statements are True or False.

1. Globe valve is a rotary motion valve.

   True ☐ False ☐

2. Check valve can control the direction of flow.

   True ☐ False ☐

3. Butterfly valves stem shall be in vertical position in services where fouling substances could collect in the lower shaft bearing.

   True ☐ False ☐

4. Check valves close with forward flow.

   True ☐ False ☐

5. If the check valve is installed in the horizontal position, the valve must be installed with the cover oriented to the bottom.

   True ☐ False ☐

Notes

1.5.23 Valves – Functional Tests

At the end of this topic, you will be able to:

1. describe different functional tests required at manufacturer premises
2. check the required functional tests performed at manufacturer premises and act accordingly
3. perform valve body (shell) test and seat test
4. state the acceptance criteria of valve functional tests.

Tests at manufacturer's premises

Hydrotest shall be completed and certified by valve manufacturer prior to release from the manufacturer premises. API 598 states that for shell and back seat tests, no visible leakage is permitted. If the fluid is a liquid, there shall be no visible evidence of drops or wetting of the external surfaces (no visible leakage through the body, body liner, if any, and body-to-bonnet joint and no structural damage).

Low pressure closure test

Low pressure closure test is an optional test only and not mandatory. It shall be performed using air / gas at 5 to 6 bar. For the low pressure closure and low pressure back seat tests, the test fluid shall be air or inert gas.This test shall be performed at the manufacturer's premises and is not required to be performed at the site.

High pressure closure test

The procedure for the high-pressure closure test shall be the same as the procedure for the low pressure closure test except that, in the case of a liquid test, leakage shall be detected with drops. Test pressure is 1.1 times that of the rated pressure. This test shall be performed at the manufacturer's premises and is not required to be performed at the site.

Instruction for Pressure Testing of valves at field / site

The body leak test and seat integrity test shall be performed at the site prior to installation if required by project / site specifications. When a liquid is used as the test fluid, the valve shall be essentially free from trapped air during the test.

A test manifold comprising inlet valve, outlet valve, provision for pressure gauge and relief valve fixing along with provisions for connecting to respective flange sizes, shall be connected to the valve to be tested. The test manifold shall have been hydrotested 1.2 times of the maximum valve hydrotest pressure. Two pressure gauges shall be installed – one at test manifold and other at blind flange side of the valve. Normally, pressure gauge range shall be not more than two times or not less than 0.25 times of the actual test pressure. If water is used for hydrotest, the same shall have been tested and certified prior to hydrotest. Additionally, stainless steel valves, testing chloride content shall not exceed 50 ppm. Pressure gauge calibration status and correct working ranges of gauges shall be verified. All gauges shall have valid calibration and calibration sticker. Safety pressure relief valve set at 1.1 times the test pressure shall be fixed so as to avoid over pressurising. Adequate provision for venting of high points and draining of the test medium shall be provided. Test pressure is applied as directed by procedure or code until test limiting pressure is reached. During hold period, a methodical check for leaks is conducted.

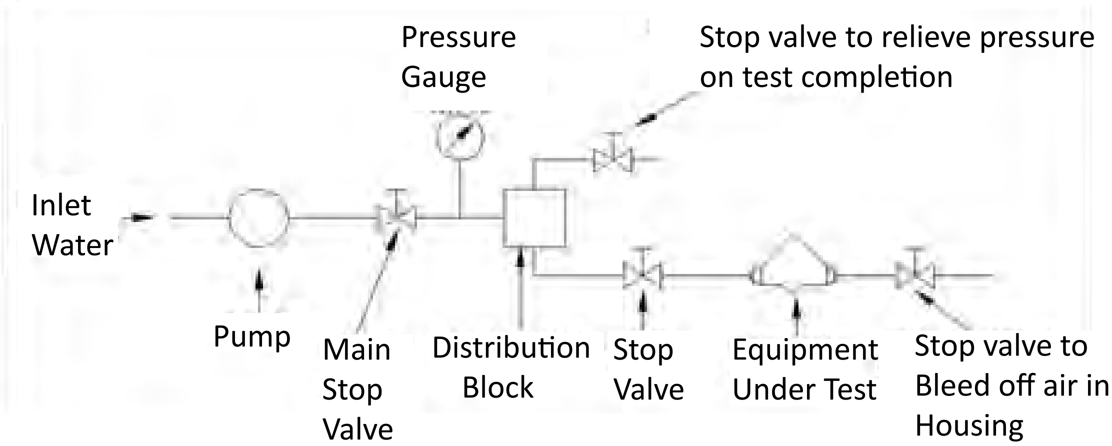


Fig. 1.5.82 Typical Pressure Test Manifold Diagram

a. Back seat test

The backseat test is required for all valves (except for bellows seal valves) that have the back seat feature and shall be performed by applying pressure inside the assembled valve with the valve ends closed, the valve fully partially open, and the packing gland loose or packing not installed. Testing shall be performed prior to shell testing. If the back seat test is performed after the shell test, the packing shall be installed and/or packing glands re-tightened after the back seat test.

The back seat shall then be closed and a minimum pressure of 1 .1 times the valve pressure rating is applied for the test duration. Monitoring for leakage shall be through a test access port or by monitoring leakage around the loosened packing. No visible leakage is permitted at this test pressure.

b. Seat test of valves

Unless otherwise specified, seat test shall be performed for both sides. In addition to the above general instructions, specific instructions for seat test are as given below:

Testing flange to be fixed on one side of the valve. Valve shall be connected with test manifold. Test fluid shall be filled without air entrapment.

Valve seat shall be kept under fully closed condition.

Seat test pressure shall be gradually applied and kept on hold for the specified duration. The test pressure for all seat tests shall not be less than 1.1 times that of the valve pressure rating.

Check the leakage through seat in opposite side of the pressurised side.

Follow the same procedure while checking the another seat except for globe and butterfly valves.

c. Hydrostatic Shell Test

In general, hydrostatic shell testing shall be performed on the fully assembled valve prior to painting valves. But this can be exempted for field hydrotest and paint removal is not required at the site. In addition to the above general instructions, further work instructions for shell test are as listed below:

- Testing flange is to be fixed on both sides.
- Valve shall be connected with test manifold.
- Valve ends shall be closed. The valve seat shall be kept partially open. Any packing gland shall be kept tight enough to maintain the test pressure.
- Test fluid shall be filled without air entrapment.
- Gradually apply the pressure inside the assembled valve.
- The test pressure shall be 1.5 times that of the valve pressure rating. The test pressure holding duration shall not be less than that specified in applicable code / specification.
- Check the leakage through body, bonnet sealing area, gland packing area.
- No visible leakage is permitted during the hydrostatic shell test.

All valves need to be checked for cleanliness and dryness. Nozzle, outlets, flanged or butt welded, saddle, bracket locations and orientations against assembly drawings are checked and operation of valve indicator and correct functioning are also to be checked.

d. API 598 – valve inspection & testing

API 598 covers the inspection, examination, supplementary examination and pressure test requirements for resilient –seated, non-metallic –seated, and metal to metal seated valves of gate, globe, plug, ball, check and butterfly valves.

e. API 6D – specification for pipeline valves

API 6D specifies requirements and provides recommendations for design, manufacturing, testing and documentation of gate valve, plug valve, ball valve and check valve types for application in pipeline systems meeting requirements of petroleum and natural gas industry for pressure ratings less than PN 420.

When API 598 covers general testing requirements for valves manufactured to API 602, API 608, API 609 etc., API 6D specifically applies to valves manufactured for petroleum and natural gas pipe lines.

h. Acceptance criteria

Maximum allowable leakage API 598

Back seat test – no visible leakage

Hydrostatic shell test – No visible leakage

Seat test – no visible leakage

Relief valves setting at site maximum allowable leakage API 6D

- Back seat test – no visible leakage
- Hydrostatic shell test – no visible leakage

Relief valve shall be set at the required pop up pressure at the site. The instruction for setting the predetermined pressure is as given below:

- make sure there is no pressure to the valve.
- break and remove the pressure tag wire
- unscrew the cap by loosening the set screw.

Valve Type	Shell		Back seat		LP-Closure		HP-Closure	
	API 598	API 6D	API 598	API 6D	API 598	API 6D	API 598	API 6D
Gate	YES	YES	YES	YES	YES	NA	OP	YES
Globe	YES		YES		OP		YES	
Plug	YES	YES	NA	YES	YES	NA	OP	YES
Check	YES	YES	NA	YES	OP	NA	YES	YES
Floating Ball	YES	YES	NA		YES	NA	OP	YES
Trunnion Mounted Ball	YES	YES	NA	NA	YES	NA	OP	YES
Butterfly	YES		NA		YES		OP	

YES - Required NO - Not Required OP - Optonal NA - Not applicable for the valve

adjust the setscrew clockwise to increase the set pressure, anticlockwise to decrease the set pressure. Recommended adjustment is one full turn maximum at a time

test the valve by pressurizing through the inlet port

depressurize the valve before making any further adjustments

replace the cap after adjustment is completed

- Rewire the pressure tag. Replace the pressure tag if it reads other than the set pressure.

Exercise

I. Answer the following questions.

1. Describe pressure test manifold with a line diagram.

----

2. Explain back seat test.

----

3. Write down the work instructions for a valve body (Shell) hydrotest.

----

4. Write down the work instructions for pressure relief valve pop up pressure setting to the predetermined pressure at the site.

II. State whether the following statements are True or False.

1. Low pressure closure test can be performed using air / gas.

   True ☐ False ☐

2. In general, test pressure for high pressure closure test is 1.1 times that of the rated pressure of the valve.

   True ☐ False ☐

3. High pressure closure test of valves need not be performed at the site.

   True ☐ False ☐

4. Unless otherwise specified, the valve body / shell hydrotest pressure shall be 1.5 times that of the valve pressure rating.

   True ☐ False ☐

Practical

1. Perform valve body test and seat test of 4 inch NB diameter ball valve.
2. Perform valve body test of 4 inch check ball valve (materials required – 4 inch NB ball valve, 4 inch NB check valve, test manifold, two pressure gauges, one safety pressure relief valve, eight set of studs and nuts, 2 spiral wound gaskets, torque wrench, spanners.)

Notes

1.5.24 Gauges, Instruments and other Installation accessories

At the end of this topic, you will be able to:

1. distinguish different piping gauges, instruments and accessories
2. install gauges and instruments into the piping system
3. install piping related miscellaneous accessories.

General instructions

The pressure and temperature rating of the fittings are very important. Whenever accessories are supplied for installation, the pipe fitter shall check the rating and ensure it is not lower than the piping rating and as specified in the drawing. Check for calibration expiry date of the gauges / instruments to be installed. If calibration has already expired or will expire very soon, recalibration shall be arranged. The inner diameter of the gasket shall not exceed the inner diameter of the meter/meter run. Select a gasket type that is centred by its outer ring. An inner ring should prevent soft material from protruding into the pipe, causing flow pattern disturbance.

Pressure gauges installation

Pressure gauge is used to read the system pressure on the spot. Pressure gauges are of various ranges and various units such as bar, kg/cm^2, psi, kpa or in combination, etc. Pressure transmitter is used to send pressure signal to distributed control system (DCS) for further processing and action. Pressure indicators shall be visible either from grade, permanent ladder or platform. Pressure gauge installation shall be in such a way that it should be readable without a portable ladder. Pressure gauge on platforms should be at least readable from a fixed ladder. Pressure gauges in piping systems at such equipments as pump discharge lines must be located as close to the equipment as possible. A suitable thread sealant is required for NPT threads such as pipe dope or teflon tape. Never use any part of the pressure gauge other than the wrench flats that is on the gauge socket. Always tighten with an open end or adjustable wrench on the wrench flats. Failure to do so, will severely damage the pressure gauge.

Temperature measurement gauges installation

Measuring temperature of a fluid in pipe and vessels is achieved by installing local temperature gauges or by temperature transmitter which send their output to the process control room. Temperature gauges consist of a metallic probe which is inserted into the pipe or vessel through a nozzle arrangement. Dial gauge connected to the probe shows temperature on a circular scale. Both centigrade and Fahrenheit scale temperatures gauges are available in various temperature ranges. If temperature must be read remotely, thermocouple type of temperature transmitters are used. They have a metallic probe same as gauge indicators, but instead of a dial attached to the other end, they have a terminal head which houses electronic circuits which transmit temperature signal to process control room for process control and display on screen.

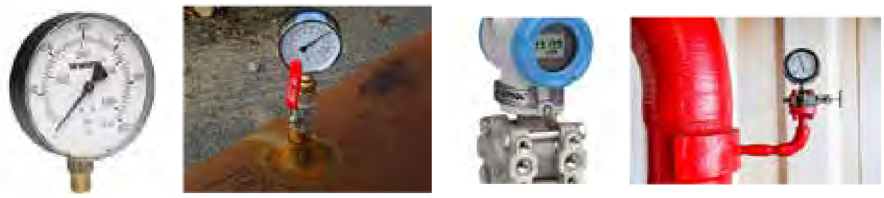


Fig. 1.5.83 Typical pressure gauge and transmitter installation

Fig. 1.5.84 Temperature Gauge

Fig. 1.5.85 Temperature Transmitter

Thermowells (TW) fittings installation

Thermowells are part of piping work. The type, length and material of the required thermowell are dictated by the specification. Flanged thermowells are generally used. Welded thermowells shall only be installed if due to high velocity and density of the fluid, the bending forces are too high for flanged thermowells or if they are subject to vortex vibration. To prevent water ingress into the assembly head, the thermoelement assembly shall be mounted in the horizontal position or in a tilted position with the head facing upwards.

a. General guidelines on installation of thermowell

The thermowell shall be located as close as possible to the place where the temperature is desired . When the steam and water are mixed directly, thermowell must be far enough from the point of the mixing to ensure that the temperature measurement is based on the complete mixing. If the pipe is wrapped with insulation, a thermowell with sufficient extension length shall be used. While installing the TW, immersion length, type of mounting–elbow, perpendicular or angle, height from floor for maintenance, clearance above the thermowell assembly for maintenance, shall be considered.

Automatic control valve

Control valves automatically regulate pressure and/or flow rate, and are available for any pressure. Globe valves are normally used for control, and their ends are usually flanged for ease of maintenance. Depending on their type of supply, the disk is moved by a hydraulic, pneumatic, electrical or mechanical actuator. The valve modulates flow through movement of a valve plug in relation to the port (s) located within the valve body. The valve plug is attached to a valve stem, which in turn, is connected to the actuator.

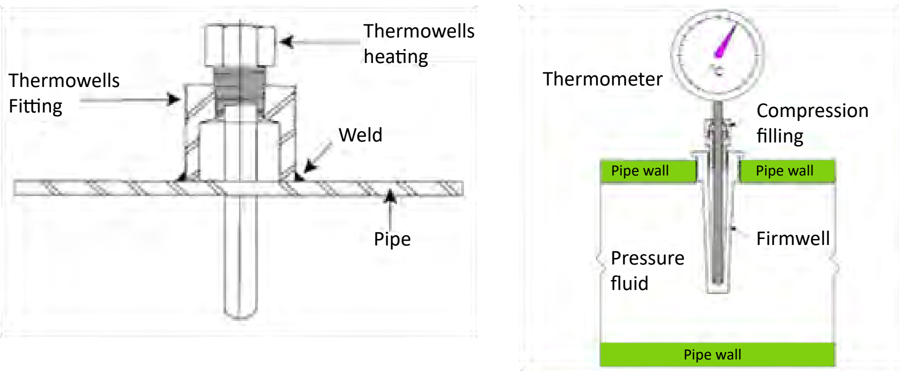


Fig. 1.5.86 Typical thermowell installation

Fig. 1.5.87 Typical automatic control valve arrangement

Flow measurement instruments installation

1. Ultrasonic, electromagnetic and coriolis flow meters can be used in unidirectional and bi-directional service.
2. Flow meters sense the amount of flow passing through a particular pipe and sends this information to process controller which then applies process logic and sends control information to control valves or pump control unit.
3. A variety of flow meters are used in process industry depending on type of fluid, operating temperatures and pressures, required flow accuracy and economy.
4. Ultrasonic flow meters can be installed at any point in the pipe run. In horizontal lines, nozzles shall be in the horizontal plane to avoid the collection of debris. The meter shall not be installed directly downstream of sources of aeration, such as cavitating pumps, throttling valves or an aerating mixing tank. Upstream and downstream straight lengths shall be as specified by the supplier.

Piping related miscellaneous accessories installation

All piping related accessories shall be installed as per drawings.

1. Drain and vent Connections

In general, test drain and vent connections shall be installed at all low and high points in piping, respectively. Drain/vent connection shall be installed as close as possible to the block valves and spades, for draining, venting and testing purposes. Vents and drains shall be as short as possible. All drain and vent points shall be closed with a blind flange or a cap. Dead leg shall be avoided in oil and gas piping. If necessary additional drain shall be installed with valve to avoid dead leg.

2. Sampling connections

The sampling point shall be positioned so that the valves are easy to operate and taking the sample will not impair the safety of personnel or plant or cause environmental impact. Good locations for sampling are typically the discharge of pumps and the suction of compressors. Sample points shall have two valves – one at the take-off point from the process pipe and another at the sampling point. The block valve at the take-off point shall be of the same size as a standard drain valve. The sampling valve size shall be maximum DN 15 and shall have good throttling properties.

3. Strainers installation

Permanent strainers shall be installed in all pump suction pipes. Y-type strainers shall be used for permanent installation in vertical suction pipes. In horizontal suction pipes, Y-type or bucket type strainers may be used. Bucket type strainers shall be used for suction pipes DN 450 and larger. In a vertical suction pipe, the Y-type strainer shall be installed pointing away from the pump. In a horizontal suction pipe the Y-type strainer shall be installed pointing downwards or at an angle of maximum 45° from vertical, in order to improve access for cleaning.

Exercise

I. Answer the following questions.

1. Explain thermowell fittings installation.

   ----

2. Write down the step by step installation for electromagnetic flow meter.

   ----

3. Describe pressure gauge installation.

II. State whether the following statements are True or False.

1. The inner diameter of the gasket shall not exceeded the inner diameter of the meter / meter run.

   True ☐ False ☐

2. Pressure transmitters is used to send pressure signal to the distribution control system.

   True ☐ False ☐

3. Temparature transmitter are used to read the temparature remotely.

   True ☐ False ☐

4. While installing ultrasonic flow meters in horizontal lines, nozzles shall be in the horizontal plane.

   True ☐ False ☐

5. In electromagnetic flow meter, it shall be ensured that the flow tube is always filled with liquid.

   True ☐ False ☐

6. Spiral wound metal gasket shall be used for magnetic flow meters.

   True ☐ False ☐

Notes

Unit 1.6 Identify Tools and Tackles

Unit Objectives

At the end of this unit, you will be able to:

1. identify appropriale tools and tackles for pipe fitting works
2. recognise and use diffrent tools
3. handle different types of equipment used for pipe fitup works.

1.6.1 Different Measuring and Marking Tools

At the end of this topic, you shall be able to:

1. name the different measuring tools and uses
2. name the different marking tools and uses.

I. Measuring tools and instruments:

1. Measuring Tape
2. Steel rule
3. Vernier Caliper & Micro Meter
4. Try Square
5. Bevel Protractor, Hi-low gauge
6. Centre Punch
7. Scribers

Fig 1.6.1 Measuring Tape (Metal)

Fig 1.6.2 Steel rules

Measuring tape

Measuring tape is a flexible ruler. It is made of ribbon, cloth, plastic, fiber, glass metal strip with lines for measurements. It is a very common measuring tool. The available range are 3,5 and 10m.

Types

1. Metal tape

Engineer's steel rule: Steel rules are made of spring steel or stainless steel. The edges are accurately ground to form straight edges. The surface of the steel rule is satin chrome finished to reduce glare and to prevent rusting.

Micrometer

Sometimes known as a micrometer screw gauge, is a device incorporating a calibrated screw. It is widely used for accurate measurement of components in mechanical engineering and machining as well as an mechanical trades.

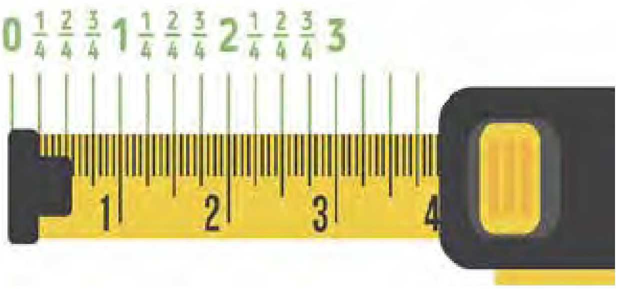


Fig 1.6.3 Measuring Tape (Metal)-inch unit

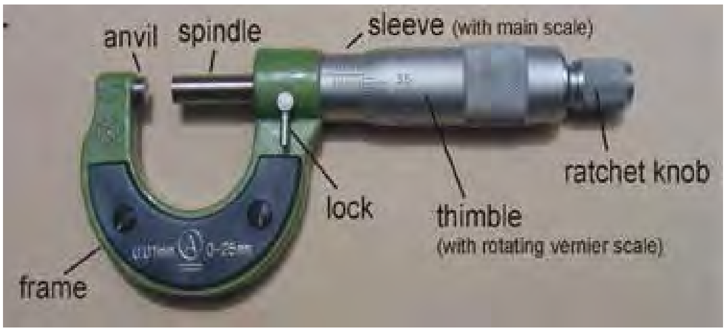


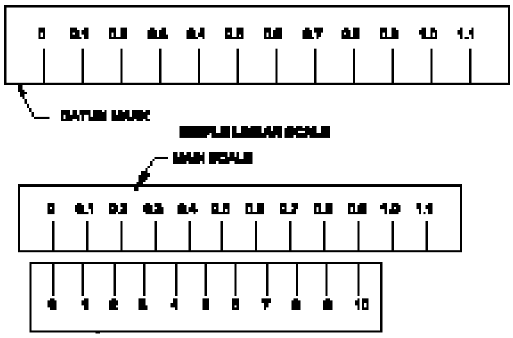
Fig 1.6.4 Micro Meter

The vernier principle: The basic principle of the vernier is that the smallest unit of size to which a vernier can be read is equal to the difference in the length between the divisions of the two scales.

The magnification on the vernier scale is given by two scales sliding over each other. The eye can detect which divisions on one of them is smaller than those on the other. The eye can detect which of these divisions are in line with each other, and it enables to read a vernier to 0.02 mm accuracy. The value of 1 main scale is 0.1 unit. In vernier scale 9 such units are taken and divided into 10 equal parts.

Hence the value of 1 vernier scale is 0.9/10=0.09 units. Now, by applying the vernier principle, the smallest unit of size is 1 M.S.D. - 1 V.S.D. (i.e.) 0.1 - 0.09=0.01 unit.

Definition of the least count: The least count is the smallest possible measurement that can be taken with the precision instrument. The zero of the vernier scale is between 0.2 to 0.3 units on the main scale and number 2 graduation of the vernier scale Fig 1.6.6 is coinciding with the 4th division of the main scale. Thus the reading is 0.2 + 2 * 0.01=0.22.



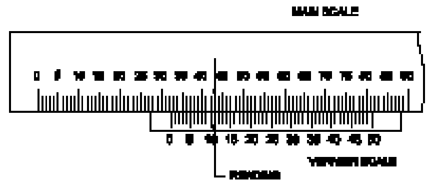


Fig 1.6.6 The Vernier scale (50 Divisions)

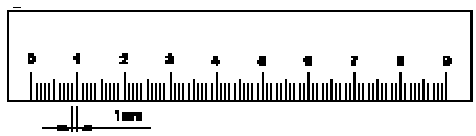


Fig 1.6.5 Vernier Scale

Fig 1.6.7 Main Scale Division into Millimetres

A typical 50 division vernier scale as used in modern metric measurements as shown in Fig. 1.6.6. The main scale of this instrument is graduated in mm. In the case of 150 mm capacity, vernier calipers the main scale, is graduated in ½ mm instead of in 1 mm. For the purpose of the vernier scale 24 such divisions are taken and divided into 25 equal divisions. So, the value of 1 vernier scale division is $\frac{1}{25}$ The purpose of a vernier 49 such divisions are divided into 50 equal divisions. So the value of vernier scale division works out to 49/50 mm.

Least count = 1 M.S.D. - 1 V.S.D.

$$\frac{1}{2}\text{ mm}\ \frac{12}{25}\text{ mm} = \frac{25-24}{50} = \frac{1}{50} = 0.02\text{mm}$$

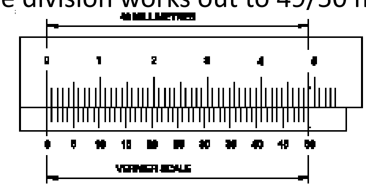


Fig 1.6.8 Main scale division into millimeters each 10th being number ed

Measurement of reading: 0mm as 'o' of vernier scale shall coincide.

Measurement of reading: 'o' of vernier is to the right of the main scale and lies between 'o' and 1st division of the main scale. The 3rd division of the vernier scale coincides with a division on the main scale. Hence, measurement is 0 mm + 3 * 0.1 mm = 0.3 mm.

Measurement of reading: 'o' of the vernier scale lies between the 44th and 45th divisions of the main scale and the 4th division of the vernier scale coincides with a division of the main scale. Hence, the measurement is 44 mm + 4 * 0.1 mm = 44.4

Measurement of reading: 'o' of the vernier scale lies between the 53rd and 54th divisions on the main scale, and the 8th division of the vernier scale coincides with a division on the main scale. Hence measurement is 53 mm + 8 * 0.1 mm = 53.8 mm.

Universal vernier caliper and its application:

One of the precision instruments having the principle of vernier applied to it is the universal vernier caliper. It is known as a universal vernier caliper because of its application to take outside, inside and depth measurements.

Its accuracy is 0.02 mm.

1. Beam
2. Fixed jaw for external measurements
3. Movable jaw for external measurements
4. Movable jaw for internal measurements
5. Blade for depth measurement
6. Main scale
7. Vernier scale
8. Fine adjustment screw
9. Set of locking screws.

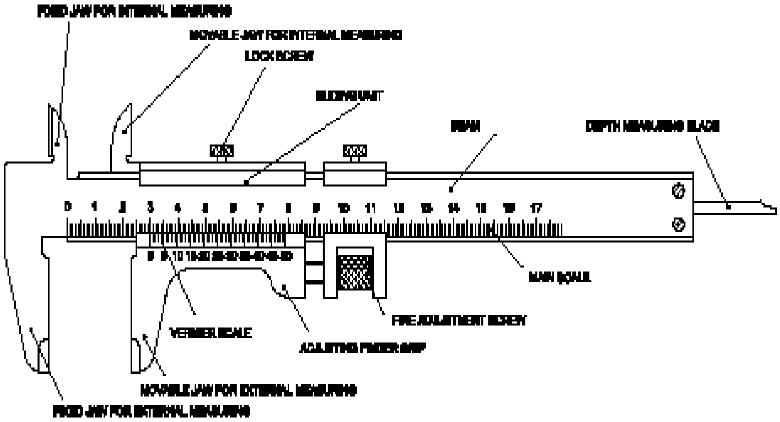


Fig 1.6.9 Vernier caliper

All parts are made out nickel chromium steel, heat treated and ground. They are machined to a high accuracy. They are stabilized to avoid distortion due to temperature variations.

Least count: In the vernier scale illustrated here, 19 mm are divided into 10 equal parts on the vernier scale. The value of 1 vernier scale division will then be $\frac{19}{10} = 1.9$mm

The difference of the two main scale divisions and 1 vernier scale division gives the least count and it is equal to 2*1m -1.9 mm = 0.1 mm For better accuracy, a 49 mm space is divided into 50 equal parts on the vernier scale so that one vernier scale division value will be $\frac{49}{50} = 0.98$mm

Here the least count will be 1 main scale division – 1 vernier scale divisions = 1 mm-0.98 mm= 0.02 mm.

Advantages

No need to have separate precision instruments for taking external, internal and depth measurements.

Disadvantages

The accuracy of reading depends on the skill of the operator. It loses its accuracy by constant usage as slackness in the sliding unit develops. It cannot be used to measure components having deviations less than +/-0.02 mm. The possibility of parallax error during noting down, the coinciding line may cause the reading of the measurement to be wrong.

Try Square

The Try Square is a precision instrument which is used to check squareness (angles of 90°) of a surface.

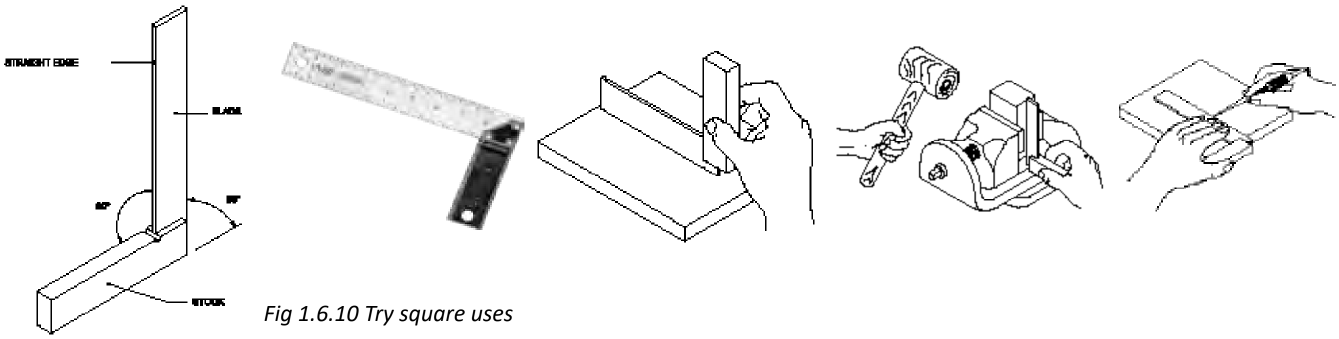


Fig 1.6.10 Try square uses

Tips

For maintaining accuracy, it is important to see to it that the edges and surfaces of instruments are protected from damage and rust.

An experienced person can transfer measurements from a steel rule very accurately. The steel rule graduations are accurately engraved, with the line thickness ranging from 0.12 to 0.18 mm. Do not place a steel rule with cutting tools. Apply a thin layer of oil when not in use. For accurate reading it is necessary to read vertically to avoid parallax errors .

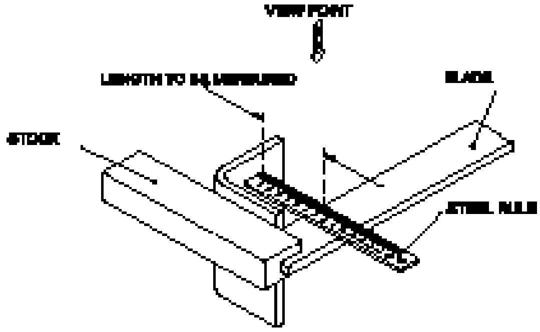


Fig 1.6.11 Try square usage

Marking punches

Punches are used to make certain dimensional features of the layout permanent. There are two types of punches. They are centre punch and dot punch.

Centre punch

The angle of the point is in a centre punch is 90°. The punch mark made by this is wide and not very deep. The punch is used to locate holes. The wide punch mark gives a good seating for starting the drill. The punch marks should not be too close to one another.

Scriber

In layout work, it is necessary to scribe lines to indicate the dimensions of workpieces to be filed or machined. The scriber is a tool used for this purpose. It is made of high carbon steel which is hardened. For drawing clear and sharp lines, a fine point is ground at one end. Scribes are available in different shapes and sizes. The one most commonly used is the plain scriber. While scribing lines, the scriber is used like a pencil so that the lines drawn are close to the straight edge.

Fig 1.6.12 Centre punch

Fig 1.6.13 Scriber

Tips

Scriber points are very sharp, and they are to be handled very carefully. Do not put the scriber in your pocket. Place a cork on the point when not in use to prevent accidents.

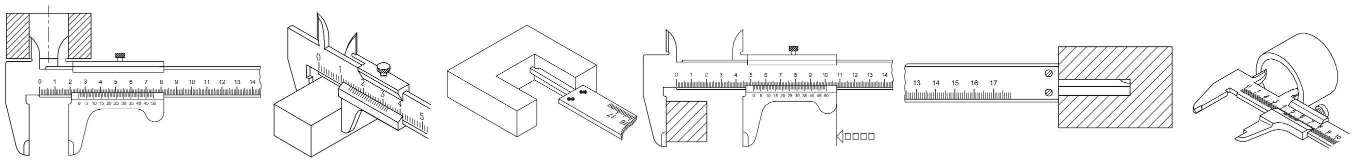
1.6.2 Measuring with Vernier Caliper

At the end of this exercise, you will be able to:

1. measure a pipe's inside diameter with a vernier caliper
2. measure a plate or pipe's wall thickness.

Practical

Required Tools / Instruments:		Required Materials / Components:	
Vernier Caliper Measuring Tape Flat File	– 1 No. – 1 No. – 1 No.	2" Ø pipe - 300mm 10xmmx300x100-plate	– 1 No. – 1 No.



Tips

Clean the vernier caliper before use with cloth and apply a light film of oil.

Check and ensure all burrs are removed from the job before taking the measurement.

Select a suitable size of vernier caliber according to the size of the pipe/plate.

Open the jaws wider than the size of the job.

Rest the job near the centre of the fixed jaw and move the slide jaw with minimum force.

Read and note the measurement. Avoid parallax error, while reading.

Hold the jaws parallel to the axis of the slot to be measured while taking internal measurement.

Tips

Safety: Use appropriate personal protective equipment. Do not give undue pressure while measuring as it will make the jaws spring and give wrong measurement

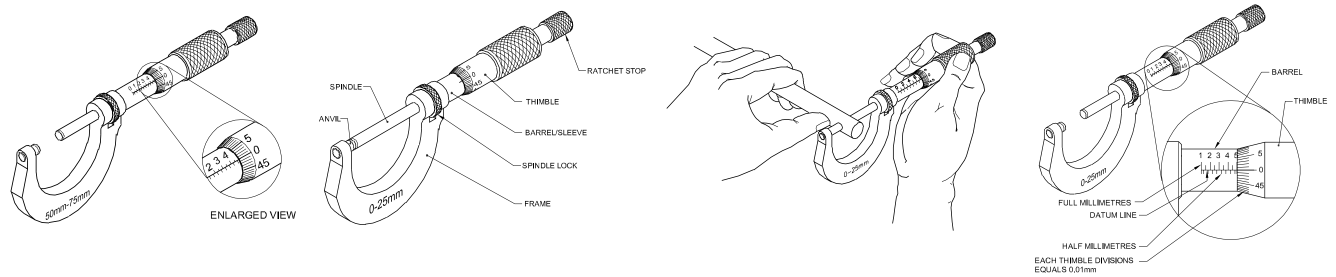
1.6.3 Measuring a Job with Micrometer

At the end of this exercise, you will be able to:

1. measure a pipe's wall thickness with micrometer
2. measure a plate's thickness.

Practical

Required Tools / Instruments:		Required Materials / Components:	
Micrometer Measuring Tape Flat File	– 1 No. – 1 No. – 1 No.	2" Ø pipe - 250mm long	– 1 No.



Clean the measuring faces of the micrometer and the surfaces of the job to be measured.

Check for zero error/accuracy.

In the case of a 0-25mm range outside micrometer, the zero of the thimble should coincide with the datum line, when the ancil and spindle are touching each other.

If they do not coincide, the instrument has an error.

Open the measuring faces so that more than the size of the workpiece is to be measured.

Use both hands for taking measurement, if the workpiece is held on a work bench.

Hold the workpiece in one hand and the micrometer in the other if the pipe size is small.

Bring the spindle slowly to touch the job to be measured.

Use the ratchet stop when the measuring face touches the workpiece.

Make sure that the measurement faces of the micrometer are square with the surface being measured.

Read the measurement.

Tips

After use, clean the micrometer with a cloth and apply a thin film of oil and store it in its box.

Exercise

I. Answer the following questions.

1. Name the measuring tools used in pipe fitup and alignment.

   ----

2. Name the marking tools used in pipe fitup and fabrication.

   ----

3. Name the two types of measuring tape used in pipe fitup.

II. State whether the following statements are True or False.

1. Steel rule is made of spring steel or stainless steel.

   True Flase

2. The least count and vernier scale accuracy in mm is 0.02

   True ☐ Flase ☐

3. The Try Square is a precision instrument which is used to check squareness of a flange surface.

   True ☐ Flase ☐

Notes

1.6.4 Hand Tools and Uses

At the end of this topic, you will be able to:

1. name the different hand tools and their use.

I. Hand tools:

File: Filing is a method for removing excess material from a workpieces tusing a file which acts as a cutting tool. Files are available many shapes and sizes.

Elements of a file: Tip or point, face or side, edge, heel, handle.

Types of cuts: Basically there are four types of cuts single cut, double cut, Rasp cut and curved cut.

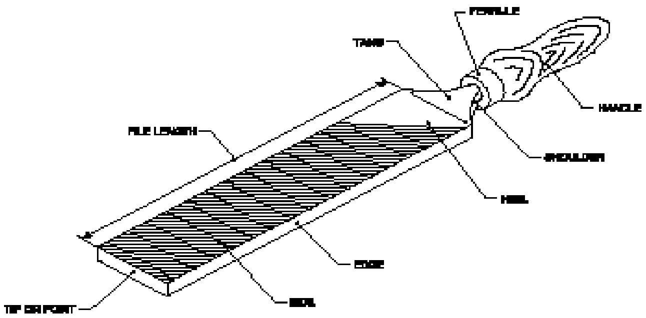
Single/cut file: A single cut file has rows of teeth cut in one direction across its face. The teeth are at an angle of 60° to the centre line. It can chip as wide as the cut of the file. The other cut, made diagonal to this, is known as and is at an angle of 51°. This removes stock faster then the single cut file.

Rasp out file: The rasp cut has individual sharp pointed teeth in line and is useful for filing wood, leather and other soft materials. These files are available only in half round shape.

Curved cut file: These files have deeper cutting action and are useful for filing soft materials like aluminium, tin, copper and plastic. The curved cut files are available only in a flat shape.

Tips

The selection of a file with a particular type of cut is based on the material to be filed. Single cut files are used for filing soft materials. But certain special files, for example, those used for sharpening saws are also of single cut.



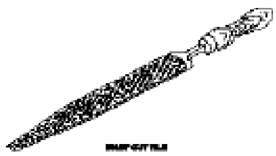


Fig 1.6.15 RASP Cut File

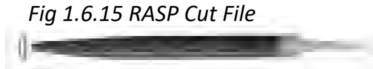


Fig 1.6.14 Elements of File

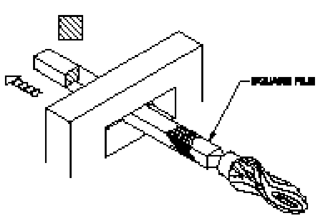
Fig 1.6.16 Curved cut file

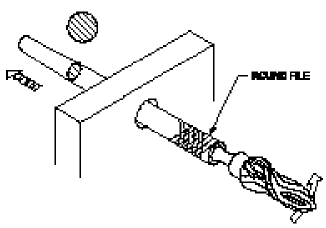
Fig 1.6.17 Different type of file

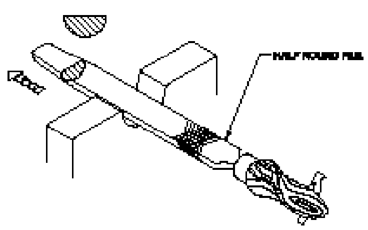
Common files of different shapes–Flat file, hand file, square file, round file, half found file, triangular file and Knife edge file.

Half round File: A half round file is in the shape of a segment of a circle. It is used for filing internal curved surfaces.

Triangular File: A triangular file is of triangular crosssection. It is used for filing corners and angles which are more than 60°.







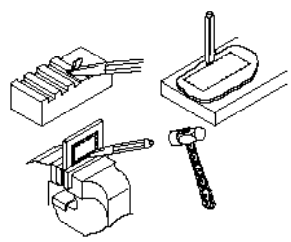


Fig 1.6.18 Square file

Fig 1.6.19 Round file

Fig 1.6.20 Half round file

Fig 1.6.21 Chisel

Chisel: The cold chisel is a hand cutting tool used by fitters for chipping and cutting off operations. Chipping is an operation of removing excess metal with the help of a chisel and hammer. Chipped surfaces are rough. They should be finished by filing.

Parts of a chisel

A chisel has the following parts – head, body, point or cutting edge. Chisels are made from high carbon steel or chrome vanadium steel. The cross-section of chisels is usually hexagonal or octagonal. The cutting edge is hardened and tempered.

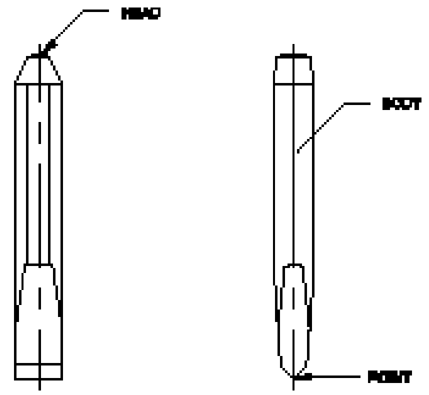


Fig 1.6.22 Parts of chisels

Common types of chisels: There are four common types of chisels. Flat chisel, Cross-cut chisel, Hall round nose chisel, Diamond point chisel.t

Flat chisels: They are used to remove metal from large flat surfaces and chip excess metal of weld joints and castings.

Cross-cut or cape chisels: These are used for cutting keyways, grooves and slots.

Half round nose chisels: They are used for cutting curved grooves (oil grooves).

Hammer: An engineer's hammer is a hand tool used for striking purposes. It includes punching, bending, straightening, chipping, forging, riveting.

Major parts of a hammer

The major parts of a hammer are head and handle.

The head is made of drop forged carbon steel, while the wooden handle must be capable of absorbing shock.

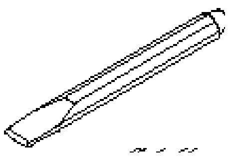


Fig 1.6.23 Flat Chisel

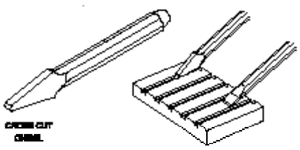


Fig 1.6.24 Cross cut chisel

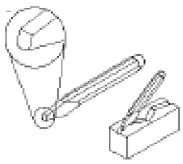


Fig 1.6.25 Half round chisel

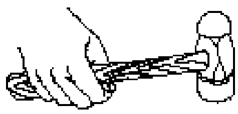


Fig 1.6.26 Hammer

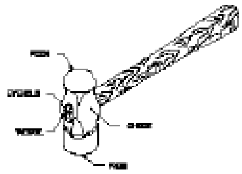


Fig 1.6.27 Major parts of a hammer

The parts of a hammer head are the Face, Cheek, Wedge, Peen, Eyehole. The face is the striking portion. Slight convexity is given to it to avoid digging of the edge. The peen is the other end of the head. It is used for shaping and forming work like riveting and bending. The peen is of different shapes like the ball peen, straight peen. The face and the peen are hardened.

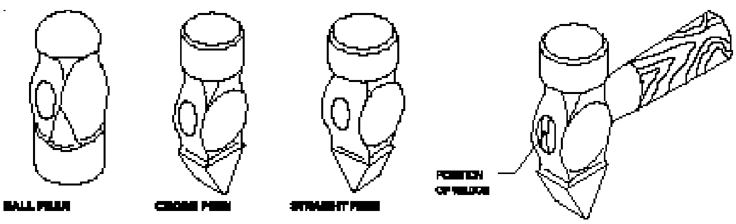


Fig 1.6.28 Different types of a hammer

Fig 1.6.29 Different types of C-Clamps

The cheek is the middle portion of the hammer-head. The weight of the hammer is stamped here. This portion of the hammer-head is left soft. An eyehole is meant for fixing the handle. It is shaped to fit the handle rigidly. The wedges fix the handle in the eye hole.

Ball peen hammer

A ball peen head is used to spread metal in all directions. This hammer has a semi-spherical peen suitable for riveting. It is used for shaping the cylindrical end of a metal rivet to form a rivet head.

Straight peen hammer

A straight peen hammer is used to spread metal in one direction at right angles to the line of striking. This hammer has a blunt wedge-shaped peen in line with the axis of the handle.

C- clamps

Purpose of using clamps: Clamps of different types are used for preventing the movement of work, and for holding the job tight.

Clamping devices

- help to manipulate for easy loading
- provide the required clamping force.
- are capable of locking with minimum movement.
- accommodate a range of sizes of jobs.

Typical C clamping device is employied to a screw and nut to provide the clamping force.

Wooden mallet

Mallets are soft hammers and are made of raw, hard rubber, copper, brass, lead or wood and are used to strike a soft and light blow on the metal.

Types and uses

Standard wooden mallets are used for general purpose work like flattening, bending, etc. Bossing mallets are used for hollowing panel beatings, etc.

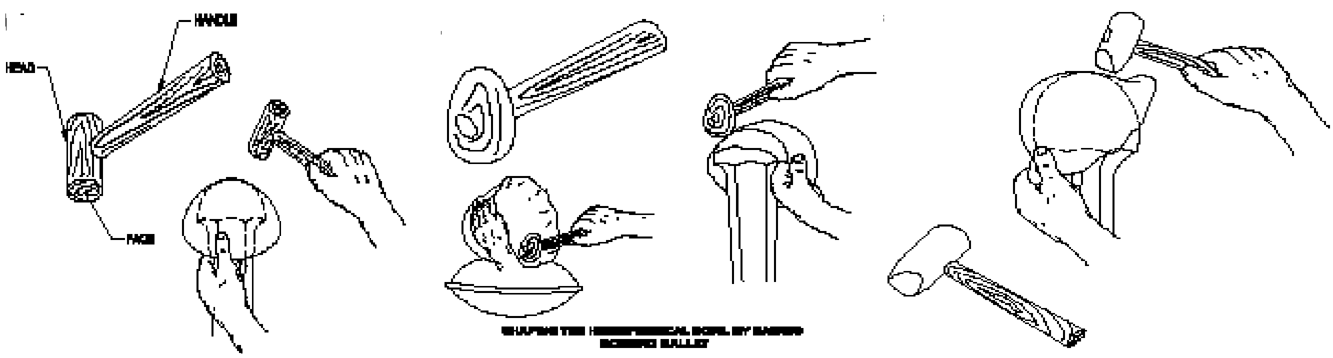


Fig 1.6.30 Standard wooden mallet

Hacksaw frame and blade

The hand hacksaw is used along with a blade to cut metals of different sections. It is also used to cut slots and contours.

Types of hacksaw frames

The two different types of hacksaw frames are soild and adjustable frames.

Soild frame

Only a particular standard length of blade can be fitted to this frame.

Adjustable frame (Flat type)

Different standards of lengths of blades can be fitted to this frame.

Adjustable frame(Tubular type)

This is the most commonly used type. It gives a better grip and control, while sawing. For proper working, it is necessary to have frames of rigid construction.

Hacksaw blades

A hacksaw blade is a thin, narrow steel band with teeth and two pinholes at the ends. It is used along with a hacksaw frame. The blade is made of either low alloy steel (LA) or high speed steel (HS) and is available in standard lengths of 250 mm and 300 mm.

Pitch of the blade

The distance between adjacent teeth is known as the pitch of the blade.

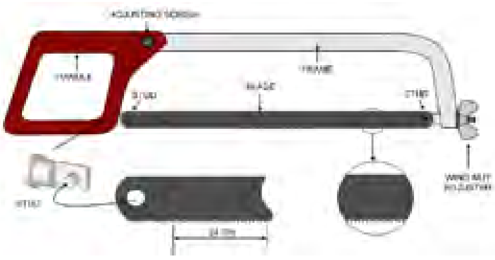


Fig 1.6.31 Hacksaw frame

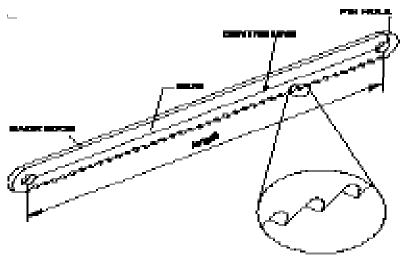


Fig 1.6.32 Hacksaw blades

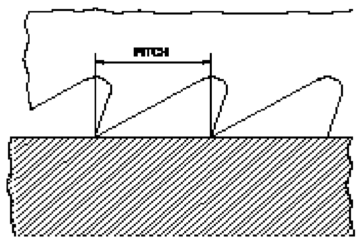


Fig 1.6.33 Pitch of the blade

Pipe bending machines: There are some situations in piping and plumbing jobs, where it is preferable to bend a pipe rather than use a pipe fitting. The portable hand-operated pipe bender consists of the following parts: Tripod stand, Pipe stop lever, Handle or lever, Inside former.

Bench type hand operated pipe bender

It is used for bending galvanized iron and steel pipes. It has the following parts inner former, lever or handle, Adjusting screw with lock nut, pipe guide.

Hydraulic bending machine

This machine can be used bending G.I. and M.S. pipes without sand filling to bend in any direction. It consists of the following the parts. Inner former, back former, hydraulic ram, pressure release valve, operating lever, bleed screws, base plate. Inner formers are interchangeable and are able to bend pipes up to 75 mm diameters.

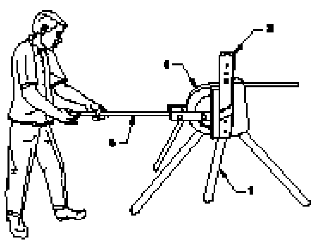


Fig 1.6.34 Pipe bending machine

Fig 1.6.35 Bench type hand operated

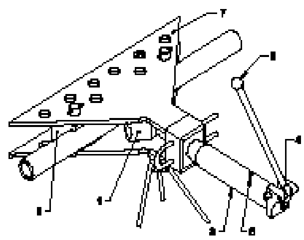


Fig 1.6.36 Hydaulic pipe bender

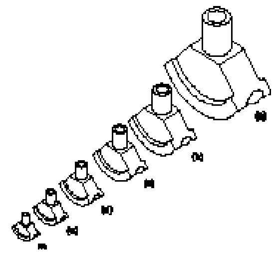


Fig 1.6.37 Pipe bend forming dies

Spanners and uses

Spanners are used for operating threaded fasteners, bolts and nuts. They are made with jaws or opening that fit square on hexagonal nuts and bolts and screw heads. They are made of high tensile or alloy steel. They are drop-forged and heat-treated for strength. Finally, they are given a smooth surface finish for ease of gripping. Spanners vary considerably in shape to provide ease of operation under different conditions.

Fig 1.6.38 Different type of spanners

The basic types of spanners are: open end spanners, tube or tubular box spanners, socket spanners, ring spanners. Use both hands as shown in the figure, when using tubular box spanners. Use two spanners as shown in the figure to stop the head of the bolt rotating as the nut is operated. Socket spanners may be turned by accessories which have square driving ends. To fit exactly, a spanner must be: of the correct size, placed correctly on the nut and in good condition.

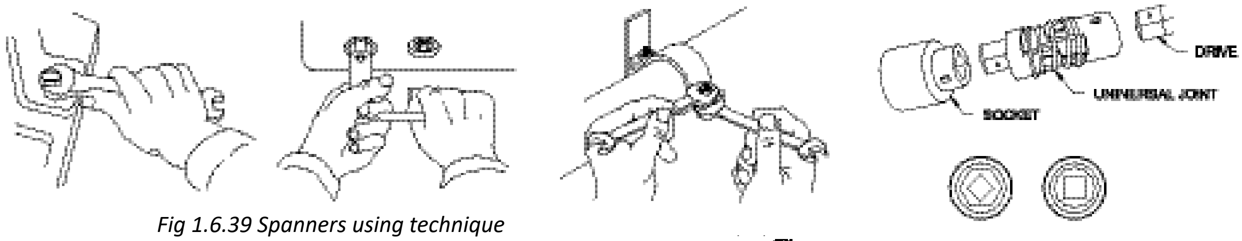


Fig 1.6.39 Spanners using technique

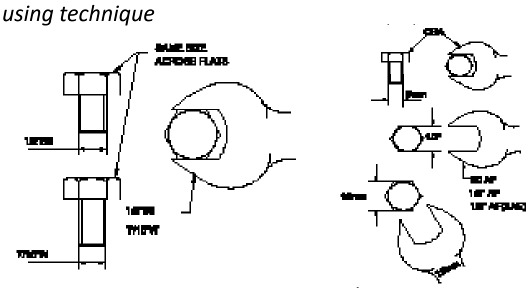


Fig 1.6.40 Spanners using technique

Adjustable spanners

Most common types of adjustable spanners are similar to open end spanners, but they have one movable jaw. The opening between the jaws of a typical 250 mm spanner can be adjusted from zero to 28.5 mm. Adjustable spanners may range in length from 100 mm to 760 mm. The type illustrated has its jaws set an angle of 21.5° to the handle. Adjustable spanners are convenient for use where a full kit of spanners cannot be carried. They are not intended to replace fixed spanners which are more suitable for heavy service. If the movable jaw or knurled screw is cracked or worn out, replace them with spare ones.

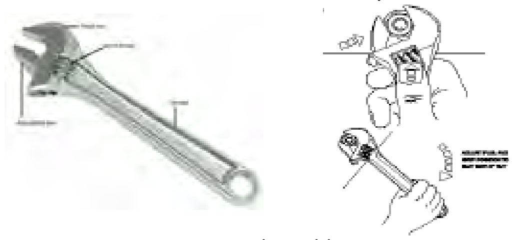


Fig 1.6.41 Adjustable spanners

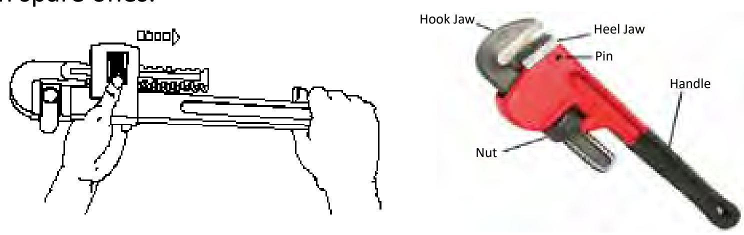


Fig 1.6.42 Wrench spanner

Wrenches

Types of wrenches – stillson pipe wrench, footprint pipe wrench, tension wrench, hexagon socket wrench.

Torque wrench: Torque wrench is used to tighten the bolts / nuts at the recommended torque. The torque wrench will measure the torque (twisting force) applied to the fastener. For example, Cylinder head nuts, bearing cap nuts, ect. (N-M; Kg-m or Ib-ft)

Pliers Features: Pliers have a pair of legs joined by a pivot, hinge or fulcrum pin. Each leg consists of a long handle and a short jaw. Elements of pliers with two joint cutters(Combination pliers) include flat jaw, pipe grip, side Cutters, joint cutters, handles.

Other types of pliers

Flat nose pliers: It has tapered wedge jaws with flat gripping surface which may be either smooth or serrated. It is used for bending and folding narrow strips of thin sheets, wires, etc.

Round nose pliers: This type of pliers is made with tapered round shape. They are used to shape loops in wires and the form curves in light metal strips.

Slip-joint pliers: These pliers are available in various ranges of positions with different shapes of pivot pins so that they have various ranges of jaw opening, and are mainly used for gripping.

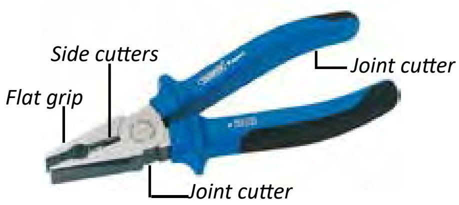


Fig 1.6.43 Elements of pliers

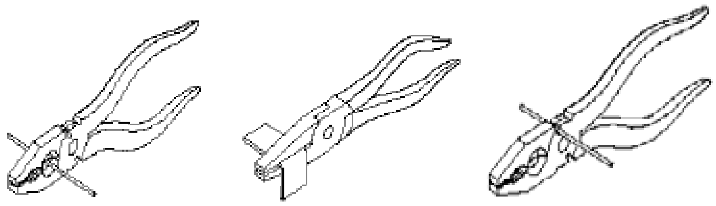


Fig 1.6.44 Different types of pliers

Combination of ring and open end spanner: These tools have a box end on one end and an open end on the other. Both ends are of the same size.

Socket spanners: The socket is one of the fastest and most convenient of all the spanners. Sockets come in two sizes–standard and deep. Standard sockets will handle most of the works, while the extra reach of the deep socket is occasionally needed.

Socket handles: Several different drive handles are used. The socket handle is used whenever possible, as it can be turned rapidly.

Fig 1.6.45 Combination spanner

Fig 1.6.46 Socket spanners

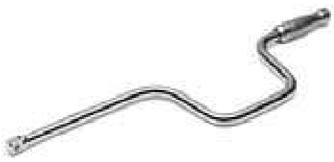


Fig 1.6.47 Socket handle

Types of vices: There are different types of vices used for holding workpieces. They are quick releasing vice, pipe vice, hand vice pin vice and toolsmaker's vice.

Quick releasing vice: A quick releasing vice is similar to an ordinary bench vice, but the opening of the movable jaw is done by using a trigger (lever). If the trigger at the front of the movable jaw is pressed, the nut disengages the screw and the movable jaw can be set in any desired place quickly.

Pipe Vice: A pipe vice is used for holding round sections of metal and pipes. In this vice, the screw is vertical and movable. The jaw works vertically. The pipe vice grips the work at four pionts on its surface.

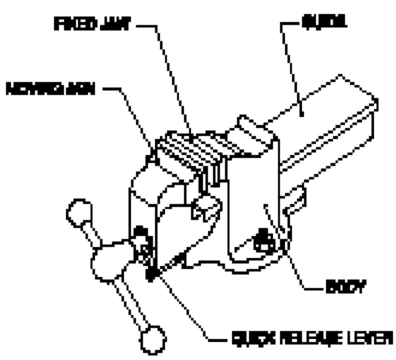


Fig 1.6.48 Quick releasing vice

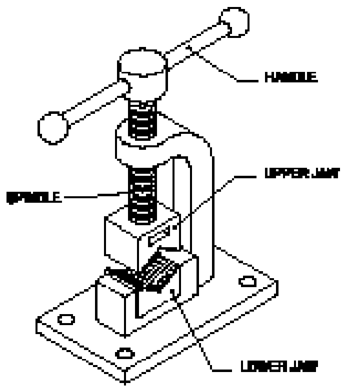


Fig 1.6.49 Pipe vice

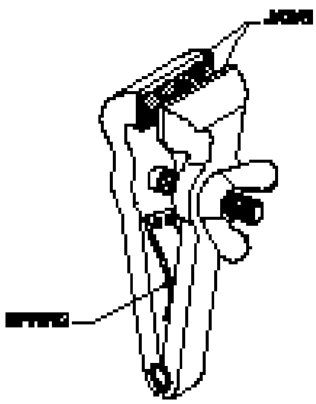


Fig 1.6.50 Hand vice

Hand Vice: Hand vices are used for gripping screws, rivets, keys, small drills and other similar objects which are too small to be conveniently held in the bench vice. A hand vice is made in various shapes and sizes. The length varies from 125 to 150 mm and the jaw width from 40 to 44 mm. The jaws can be opened and closed using the wing nut on the screw that is fastened to one leg and passes through the other.

Toolmaker's vice

The toolsmaker's vice is used for holding small workpieces which require filing or drilling and for marking of small jobs on the surface plate. This vice is made of mild steel. Toolmaker's vice is accurately machined.

Bench vice

These vices are used for holding workpieces. They are available in different types. The vice used for bench work is called as bench vice or engineer's vice. A bench vice is made of cast iron or cast steel and it is used to hold work component / item for sawing, threading and other hand operations. The size of the vice is stated by the width of the jaws.

Parts of a bench vice

The following are the parts of the vice. Fixed jaw, movable jaw, hard jaws, spindle, handle, box-nut and spring. The Vice is generally bolted and secured in a wooden work table, and is useful for operations like filing, chipping, hacksawing, bending sheetmetal, etc. The box-nut and the spring are the internal parts. Do not over-tighten the vice as, the spindle may get damaged.

Flaring, flare fittings and testing the joints

Flaring necessity

When connecting tubing to fittings, it is common practice to flare the end of the tube and to use fittings designed to grip the flare for a vapour tight seal. Special tools are used for making flares.

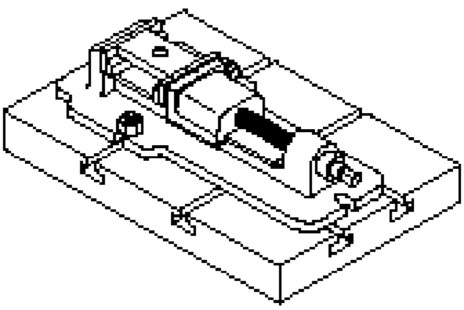


Fig 1.6.51 Tool maker vice

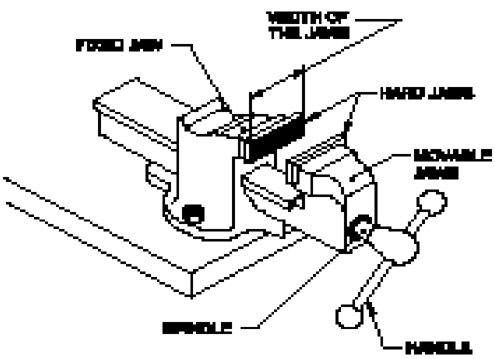


Fig 1.6.52 Bench vice

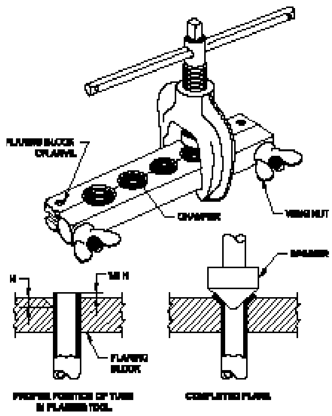


Fig 1.6.53 Flaring tools

Types of flaring

There are two types of flaring – single thickness flare and double thickness flare.

Single thickness flare

It can be made on smaller size copper tubing.

Double thickness flare

Double thickness flares are recommended for only the larger size tubing 5/16 inch (9mm) OD and over. Such flares are not easily formed on smaller tubing. The double flare makes a stronger joint than a single flare.

Flared tubing fittings

To attach a fitting to soft copper tubing, a flared type connection is generally used.

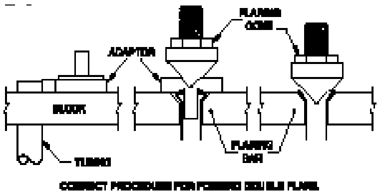
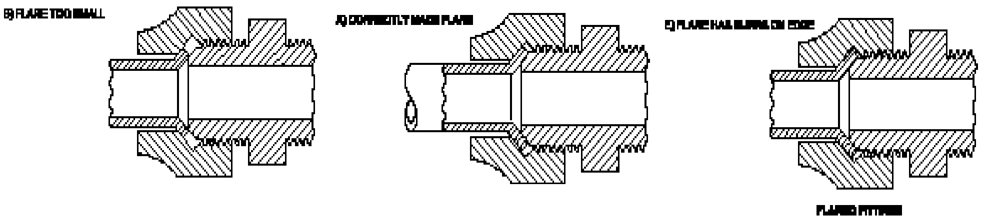


Fig 1.6.65 Correct procedure for forming double flare



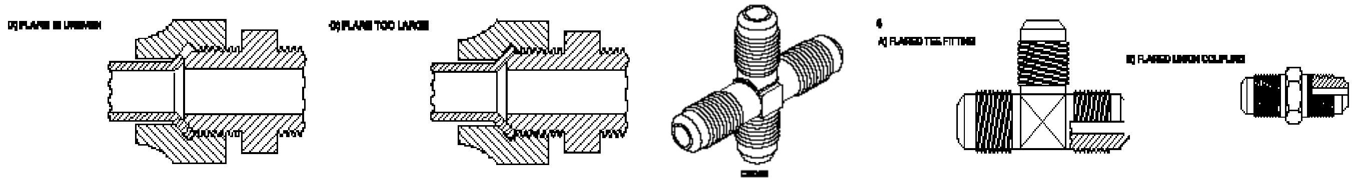


Fig 1.6.66 Different type of flared fittings

Pipe cutter

A pipe cutter is more convenient and neater than a saw when cutting pipes and metal tubing. The sharpened wheel does the cutting. As the tool turns around the pipe, the screw increases the pressure, driving the wheel deeper and deeper through the pipe until it finally cuts rights, through.

Fig 1.6.67 Pipe and Tube Cutter

Standard and special screwdrivers and use

Screwdrivers are used to tighten or loosen screws which are fixed in the machine element.

Classification:

1. Standard type with tips to suit recessed head screw slots.
2. Special type with tips to suit recessed head screws.

Standard screwdrivers

Standard screwdrivers are classified as heavy duty screwdrivers, light duty screwdrivers, stumpv screwdrivers.

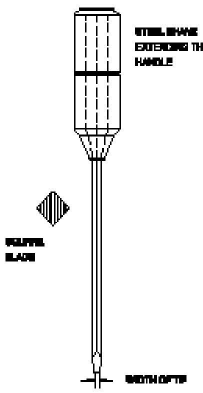


Fig 1.6.69 Heavy duty screw driver

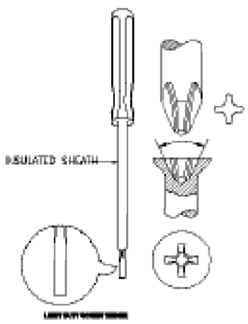


Fig 1.6.70 Light duty screw driver

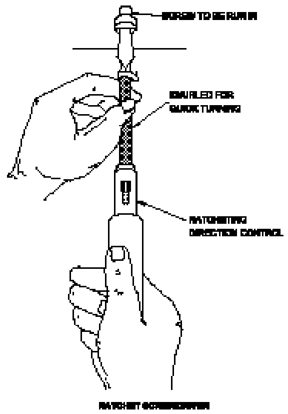


Fig 1.6.71 Philips screw driver

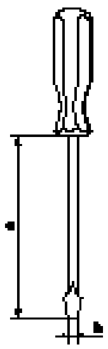


Fig 1.6.72 Ratchet screwdriver

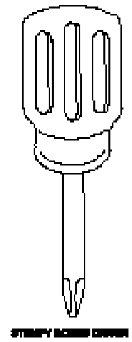


Fig 1.6.73 Special screw driver

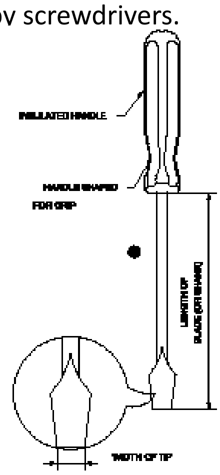


Fig 1.6.68 Screw driver

Hexgon socket screw keys (Allen Keys)

Hexagon socket screw keys/Allen keys are made from hexagonal section bars of chrom vanadium steel. These are hardened and tempered. These are bent to L shape. The size of an Allen key is identified by the size across the flat of the hexagon.

Uses: They are used to tighten or loosen screws having internal hexagon sockets. Allen keys are available in different sets in plastic wallets, comprise a set of 8 (2 to 10mm).

Puller: The puller is a general workshop tool which is used to remove gears, bearings pulleys, flanges, bushes. The puller is made of steel material, generally, with two or three legs and they are adjusted to hold the outside of the gears or bearing sleeves while the central threaded shaft is screwed forward exerting force on the gear/ bearing. This enables to remove the bearing without damaging the shaft. Pullers are classified according to the application and the number of legs. Another classification is based on the power utilised mechanical puller and hydraulic puller.

Two legs puller, is, generally, used for removing the gearss whereas puller, with three legs are for removing pulleys. flanges and bearings. It is also called gear puller.

Special pullers: These are mainly used for specialised application such as crank shaft, bearing removal, brake drum removal, pilot bearing removal.

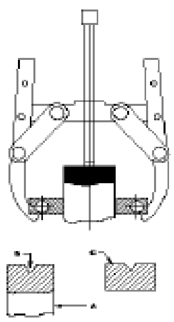
Hydraulic puller: These pullers eliminate time consuming and unsafe hammering, heating or prying. Damage to part is minimised through the use of hydraulic pullers.

Safety: To avoid person injury during system operation, always wear proper PP gear. Never use a tool to strike a puller. Make sure that items that are pulled are well and adequately supported. Do not apply heat to a puller. Before every use lubricate the centre bolt threads with graphite-based lubricant. Use puller only with recommended attachment. Do not overload a pulley which may cause to break.

Shawal: Shawal is used for mixing concrete and also for carrying concrete to mortar pans. Shawals are made of tool steel sheets. The size is designated by its length and width.

Pickax: Pickax is used to excavate hard soil. It is manufactured from tool steel. One end of the pickax is flat, while the other end is sharp. It helps for two different oprations. The size is denoted by its lengths.

Fig 1.6.74 Allen Key Sets



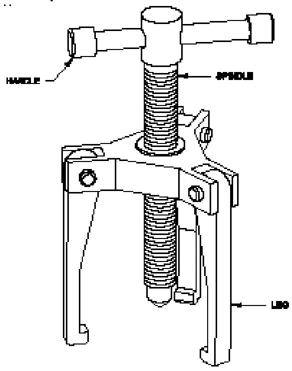


Fig 1.6.75 Puller

Fig 1.6.76 Shawal

Fig 1.6.77 Pickax

Exercise

I. Answer the following questions.

1. List of the hand tools.

   ----

2. How many types of files can be used for pipe edge preparation?

   ----

3. Name any three types of pipe wrenches.

   ----

4. Name the elements of ball peen hammer.

----

5. What are the types of hammers mainly used in pipe fitup application?

----

6. State the purpose of pickax.

----

7. Name any three types of spanners and their uses.

II. State whether the following statements are True or False.

1. File and pipe vice are used in pipe edge perparation.

   True ☐ Flase ☐

2. Chisel and hacksaw are hand cutting tools used by pipe fitter for chipping and cutting off operation.

   True ☐ Flase ☐

3. Mallets are used to strike a soft and light blow on the metal.

   True ☐ Flase ☐

4. Pipe vice is used to hold the round section of metal and pipe.

   True ☐ Flase ☐

Notes

1.6.5 Power Tools and Equipment

At the end of this topic, you will be able to:

1. name the different types of power tools and equipment
2. handle different types of power tools and equipment.

Drilling machine (portable type)

Necessity

Portable hand drills of different types are used for certain jobs which cannot be handled on stationary drilling machines.

Types: There are two types of portable drilling machines – power operated and hand operated.

Power Operated drilling machines

Electric hand drill (light duty): These are available in different forms. The electric hand drill has a small electrical motor for driving the drill. On the end of the spindle, a drill chuck is mounted. Electric hand drills used for light duty will have, usually, a single speed.

Electric hand drill (heavy duty): This drill has an additional feature by which the drill speed can be varied through a system of gears. This is particularly useful for drilling larger diameter holes.

Pneumatic hand drill: This type of drill is operated by compressed air. An air driven motor is housed in the casing, and a handle is fitted along with an air pipe to operate the drill conveniently. This drill is used where electrically operated drills are prohibited, for example, explosives factories, petroleum refineries, etc.

Hand operated drilling machines: Different types of hand operated drilling machines are available. They are used in structural fabrication, sheet metal and carpentry, particularly, where electricity or pneumatic supply is not available. The ratchet drilling machine is commonly used in structural fabrication. Square head, taper shank drills are used on these machines. The bevel gear type drilling machine is used for drilling small diameter holes up to 6mm. The breast drilling machine is used for drilling holes of larger diameter as more pressure can be exerted. Drills between 6 mm to 12 mm can be used on these machines. (Fig. 1.6.78)

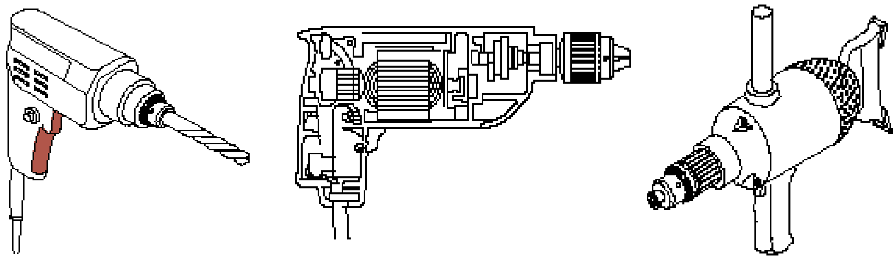


Fig 1.6.78 Electric hand drill

Fig 1.6.79 Hand operated drilling machine

Drill (parts and function):

Drilling is a process of making holes on workpieces. The tool used is drill bits. For drilling, the drill bit is rotated in the clockwise direction with a downward pressure causing the tool to penetrate into the material.

Parts of a drill: The various parts of a drill can be identified from the Fig. 1.6.81.

Point: The cone shaped end which does the cutting is called the point. It consists of a dead centre, lips or cutting edges.

Shank: This is the driving end of the drill which is fitted on the machine. Shanks are of two types. Taper shank is used for larger diameter drills and straight shank is used for smaller diameter drills.

LIP: LIP is the cutting edge which penetrates into metal while drilling.

Tang: This is a part of the taper shank drill which fits into the slot of the drilling machine spindle.

Body: The portion between the point and the shank is the body of the drill. The parts of the body are flute, land/ margin, body clearance and web.

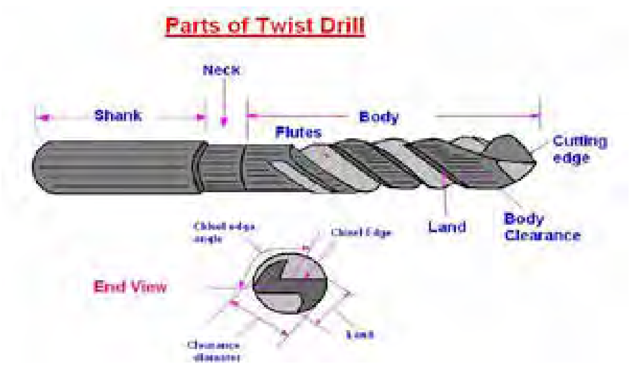


Fig 1.6.80 Typical drill bit

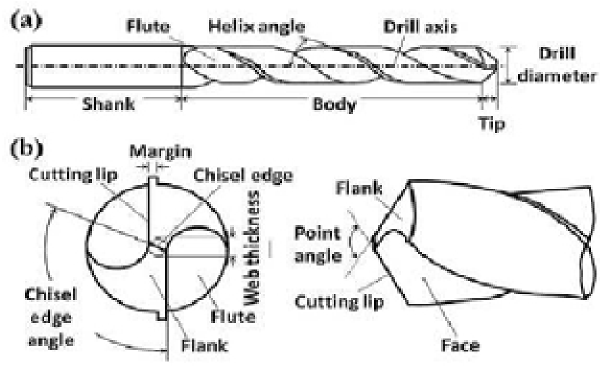


Fig 1.6.81 Parts of a drill

Flutes: Flutes are the spiral grooves which run to the length of the drill. The flutes help to form the cutting edges to cut the chips and, allow them to come out, the coolant to flow to the cutting edge.

Land/margin: The land/margin is the narrow strip which extends to the entire length of the flutes. The diameter of the drill is measured across the land/margin.

Body clearance: Body clearance is the part of the body which is reduced in diameter to cut down the friction between the drill and the hole being drilled.

Web: Web is the metal column which separates the flutes. It gradually increases in thickness towards the shank. A drift is used to remove drills and sockets from the machine spindle. While removing the drill from the sockets/ sleeves, do not allow it to fall on the table or jobs.

Drill angles: Like all cutting tools, the drills are provided with certain angles for efficiency in drilling.

Angles: There are different angles for different purposes. They are – Point angle, helix angle, rake angle, clearance angle and chisel edge angle.

Cleaning Tools - Brushing and abrasive Cleaning tools: It should be used very carefully on soft metals. Heavy deposits that exists even after chemical cleaning can be removed by mechanical cleaning. The General Cleaning Tools are wire brushes, emery paper.

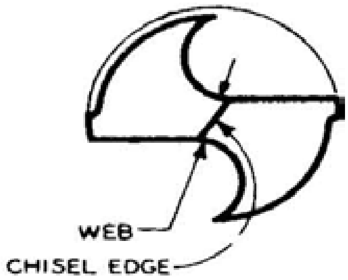


Fig 1.6.82 Web

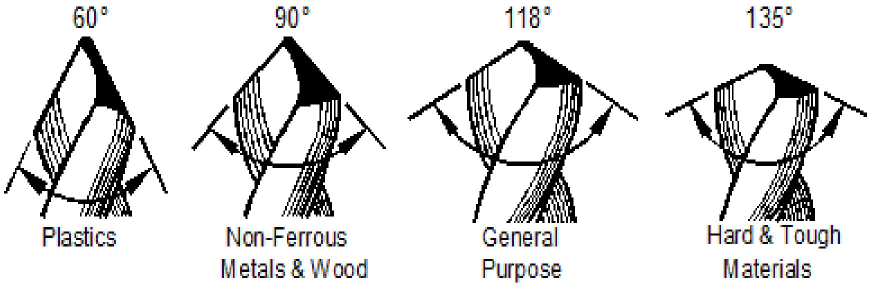


Fig 1.6.83 Drill angles

Wire Brushes: Wire brushes are generally used for cleaning the work surfaces. It is made of steel wires or nylon bristles fitted on a wooden piece. The steel wires are hardened and tempered for long life to ensure good cleaning action.

Emery Paper: This is a type of paper used for cleaning hard and rough surfaces and also used for resistant technology purposes to give a smooth, shiny finish to manufactured products.

Fig 1.6.84 Emery paper

Fig 1.6.85 Wire brushes

Metal-cutting saws of different types are used in industries. The most commonly used are power saw, horizontal band-saw, circular saw, contour band-saw.

Circular saw: This type of cutting machine is used when cutting materials having a large cross-section. The circular saw has a continuous cutting action and is economical in production work where heavy section metals are used.

Power hacksaw: Cut-off saws are used to cut metal stock roughly to the required length. The commonly used cut-off saw in small scale industries is a power saw.

Power hacksaw blades: The saw blades are selected depending on the machine and the type of work on hand. The blades are made of low alloy steel or H.S.Steel and are fully hardened. For different materials, blades of different pitches are used (number of teeth per 25 mm length). As a general rule, the softer the material, the lesser is the number of teeth per length of 25 mm. Teeth with a large pitch can accommodate large chips. Blades are available with varying coarseness between 4 to 14 teeth per 25 mm length. Coarse pitch blades are also used while cutting large sections of stock, as this will help in greater chip clearance and increased penetration. For cutting hard material (tool steel) and thin material, a 14 pitch blade is recommended. For general purpose sawing, a 10 pitch blade will be useful.

Tips

While selecting blades, make sure atleast two teeth of the blade will be in contact with the work at all times.

Clamping arrangement: Power saws are provided with clamping devices similar to those in machine vices, and the work can be gripped by using the crank handle. When a number of pieces of the same size are to be cut, an adjustable stop is used. Long bars are supported, and the level maintained by the use of adjustable floor stands.

Fixing blades: The blades are mounted on frames using screws. The teeth of the blade should point towards correct directions. (Depending on the type of machine, the blade cuts either on the forward or on the return stroke. It is necessary to follow the directions given by the manufacturers as indicated in the frame. Tension the blade using the tensioning device.

Fig 1.6.86 Horizontal band saw

Fig 1.6.87 Power hacksaw

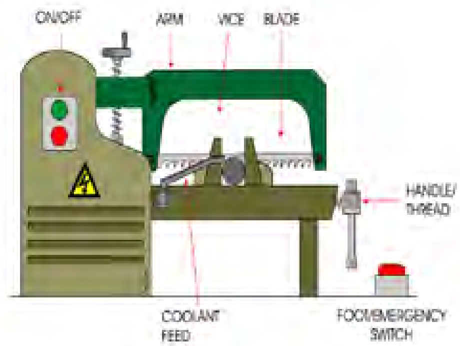


Fig 1.6.88 Power hacksaw with blades

Precautions while machine - sawing

In order to work safely and efficiently, certain precautions are to be observed. While taking measurements of the work for setting, always stop the machine. Projecting ends of the work should be well guarded to ensure safety of all. Ensure that the work does not protrude into the gang-ways. When sawing thin pieces, hold the material flat in the vice to prevent the saw teeth from breaking. Ensure a cutting fluid is always used. Avoid giving excessive cutting pressure, because this can cause breakage to the blade, and cut the work out of square. When several pieces of the same length are to be cut, use a stop gauge. When holding short workpieces in a vice, be sure to place a short piece of the same thickness in the opposite end. This will prevent the vice from twisting, when it is tightened.

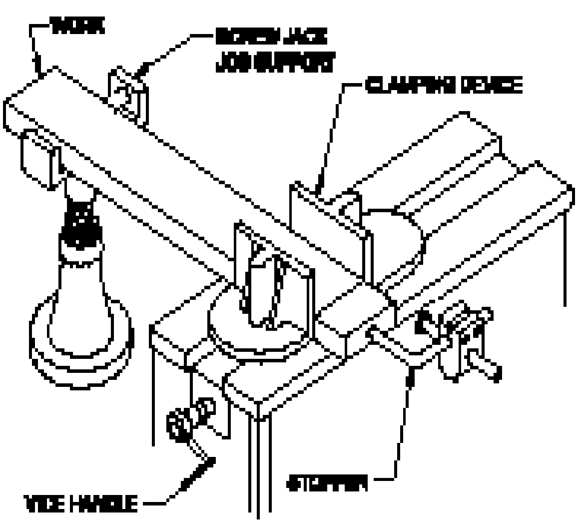


Fig 1.6.87 Clamping arrangement

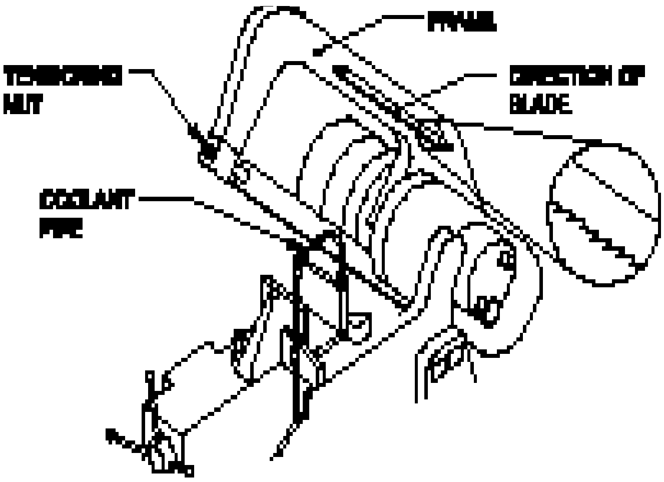


Fig 1.6.88 Fixing blades

Table 1

Table for tap drill size					
ISO Metric(60^0)				B.S.W.(55^0)	
Nominal diameter mm	Pitch	Tap drill sizes	Nominal diameter (inch)	Threads per inch (mm)	Tap drill sizes
3	0.5	2.50	1/8	40	2.5
4	0.7	3.30	5/32	32	3.2
5	0.8	4.20	3/16	24	4.0
6	1.0	5.00	1/14	20	5.0
8	1.25	6.80	5/16	18	6.5
10	1.50	8.0	3/8	16	8.0

Exercise

I. Answer the following questions.

1. Name the power tools that are used in pipe fitup application.

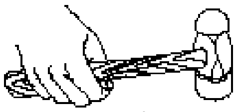
   ----

2. Name the different types of drills that are used for piping assembly fitup.

   ----

3. Name the power tools which are used in pipe cutting operation.

II. Identify the image and note it down in the Table 2.



1

2

3

4

5

6

7

Sl.No	Name of image	use	
1			
2			
3			
4			
5			
6			
7			

Notes

Unit 1.7 Pipe Fitting Operation

Unit Objectives

At the end of this unit, you will be able to:

1. select appropriate equipment and accessories used in pipe fitup
2. select correct marking tools and materials
3. fabricate, install, repair and maintain low and high pressure piping system
4. produce pipe bends using the appropriate tools and equipment
5. fabricate piping spools with a range of different fittings.

1.7.1. Equipment and Materials Used in Piping Fabrication

At the end of this topic, you will be able to:

1. identify types of equipment used in piping spools fabrication work
2. list codes and standards as applicable
3. specify the list of materials used in pipe fitup
4. define technical terms in process piping (oil & gas).

Equipment and accessories used in piping spools fabrication work

Set of PPE (personal protective equipment)

1. Pipe cutting and beveling machine (Cold cutting)
2. Orbital pipe cutting and beveling equipment (Hot cutting)
3. Grinding machine – AG4, AG7
4. Lifting crane, forklift and accessories
5. Chain block
6. Oxyacetylene cutting equipment and saw cutting machine
7. High speed cutter
8. Marking Tools

Personal Protective Equipment (PPE)

Hard hat (Helmet)

A hard hat is a type of helmet predominantly used in the workplace environments such as industrial fabrication and construction sites to protect the head from injury due to falling objects, impact with other objects.

Fig. 1.7.1 Hard Hat

Fig. 1.7.2 Safety Harness

Fig. 1.7.3 Hand Gloves

Fig. 1.7.4 Safety Shoes

Safety goggles

Safety goggles are a type of personal protective equipment (PPE) that is worn on the eye for protection.

Safety harness: A fall Protection accessory that protects workers in case of falling while working at heights.

Hand Gloves: Hand gloves are personal protective equipment worn to cover and protect the hands from the wrist to the fingers.

Safety shoes: A steel toe boot is a durable boot or shoe that has a protective reinforcement in the toe. It protects the foot from injury.

Reflective jacket: A reflective fabric will keep workers visible at all times.

Dust mask: A flexible pad worn over the nose and mouth to protect against dust in the construction site.

Ear plug: A earplug is a device meant to be inserted in the ear canal to protect the ears from loud noises.

Fig. 1.7.5 Safety goggles Day and Night

Fig. 1.7.6 Reflective Jacket

Fig. 1.7.7 Dust Mask

Fig. 1.7.8 Ear Plug

Pipe cutting and beveling machine:

Pipe cutting is a mechanized or normal cutting process that removes material from pipe to create desired profile. Pipe beveling is the process where an angle for fitup and welding is prepared such as 30°/37.5°.

Orbital pipe cutting and beveling equipment: A pipe cutting and beveling machine used for the cutting and beveling of pipe ends / edges.

Oxy acetylene cutting equipment: Oxy fuel cutting processes that use fuel gases (Acetylene) and oxygen to cut pipes.

Fig. 1.7.9 Beveling and cutting equipments

Fig. 1.7.10 Oxy-Acetylene cutting equipment

High speed cutter / grinding machine: A machine designed for cutting and beveling of pipe ends by mechanical method.

Fig. 1.7.11 High speed cutter/grinding machine

Mobile crane: Mobile crane is a controlled crane mounted on crawlers or with rubber-tyre telescope boom mounted on truck. They are designed to easily transport to a site and use for different type of loading, lifting and set up piping assembly.

Fork lift: Fork lift is one of the most important and widely used equipment in pipe material handling, piping spool fabrication workshop yards. The lift truck is a powered industrial vehicle used to lift and transport piping materials.

Chain block: Chain block is a mechanism used to lift and lower heavy loads using a chain block with two wheels in which chain is wound around. When the chain is pulled, it winds around the wheels and begins to lift piping spools /fittings.

Hoisting equipments and their application (chain hoists): Lifting and moving of loads by hoisting equipment is a rigging operation. In rigging, many types of hoisting equipment like hoists, derricks and cranes are employed. Both hand and electrically operated hoisting equipment are available and used widely in piping / pipeline construction works. All lifting equipment shall be calibrated to the maximum load carrying capacity.

Chain hoist: The chain hoist is a most widely used device for lifting loads. Chain hoists are dependable and usually portable. Three basic types of chain hoists are the differential, screw-geared, spur-geared.

Fig. 1.7.12 Mobile crane

Fig. 1.7.13 Fork lift

Fig. 1.7.14 Chain Block

Fig. 1.7.15 Hoisting Equipments

Spur-geared hoist: The spur-geared hoist is the most efficient type of hoist which uses an endless chain to drive a pocket sheave. The pocket sheave drives a gear reduction unit that is fitted with the second or load chain. One end of the load chain is fitted with a hook.

The come along chain hoist is another type of chain hoist. It uses a ratchet operated by a lever for lifting. The come along chain hoist is used to lift loads to short distances. But it is used more often to stretch wires and cables. It is also known as pull lift. Wire rope hoistings are also used for hoisting the load. Generally, manila ropes are used to hoist the load.

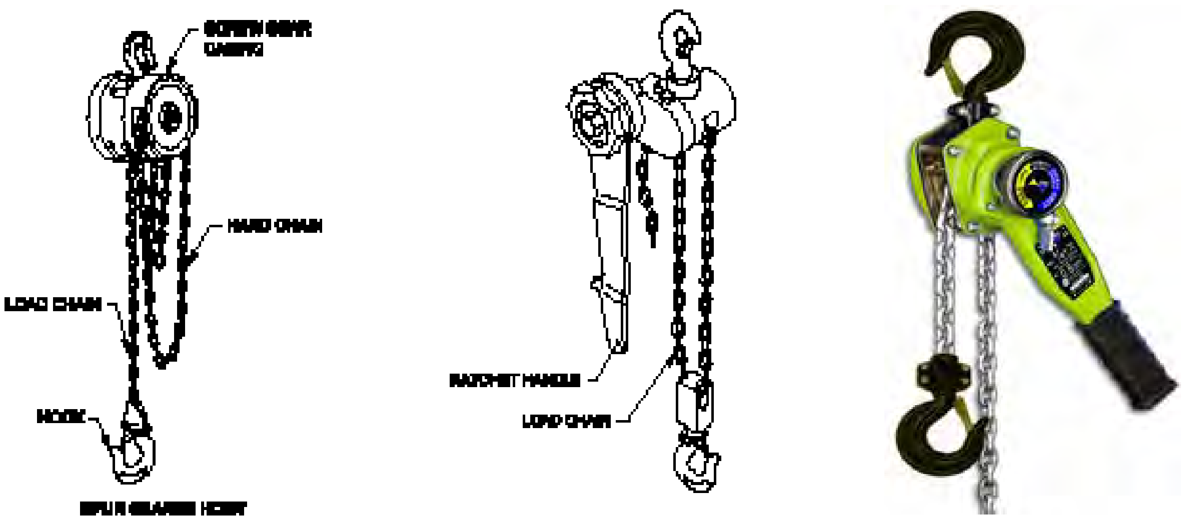


Fig. 1.7.16 Different type of chainhoist

Exercise

I. Answer the following questions.

1. What are the equipment required for pipe fitup and assembly?

   ----

2. What is the purpose of using chain block?

   ----

3. Name the important PPEs?

II. State whether the following statements are True or False.

1. Tube is always used to measure (OD) outside diameter.

   True ☐ False ☐

2. Stainless steel is the alloy of chromium and nickel.

   True ☐ False ☐

3. Fuel gases acetylene and oxygen are used in oxy-fuel cutting processes.

   True ☐ False ☐

Notes

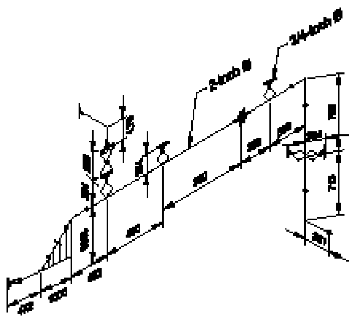
1.7.2 Planning Pipe Fitting Activities before Starting Fitup

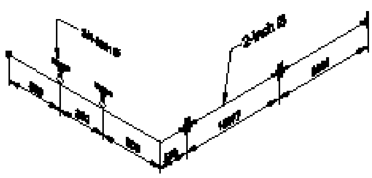
At the end of this topic, you shall be able to:

1. interpret the drawing carefully and prepare material MTO
2. perform material transportaion, storage and handling in store / site
3. carryout material receiving, checking and issue from store
4. carryout material issuing for fabrication and construction purpose.

Material reveiving and checking in store / site

The first step to ensure the quality of the piping product is to make sure that the incoming material being used, meets the specified quality standards requirement. Ensure that this happens as per company approved procedure. It should also be ensured that secure storage areas are provided for pipe materials, fittings and equipment irrespective of their point of origin. The site store keeper should be responsible for the receipt storage, issuing of materials at store / site.





MTO				
DESCRIPTION	[illegible] NUMBER	QTY	UNIT	REMARKS
[illegible]	[illegible]	[illegible]	MTR	
[illegible]	[illegible]	1.5	MTR	
[illegible]	[illegible]	02	PCE	
[illegible]	[illegible]	02	PCS	
[illegible]	[illegible]	02	PCE	
[illegible]	[illegible]	01	PCS	
[illegible]	[illegible]	01	PCS	[illegible]
[illegible]	[illegible]	01	PCS	
[illegible]	[illegible]	01	PCS	
[illegible]	[illegible]	07	PCS	
[illegible]	[illegible]	13	PCE	
[illegible]	[illegible]	02	PCS	
[illegible]	[illegible]	02	PCS	
[illegible]	[illegible]	01	PCS	
[illegible]	[illegible]	01	PCE	
[illegible] THERMOWELL [illegible]	[illegible]	01	PCE	
[illegible] GASKET	[illegible]	04	SET	
[illegible] GASKET	[illegible]	16	SET	
[illegible] GASKET	[illegible]	02	SET	
[illegible]	[illegible]	04	SET	
[illegible]	[illegible]	[illegible]	SET	
[illegible]	[illegible]	[illegible]	SET	
[illegible]	[illegible]	04	SET	
[illegible]	[illegible]	[illegible]	PCE	
[illegible]	[illegible]	01	PCS	
[illegible]	[illegible]	01	PCS	
[illegible]	[illegible]	01	PCE	

MADE BY:	DATE [illegible]	CHKD BY:	APPRD BY:	TITLE: LINE [illegible] FOR WELL [illegible]
DESIGN PRESSURE [illegible]	PIPING CLASS [illegible]	LINE NO: [illegible]		CAD DRAWING
DESIGN TEMP (MAX) [illegible]				[illegible]
TEST PRESSURE [illegible]	PAINT REQUIRED	NO		
[illegible]	REV [illegible]			
[illegible]	DATE [illegible]			[illegible]

Protective Coatings: Protective painting and coating systems, external surface of carbon steel structures piping and equipment on shore piping shall be protected with suitable coating systems.

Painting and coating related terms

Anticorrosive paint	–	A paint formulated to prevent corrossion of steel substrates/ pipe surface.
Primer	–	Paint intended for protection of metals against corrosion or for preparing a surface for subsequent top coats, the primer must have sufficient wetting properties to saturate the surface and maintain the adhesion.
Thinner	–	Any volatile liquid used for reducing the viscosity of coatings, may consist of a simple solvent.
Epoxy	–	A resin based on polymerised bisphenol containing epoxy groups.
Air less spraying	–	Method of paint application which uses hydraulic pressure to atomise the paint. Airless spraying is a very fast and efficient method of painting application.

Different types of protective coatings applied in piping system include:

- Liquid Epoxy – External and Internal coating
- Zinc rich epoxy – Coating for pipes
- Poly urethane – External coating for pipes
- Fusion bonded epoxy – External and internal
- Galvanizing – For pipes and supports
- Mastic coating for pipes – External and internal surface coating
- Glass Flake coating – For tanks
- PE Coating – High density Polyethylene coating.

Purpose of painting and coating include: protection, decoration, information

Protection: Paint is used to protect objects / pipes from adverse effects of weather Epoxy layer protects the pipe against corrosion and damages.

Decoration: Paint is used to decorate all sorts of objects.

Information: Paint is used to give information by means of painted signs / colour coding.

Material transportation, storage and handling

1. It shall be ensured that adequate protection against damage is provided for all components during transportation, loading, storage activities by providing adequate timber bearers during the transport and the wrapping of lifting points.
2. Pipes and fitting, flanges or component parts should be stored above ground on pallets and kept free from dirt, grease, paint sprays.
3. Pipe and fitting open ends should be protected by the use of end caps.
4. Particular care should be taken in the storage and handling of coated, painted and galvanized piping materials.
5. Different grades of materials including cut segments or shapes should be clearly marked using identification coding system. Stainless steel and duplex stainless steel should be stored in different locations to avoid contamination (or) mixing.

Fig. 1.7.17 Typical Piping Material storage (Flanges, Pipes, Fittings)

Corrosion: Corrosion is usually described by its results. Familiar terms include rust, scaling, pitting etc., The corrosion process involves the deterioration of a pipe or its properties because of reaction with environment.

Handling and storage of coated pipes and associated assembly

When handling coated pipes, special attention to be taken, as follows:

1. To prevent damage to the coatings and pipes.
2. Pipe bevel ends should be protected with suitable protector.
3. Pipe must be handled with suitable lifting gear. Only soft, non–metallic slings should be used.

Storage of pipes

1. Plan and arrange the safe storage of pipes.
2. Protective plastic stoppers and metallic bevel protection must be kept in the correct places.
3. A sufficient number of wooden base and separators must be used when storing pipes indoors and outdoors.

Lifting of coated pipe and associated components

1. Pipe must always be horizontally positioned when lifting to prevent damage to the coating.
2. Coated pipe should not be lifted with chains in direct contact.
3. Do not damage pipe coating ends and welding bevels.

Fig. 1.7.18 Image for Pipe storage and handling

Tips

Painting and coating

Pipe ends (cut back) should not applied in the range of 50 - 75mm in order to facilitate fitup and welding.

Support wedges

Wedges are nailed onto the base and separators to prevent pipes from moving and avoid abrasion during unnecessary moving of pipes.

Exercise

I. Answer the following questions.

1. How are pipe ends and flanges protected?
2. How are SS and duplex piping materials stored at the construction site?
3. Define corrosion.
4. Explain the purpose of painting and coating.
5. Name the different types of coating and painting system.

II. State whether the following statements are True or False.

1. The corrosion process involve the deterioration and loss of material and its critical properties due to chemical and electro-chemical reaction.

   True ☐ False ☐

2. Pipe ends are (cut back) 50-75mm left without painted and coated for good fitup and welding.

   True ☐ False ☐

3. Pipe should always be lifted in the horizontal position.

   True ☐ False ☐

4. Pipe ends and spools ends and flange surface should always be protected from damage.

   True ☐ False ☐

Notes

1.7.3 Cutting Fluids Used on Ferrous and Non-ferrous Metals

At the end of this topic, you should be able to:

1. list the different cutting fluids used for ferrous metals
2. list the different cutting fluids used for non-ferrous metals
3. state the function of cutting fluids.

Cuttings Fluids: Cutting Fluids and compounds are the substances used for efficient cutting while the cutting operation takes place. The function of cutting fluids include:

1. To reduce the friction between the chip and the tool face by lubricating.
2. To prevent rusting of the work and machine.
3. Heat is dissipated to some extent.

Advantages of cutting fluids: As the cutting fluid cools the tools, the tool retains its hardness for a longer perid. so the tool's life lasts longer. As the chips are flushed away, the cutting zone will be neat and clean.

Properties of good cutting fluid

Good cutting fluid should be sufficiently viscous. It should have low evaporation rate. It should be stable and should not foam or fume. It should not create any health problem to the operator.

Type of Cutting Fluids

The following are the common cutting fluids:

1. Straight mineral oil
2. Chemical solution (synthetic fluids)
3. Blended oil
4. Fatty oils
5. Soluble oil (Emulsified oil).

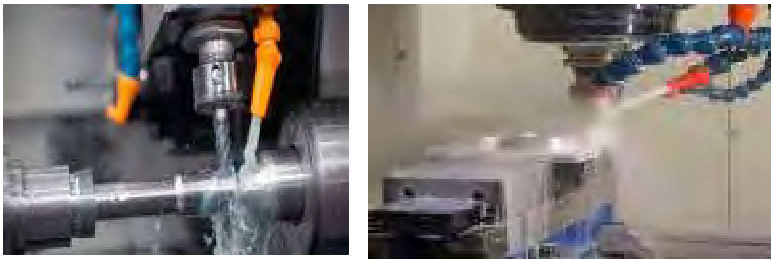


Fig. 1.7.19 Metal cutting fluids

Straight mineral oil: Straight mineral oil is the coolant which can be used undiluted. For example, kerosene, which is straight mineral oil widely used as a coolant for machining aluminium and its alloys.

Chemical solution (synthetic oil): These consist of carefully chosen chemicals as dilute solution with water. They possess good flushing and cooling action, and are non-corrosive and non-clogging. Hence, they are widely used for grinding and sawing. They do not cause infection and skin trouble. They use artificially coloured.

Fatty oil: Lard oil or vegetable oil are fatty oils. They are used on heavy duty machines with less cutting speed. They are also used on bench-works for cutting threads by taps and dies.

Soluble oils (emulsified oil): Water is the cheapest coolant, but it is not suitable because it causes rust on ferrous metals. An oil called soluble oil is added to water which gets a non-corrosive effect with water in the ratio of about 1 : 20. It dissolves in water giving a white milky solution. Soluble oil is an oil blend mixed with an emulsifier. Other ingredients are mixed with the oil to give better protection against corrosion and help in the prevention of skin irritations. Soluble oil is generally used as a cutting fluid for centre lathes, drilling, milling and sawing.

Exercise

I. Answer the following questions.

1. Name the different types of cutting fluids used for ferrous metals.

   ----

2. Name the different types of cutting fluids used for non-ferrous metals.

   ----

3. State the function of cutting fluids.

   ----

4. What are the key properties of cutting fluids?

   ----

5. What is the mixing ratio of water in soluble oils?

II. State whether the following statements are True or False.

1. Kerosene can be used as a coolant for machining aluminium and its alloys.

   True ☐ False ☐

2. Cutting fluids are to reduce the friction between chip and the tool face.

   True ☐ False ☐

3. Good cutting fluids have sufficient viscosity.

   True ☐ False ☐

4. Blended or compounded oil is used in automatic cutting lathes.

   True ☐ False ☐

5. Fatty oil is also called vegetable oil.

   True ☐ False ☐

Notes

1.7.4 Different Typess of Thread and its Plumbing Applications

At the end of this topic, you should be able to:

1. define different types of thread on pipe and its application in plumbing work
2. produce different types of threads on pipe with different methods of production
3. name the types of equipment used for threading of pipes
4. recognise on different instruments used in plumbing.

Pipe thread types

There are six types of threads commonly used on pipe / tube Fittings. (ASMEB 16.11)

- UN / UNF – Unified Fine
- NPT / NPTE – (National Pipe Thread)
- BSPP – (British standard pipe parallel thread)
- BSPT – (British standard pipe taper thread)

Manufacturers follow pipe thread industry standards. The two main pipe thread standards are

1. NPT – National pipe thread
2. BSP – British National Pipe Thread

Plumbing plan – blue print reading: Plumbing plan describes the piping systems and plumbing fixtures. The term blueprint will be used when referring to drawings. Ability to interpret drawings and specifications for a building is absolutely necessary if fitters are to do their work correctly. In most cases, the location of the plumbing fixtures and the basic layout of the piping system will be shown on the drawing. It is the fitter's responsibility to interpet the drawings and install the plumbing system according to the plan.

Plumbing symbols: Plumbing symbols are used on the working drawings or sketches. The fittings are shown by symbols. The symbols are used for representing elbow, valves, unions, reducer, etc. These symbols should be recognised to locate fluid supply systems on drawings. A model assembly of pipe fitting arrangement is shown in Fig 1.7.20. Observe the symbols and interpret the drawing.

Fig 2

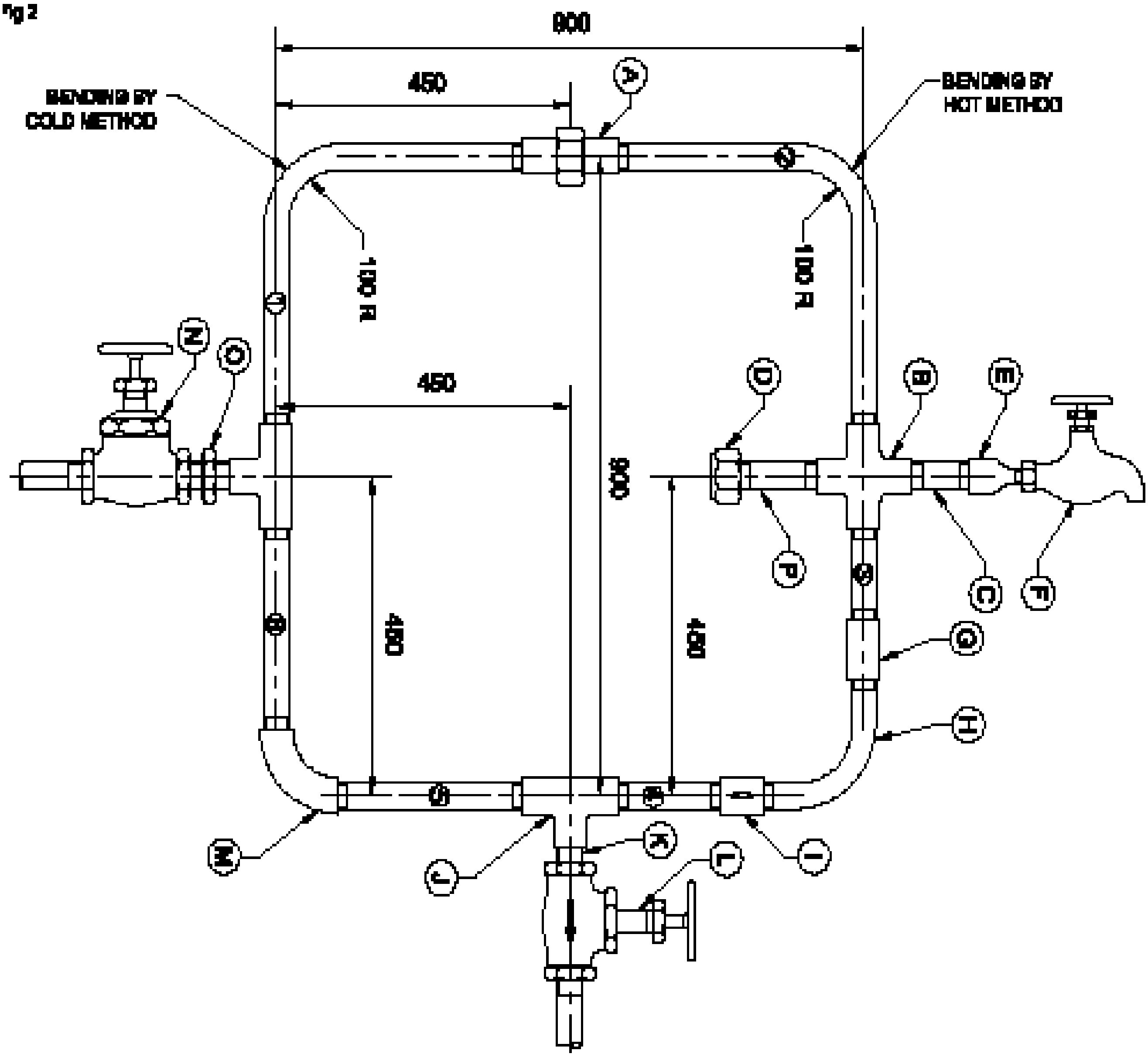


Fig. 1.7.20 Plumbing plan Drawing

1	25 x 100mm	[illegible] NIPPLE	G.I		P	
1	25 x 50mm	HEXAGONAL NIPPLE	G.I		O	
1	25mm	GATE VALVE	COPPER ALLOY		N	
1	25mm	ELBOW	G.I		M	
1	25mm	GLOBE VALVE	COPPER ALLOY		L	
1	25 x 100mm	BARREL NIPPLE	G.I		K	
2	25mm	TEE	G.I		J	
1	25mm	[illegible] COUPLING	G.I		I	
1	25mm	BEND 90°	G.I		H	
1	25mm	PLAIN COUPLING	G.I		G	
1	1/2 inch	[illegible] COCK	[illegible]		F	
1	25 x 15mm	REDUCER	G.I		E	
1	25mm	CAP	G.I		D	
1	25 x 100mm	BARREL NIPPLE	G.I		C	
1	25mm	CROSS	G.I		B	
1	25mm	UNION (WITH WASHER)	G.I		A	
1	Ø 25 x 4.05 - [illegible]	PIPE (CLASS B)	G.I		6	
1	Ø 25 x 4.05 - 410	PIPE (CLASS B)	G.I		5	
1	Ø 25 x 4.05 - [illegible]	PIPE (CLASS B)	G.I		4	
1	Ø 25 x 4.05 - 300	PIPE (CLASS B)	G.I		3	
2	Ø 25 x 4.5 - [illegible]	PIPE (CLASS B)	G.I		1 & 2	[illegible]
NO. OFF	STOCK SIZE	DESCRIPTION	MATERIAL	REMARKS	PART NO.	EX. NO.

NPT thread (American National Pipe Thread): National pipe thread tapered is the best known and most widely used connection where the pipe threads provide both the mechanical joint and hydraulic seal. NPT has a tapered male and female thread which seals with thread tape or adhesive compound.

British Standard Pipe Thread (BSPT): The joint is made self sealing by thread cutting on at least one of the threads on a tape (usually the male thread). This is known as the British standard pipe thread and has been adopted internationally for interconnecting and sealing pipe ends.

Sealing a tapered thread

For pipe fitters, it is more convenient to know how many turns to make by hand and how many with a wrench. A simple rule of thumb for installing tapered pipe threads is finger tight plus remaining turns with a wrench when standard torque specification cannot be generically applied.

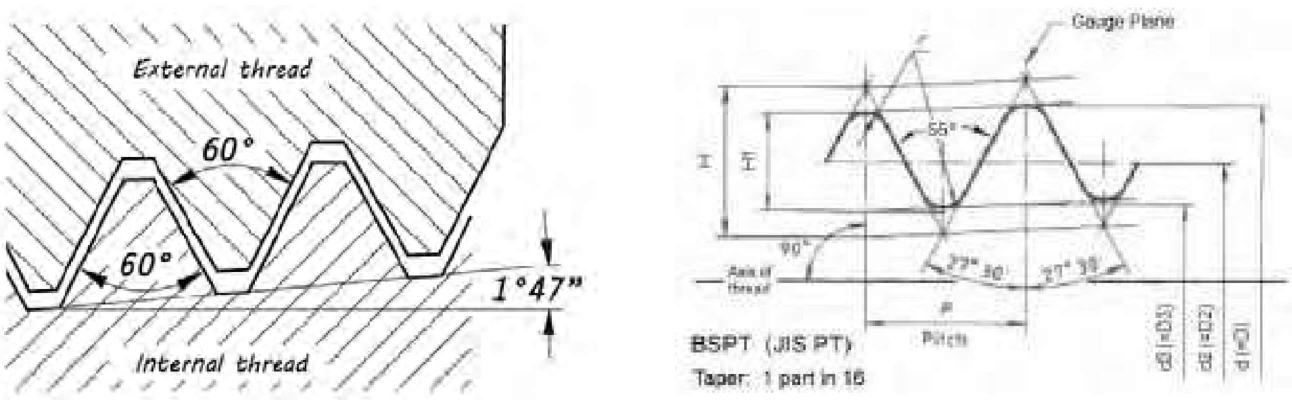


Fig. 1.7.21 NPT and BSPT Thread

Table 2

	British BSP		American NPT		
Nominal Size	Actual OD	Threads per inch	Actual OD	Threads per inch	Turns for a hand tight joint
1/8"	0.383"	28	0.405"	27	3.3 turns
1/4"	0.518"	19	0.540"	18	3.1 turns
3/8"	0.656"	19	0.675"	18	3.3 turns
1/2"	0.825"	14	0.840"	14	3.4 turns
3/4"	1.041"	14	1.050"	14	3.7 turns
1"	1.309"	11	1.315"	11.5	3.7 turns
11/4"	1.650"	11	1.660"	11.5	3.8 turns
11/2"	1.882"	11	1.900"	11.5	3.8 turns
2"	2.347"	11	2.375"	11.5	3.9 turns

Pipe threading equipment

Manual equipment used for threading pipe, External pipe threading machine, Internal pipe threading machine.

Manual pipe threading equipment: Handheld threading equipment is made of a stock to which the handles are attached and in which cutting die is inserted. There are two sets of set screws on the stock–one set for holding the dies in place and the other set for adjusting the dies. On the stock, there is a deep mark to correspond with the standard thread mark on the dies. On the opposite side of the stock, there is a place for pipe fitter / turner, which helps to guide the cutting dies onto the pipe that is to be threaded.

Portable hand held threading machine: Portable handheld threading machines are light weight and are ideal for plumbers. They can thread pipe from 1/8" to 2" in diameter.

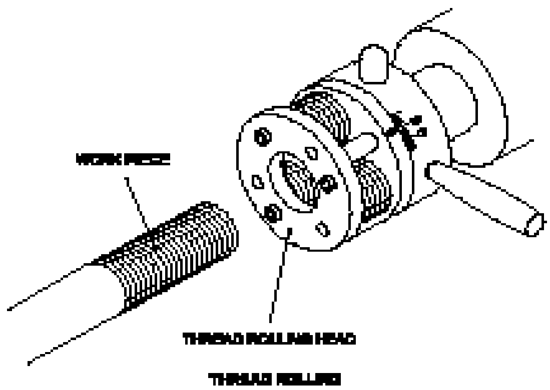
Methods of producing External threads: External threads are generally manufactured by using a single point tool with self opening die heads and by thread rolling heads.

Self-opening die heads: Self-opening die heads are most commonly used in the thread manufacturing process. They are made in a wide range of sizes for producing threads up to about 100 mm diameter.

Fig. 1.7.22 Different type of theading machine

In addition to dies / chasers for standard threads, many dies / chasers for special threads are also available. The die head is fed to the work by the operator which then allows it to feed itself along the work, and follows up with the turret. The turret stop is set slightly short to the thread length. When the die head movement is stopped by the turret stop, the front portion of the die head continues to feed forward under the self-feeding action until it is pulled clear of the detent pin. Long accurate threads need a positive method of feeding the die head over the work. On capstan lathes, this is achieved with a hexagon turret, lead-on attachment. If the machine is equipped with a cross-slide and the thread chasing attachment, the cross-slide is linked to the hexagon turret to provide positive lead.

The markings on the die piece indicate the die type thread diameter - die number, thread relieved on the leading side and slots to locate the die in the die head.



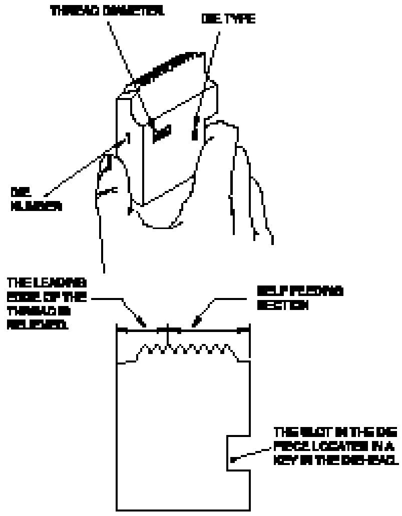


Fig. 1.7.23 Thread rolling heads and c

Threading oils: Threading oils are used to cool and lubricate the cutting die and workpiece. The use of threading oils assists the threading process for the following reasons:

1. keeping the threading dies and the workpiece at a stable temperature.
2. Increasing the life of the cutting dies by lubricating the working edge.
3. Reducing the threading torque and speeding metal removal.
4. Preventing rust on the threading dies and on the machined threads.

Sealing tape: BSPT fittings and NPT threaded pipe and ends must be made leak-free with the aid of thread seal tape. The most common pipe thread tape is polytetrafluoroethylene (PTFE) tape. Pipe thread tape prevents seepage and reduc thread damage.

Threading sealants: There are different types of sealant for different applications depending on the type of pipe and service conditions.

Fig. 1.7.24 Sealing Tape

Fig. 1.7.25 Threading sealants

Internal threads are cut using 2 types of tools single point thread cutting tool and solid tap.

Internal threading by using a single point thread cutting tool: Threading with a single point tool is usually carried out on large workpieces or when special threads are required. The tool may be mounted either on the hexagon turret or on the square turret fitted to the cross-slide. A threading drive accessory is fitted to the lathe, which enables the tool to be fed along the work at the appropriate rate for the desired pitch. Several cuts are normally made, each slightly deeper than the previous cut, until the thread depth appropriate to the selected pitch is obtained. The threading tool is normally held in a bar mounted in a slide tool-holder.

Solid taps:

Solid taps are used for small diameter threads. They are usually spiral fluted. The tap is fitted to the hexagon turret in a special tap-holder. The holder is designed to release the tap automatically at the end of the cut, permitting the tap to rotate along with the workpiece.

The procedure for cutting the thread is as follows: Move the turret to the workpiece and start the tap in the hole by exerting pressure on the turret drive hand wheel. Keep slight forward pressure on the turret drive to prevent the tap from pulling the turret along as the thread cutting operation progresses. This precaution will prevent distortion of the thread and excessive forward drive pressure will also distort the thread.

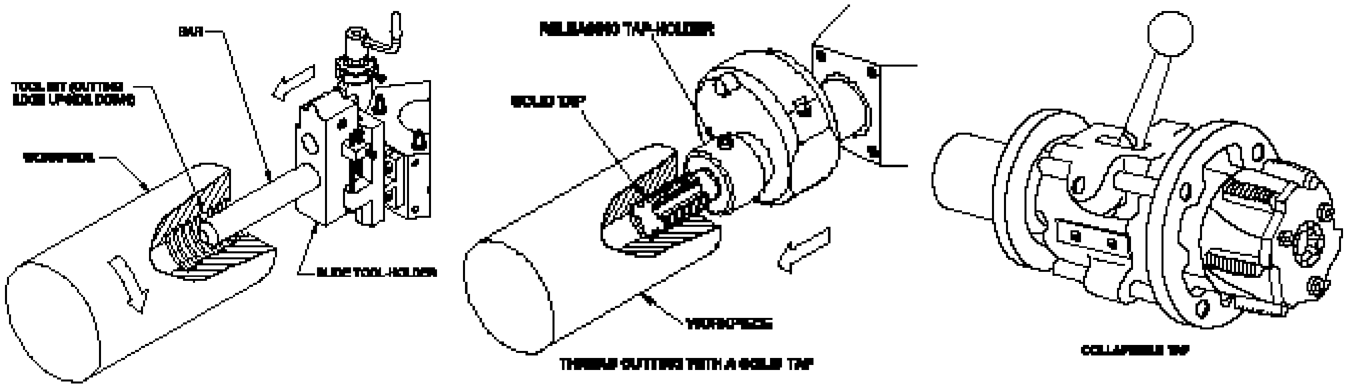


Fig. 1.7.26 Threading and taping

Forward motion of the tap should be stopped first before it reaches the end of the hole being threaded. When using the hexagon turret, this distance is set with the turret stop. When the stop is reached by the advancing turret, the automatic release operates, releasing the tap and allowing it to revolve with the workpiece.

Reverse the headstock spindle rotation to drive the tap back out of the threaded hole.

Screw thread measurement (gauges): The selection of measuring instruments used for checking the threads depends very much on the accuracy requirement and the feature of the thread to be checked. The accuracy requirement varies from a bolt used in structural work to threads of a fine measuring instruments. The surface of a screw has a complex shape. The following elements of a screw thread are to be considered in thread measurement–major diameter, minor diameter/root diameter, pitch, effective, diameter, thread angle, form of root and crest. They contribute to the strength and interchangeability of the threads. The most important elements to be checked are the pitch of the thread, the angle and, the effective diameter.

Screw pitch gauge: This gauge is mainly used to check the pitch of external and internal threads. This consists of a number of blades with accurate notches made to the profile and pitch of the thread. The decision about the correctness of the pitch is taken by comparing them by placing the appropriate blade on the screw. Each blade has an indication about the size of the screw and the pitch.

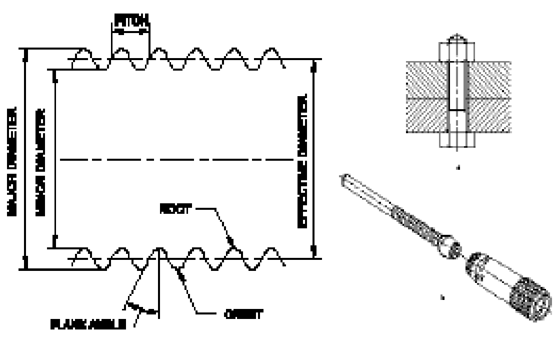


Fig. 1.7.27 Screw thread method

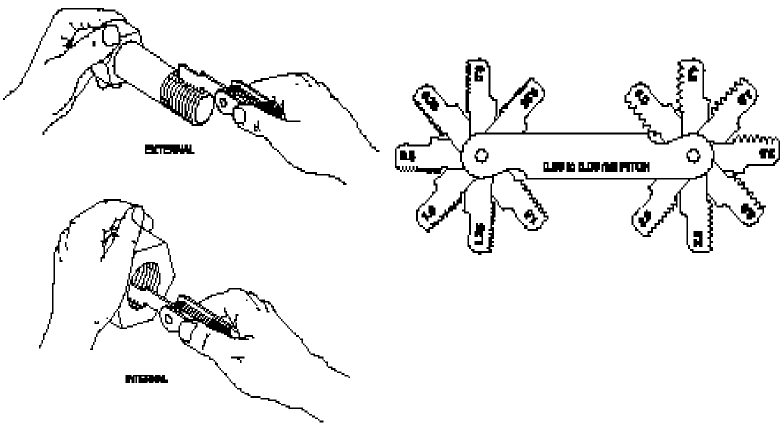


Fig. 1.7.28 Screw pitch gauge

Thread gauges:

The screw thread plug gauge is used to check the internal thread. It checks whether a thread dimension is within its tolerance. The 'Go' side of the gauge checks the following the profile angle (β), the pitch (P), the major diameter (D), the effective diameter (D_2), the minor diameter (D_1).

Thread ring gauge: This is used to check the external thread for its accuracy. Go No Go gauges are used to check whether the thread is within tolerance.

(**Screw thread caliper gauge):** This is used for checking external threads. This gauge is a highly efficient type. This finds greater usage than the ring gauge for checking external threads. In this, the external threads are gauged with a caliper type gauge with two sets of anvils representing the Go and No Go conditions. The Go anvils have full thread form and are set to ensure no element of the thread is oversize. The No Go anvils have truncated thread form to ensure that the contact is made only on the flanks of the thread and checks that the effective diameter of the workpiece thread is not undersize. The gauges are adjustable and are set by means of master setting plugs. The gauges can be used for right or left hand threads.

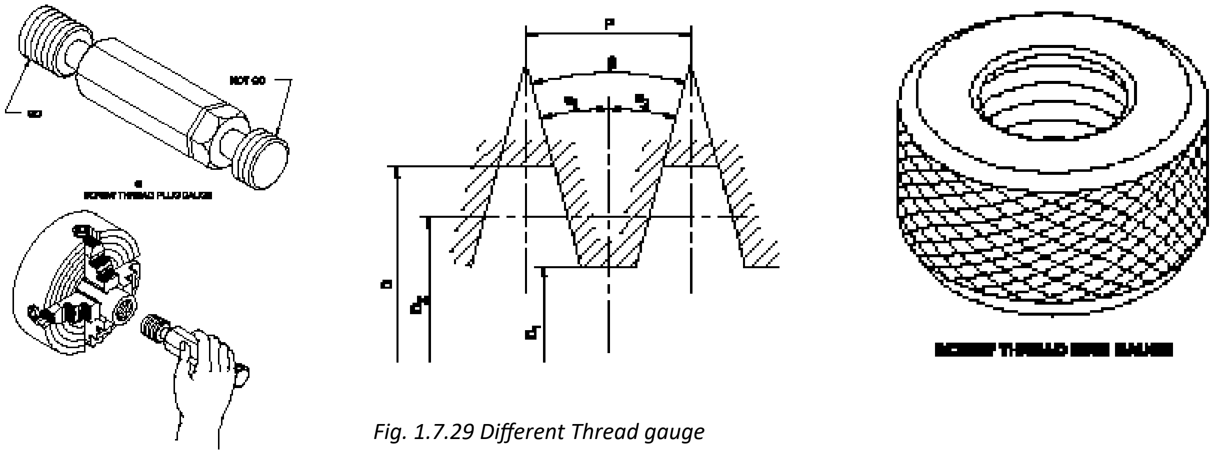


Fig. 1.7.29 Different Thread gauge

General safety precautions for pipe threading

1. When operating pipe threading equipment, the operator should be properly trained and monitored and observed by supervisor.
2. Do not allow untrained persons to operate threading equipment.
3. Wear IS / ANSI approved safety goggles and heavy duty work gloves during threading operation.
4. Keep hands, fingers, feet away from the threading machine during operation.
5. Keep working area clean, tidy and free from unrelated materials.

Assembling the threaded pipe joints

Tools and equipment required to complete a threaded pipe joints include pipe vice, pipe cutter, threading die, reamer, set of pipe wrenches, cutting fluid and sealing tape.

Fig. 1.7.30 Threaded Pipe Joint assembly

Assembling the threaded pipe joints: The threaded pieces are joined together using couplings or fittings and suitable sealing materials must be used on the threads at each joint. This can be either teflon tape or a pipe thread sealing compound. With the sealing material in place, hand tighten the pipe and fittings. Then, using pipe wrenches, one on the pipe and one on the fittings, tighten one and a half more turns.

Pressure testing of threaded piping system: Pressure testing of threaded piping system should normally be carried out by using compressed dry air, and then only under carefully controlled conditions. A pneumatic leak test with a soap bubble test at all joints should be performed.

Tips

1. Prior to execution of the test the supervisor / pipe fitter should ensure that all test gauges are calibrated in accordance with proper procedure and National / International Standards.
2. The maximum test pressure shall not exceed 1.5 times of the maximum system operating pressure.

1.7.5 External Pipe Threading and Assembly

At the end of this exercise, you will be able to:

1. perform measuring, marking and cleaning
2. carryout hacksaw cutting and deburring
3. perform external threading by manual (NPT) type
4. assemble the threaded pipe with fittings.

Practical

Requirements		
Tool/Instruments		**Materials / Components**
Measuring tape Pipe vice, Pipe cutter		Sealing Tape Sealing compound
Tri square, Reamer Set of pipe wrenches		Require pipe size –1” – 1 meter length 1” – Tee, coupling
Equipment/Machines		1” – Elbow 90°, 45° – EA
Personal protective equipment	1 - set	1” – CAP – 1 1” – union
Manual threading equipment	- 1No.	1” – Cross 1” square Edge plug

Select the required piping materials as per drawing.

- Check the diameter and thickness of the pipe with the help of vernier caliper.
- Carryout marking with the help of scriber.
- Hold the pipe with the pipe vice and cut manually with the help of hacksaw and frame.
- Check the dimension of the cut lengths.
- Choose an appropriate die set for external threading.
- Hold the pipe with pipe vice and start threading (NPT type) is the proper sequence
- At the time of threading thread the protective gap at both the ends.
- Check the threads using calibrated thread gauges (ring gauge).
- Place a temporary thread protective gap at both the ends.
- Apply thread sealing tape/sealing compound.
- Hand tighten the pipe and fittings using pipe wrenches.

Fig. 1.7.31 GI – piping threading and assembling

Safety : Use appropriate personal protective equipment (PPE's)

Exercise

I. Answer the following questions.

1. How many type of threads are used on pipe / tube Fittings?

2. Name the two main pipe thread standards that are most commonly used.

3. Name the three types of pipe threading equipment.

4. Name the pipe thread tapes and sealents used to reduce seepage.

5. Name any two thread measuring gauges.

6. List tools required to complete thread joints.

II. State whether the following statements are True or False.

1. NPT stands for National Pipe Threading and is the most widely used type in plumbing.
   True ☐ False ☐
2. Threaded piping is commonly used in low pressure piping system and non-critical applications.
   True ☐ False ☐
3. Portable handheld threading machines are ideal for plumbers and they can thread up to 2" Inch, diamter Pipe.
   True ☐ False ☐
4. Threading oils are used to cool and lubricate the cutting and work piece and increase life of the Cutting Tool.
   True ☐ False ☐
5. Threading machine allow the threading process to produce uniform pipe threads.
   True ☐ False ☐

Notes

1.7.6 Fitup, Assembling and Alignment of Piping Work

At the end of this topic, you shall be able to:

1. explain marking, measuring, cutting and edge preparation
2. define pipe fittings and flanges, piping class
3. recognise up pipe and alignment sequence
4. produce pipe work assemblies and subassemblies using approved piping drawing
5. check dimension with approved drawing.

Measuring, marking, cutting edge preparation and cleaning

Introduction to pipespools fabrication

The word pipe - spool is a unit of prefabricated piping consisting of pipe, fittings, flanges and other components integral to the assembly. This piping is assembled and welded in the shop and transported to the construction site for installation.

All pipe spools fabrication, installation / assembly shall be performed with reference to approved construction drawings. All procedures and inspection and test Plans (ITPs) requirements shall be followed and met. Pipe spools may be fabricated in shop or site or in the actual installation field. It is recommended to perform pipe spool prefabrication due to many advantages as discussed below.

The shop fabricated spool will include all branch connections for field piping, up to the first field butt weld, first field socket weld, first screwed connection or first flanged joint including the first flange.

Pipespools in all sizes of butt welded and socket welded construction will be prefabricated in the shop.

Quality of the work is easier to manage and maintain in a controlled environment. High accuracies on specified tolerances will avoid rework at the site.

Weather independent fabrication will minimize production delays. Better control on welding parameters in controlled environments will result in lesser probability of rework at the site.

Prefabricated Spools are the perfect answer to severe skill and labour shortage. Users do not have to mobilize significant workforce for fabrication of spools on site and Mass production will result in lower manufacturing costs compared with site fabrication.

Prefabricated spools will take lesser fabrication / assembly time, thereby avoiding time and cost overruns.

Checking calibration status of measuring equipment: All pipe spools assembly / installation shall be performed and checked with calibrated monitoring and measuring equipment. All monitoring and measuring equipment will have calibration certificate / calibration sticker. Calibration certificate / sticker shall be verified for calibration date and calibration expiry date. If calibration has expired, those equipment shall not be used, till recalibrated and validated.

Measuring, marking, cutting and edge preparation:

Cleaning: The pipe and fitting surface shall be cleaned using a stainless steel wire brush for a distance of 25mm up the bore and on the outer surface. The ends shall be completely dry before the fitup.

Measuring and marking: Measuring and marking shall be done accoriding to drawing requirement and the same - shall be checked prior to cutting.

Cutting: The cutting shall be generally done as follows:

1. carbon steel pipes by gas cutting saw cutting and grinding
2. alloy steel pipes by grinding or flame cutting or saw cutting
3. stainless steel pipes by grinding or plasma cutting
4. based on spool breakdown of piping isometric, pipe length shall be cut with extra length pipe for field adjustment
5. before cutting the pipe, heat number will be transferred to the cut pieces by low stress dye stamping, paint marking or tagging
6. end / edge preparation shall be done by grinding or machining cutting method in according to drawing and approved welding procedure specification.

Fig. 1.7.32 Image for Measuring and Marking

Fig. 1.7.33 Image for Cutting and Edge Preparation

Pipe bending

In general, pipe bends manufactured at factory / vendor premises shall be used as bending is performed under controlled conditions and supplied after appropriate heat treatment. Field pipe bending shall be avoided. Pipe bending shall be carried out in pipe bending machines or presses using formers as required by project specification, approved procedure. Cold bends to a centerline radius greater than five (5) times the nominal pipe diameter may be manufactured / fabricated. Cold bends to a radius less than five (5) times the nominal pipe diameter is generally not allowed.

Pipe fitup and alignment

1. Pipe end shall be beveled and cleaned prior to fitup and placed on pipe stand / pipe support and eusured that supports are secured properly.
2. Welding / fusion faces may be prepared by chipping, machining or grinding. They shall be smooth and free from defects such as gas-cut notches / undercuts, gas-cut slags, scales / oxides. Joining faces together with the adjacent material shall be thoroughly cleaned of oil, grease, paint and shall be free from all rust, scale, etc for a distance of about 25 mm from the edge of the weld.
3. Pipe fitter should check the pipe ends inside and outside for damages, dents, contamination, etc.
4. Pipe to pipe beveled ends should be set up and correctly spaced according to drawing and approved welding procedure specification (WPS).
5. External alignment (tools) clamp should be used for alignment and to reduce misalignment by the use of clamp and rotation of pipe to the best fit.
6. For pipes of same nominal wall thickness, offset misalignment shall not exceede 1.6mm.
7. In general, shop welds are identified as W1, W2, etc., and construction / installation field welds are identified as “FW”. All weld numbers and welder’s identification numbers shall be marked / painted close to the weld, to enable traceability of each weld and welder.

Fig. 1.7.34 Pipe Fitup and Alignment

8. All attachments to piping – saddles, pads, etc., are to be made of same material as that of the pipe.
9. Tack welds shall be removed so that they do not form part of the finished weld unless they are produced by fully qualified and tested welders to the same procedure as the finished weld, in which case they may be absorbed into the finished weld.
10. During welding, flange faces shall be protected to keep free from weld spatter and arc strike.

Pipe to pipe fitup and alignment

1. Align the pipe or pipe as closely as possible and hold it the correct position.
2. For butt-welding of all piping components (pipe ends, fittings and welding neck flanges), a uniform root gap shall be provided as specified in the relevant welding procedure specification.
3. If the pipe contains a longitudinal weld, this weld shall not be located at the bottom of the pipe after installation. It should be located at least 45° from the bottom of the pipe.
4. Longitudinal seams in seam welded pipe shall be located to clear openings and external attachments possible. Longitudinal seams in adjoining courses shall be preferably at 180 degree. The minimum separation between long seams are to be in accordance with construction specification.
5. If required as per drawing, pipes are to be installed with necessary slopes duly ensuring that pipe slopes are maintained in the required direction.
6. Join together with proper root gap and align for straightness without hi-low at the joint.
7. Tack on one side (apply bridge tack method). Tack welding should be done by qualified welder only. On the side opposite to the tack, again align pipe for straightness then open the clamp / joint slightly to allow for shrinkage, then tack.
8. Roll pipe one quarter turn, check for straightness. Open one side slightly and tack.
9. Tack opposite side. Apply bridge tack method with similar grade of pipe by employing qualified welder.
10. Tacks should be in the range of 1/2 to 3/4 of an inch.
11. Squarness should be checked for alignment.

Pipe to elbow fitup and alignment: The proper fitup of a small diameter elbow is not as critical as two pipe section which must be straight, due to the small size and ease of allowance for the pipe which must butt onto the other end of the elbow. The difficulty in fitting up the pipe on the other end of the elbow seams to increase proportionately with the increase in diameter.

1. Align pipe and elbow with proper root gap.
2. Check hi-low at joint area and ensure that it does not exceed 1.6mm.
3. Tack on top side (apply bridge tack method by employing qualified welder).
4. Again align, then open up bottom slightly to allow for shrinkage.

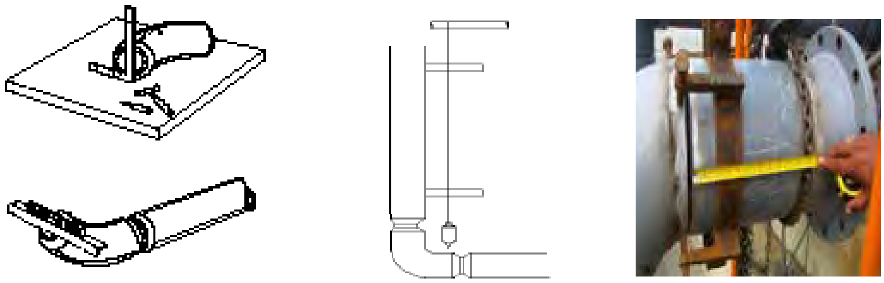


Fig. 1.7.35 Pipe to Elbow Fitup and Alignment

5. Check root gap and tack weld at the bottom.
6. Check orientation and squareness prior to welding.

Flange fit-up orientation: Flanges can be installed with bolt holes oriented in "on Centre" or "off centre". Unless otherwise specified, all flanges shall be fit and aligned in "off centre". Off centre holes shall straddle the centrelines / axis.

Pipe to flange fit up orientation

For fitup flange to pipe, three things have to be watched at the time of fitup.

1. Any damage to the gasket seating surface, would prevent gasket seating. The flange should be replaced, if damage is severe.
2. Root gap, hi-low orientation and level of holes should be checked prior to tack weld.

Fig. 1.7.36 Pipe to Elbow Fitup and Alignment

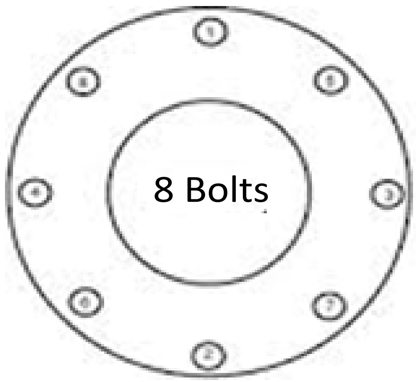


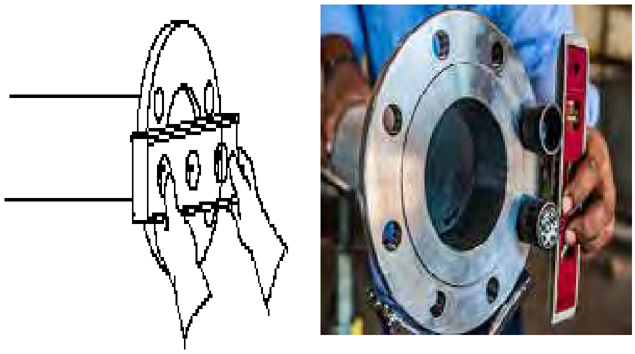
Fig. 1.7.37 Flange orientation – On centre.

3. Tack weld on top side (apply bridge tack method by employing qualified welder).
4. Align bottom, with required root gap, then open slightly to allow for shrinkage. A square or a vertical spirit level should be used to check squareness.
5. Tack weld on bottom side (apply bridge tack method by employing, qualified welder).
6. Using a square on the sides, check squareness of flange, then tack weld both sides duly ensuring proper root gap, alignment, squareness and orientation.

Small diameter pipe jig: Jig made of channel is helpful in aligning small diameter pipe and elbows. Layout a 90° notch on both sides and channel and cut out to form a 'V' heat and bend to a 90° angle and weld.

Pipe to tee fitup and alignment

1. Align pipe end with equal tee or unequal tee.
2. Check hi-low at joint area.
3. Tack on top side joint (Apply bridge tack method by employing qualified welder).



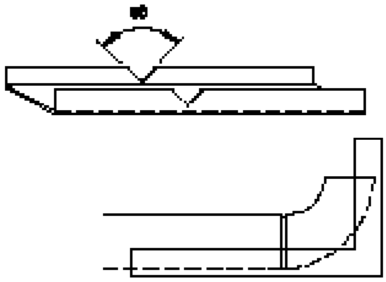


Fig. 1.7.38 Pipe to Flange Fit up and Alignment

Fig. 1.7.39 Pipe jig and fixture

4. Again align, the open up bottom slightly to allow for shrinkage.
5. Check root gap and tack weld at bottom side of the joint (Apply bridge tack method by employing qualified welder).
6. Check orientation and squareness prior to welding.

Dimensional and alignment checks for piping assembly: All Fabricated piping spools shall be checked with issued fabrication / construction drawing (IFC) for the following:

1. Fitup tolerance for length, depth, orientation and straightness of piping members.
2. Piping elevation and degree of levelness and the date of inspection shall be marked near to the joint with metal paint marker.
3. Flange alignment and hole orientation should be checked.
4. All butt welds should be spaced at a minumun of 50 mm or four times the wall thickness or whichever greater.
5. Care should be taken to ensure that the longitudinal welds clear form the branch connection.
6. Line number, component heat number, joint number, date of fitup, etc., shall be marked near to the joint with metal / paint marker pen
7. Spool number shall be marked with paint marker and aluminum tag will be tied with the spool.
8. Fitup and visual acceptance status, signature and date of instpection shall be marked near the joint with metal paint marker.

Fig. 1.7.40 Pipe to Tee Fitup and Alignment

Fig. 1.7.41 Stainless Steel and Duplex Stainless Steel Pipe spools

Stainless steel and duplex stainless steel pipe fitup and alignment

In addition to the above:

1. stainless steel pipe fitup should be done in the shop with an isolated / segregated area from carbon steel and alloy steel piping materials.
2. No tools and tackles, equipment shall be used for SS, DSS which has been used for CS. All tools and equipment dedicated to SS, DSS work should be clearly marked for stainless steel only.

3. eor stainless steel, duplex steel materials, stainless tools will be used for grinding, brushing and clamping, alignment pipe to pipe, pipe to elbow, pipe to flanges, etc.

Fabricated spools protection: Pipe fitter must provide adequate protection for piping, flange faces, threaded connections, etc. to prevent damage during handling and storage. Pipe fitter shall ensure that flange faces are protected from corrosion or rust. Pipe ends and flange faces shall be properly protected against the ingress of dirt, mechanical damage and atmospheric corrosion. The term pipe end shall include any weld preparation. The pipe protection applied shall not be capable of passing into the bore of the pipe.

Threaded connections shall be fitted with a line class plug or covered with a plastic sheet securely wired or taped to the spool. Socket weld connections shall be fitted with taped polyethylene plugs or plastic sheet securely tied with wire or taped to the spool. All flange raised facess of completed piping spools should be fitted with plywood blinds for protection and spool ends shall be fitted with proper caps.

Dimensional Tolerances

1. ± 3mm maximum from the indicated dimension for face to face, centre to face, location of attachment, etc.
2. ± 3mm maximum lateral deviation of branches or connections.
3. ± 1.5mm maximum rotation of flanges from indicated position measured.
4. ± 0.8mm out of alignment of flanges from the indicated position measured across any diameter.
5. Tolerances on dimensions which do not include pipe segments are to be based on ANSI specifications for fittings and / or flanges.Unless otherwise specified, in drawing or procedure or specification, the spools / piping shall be fabricated within the dimensional tolerances specified.

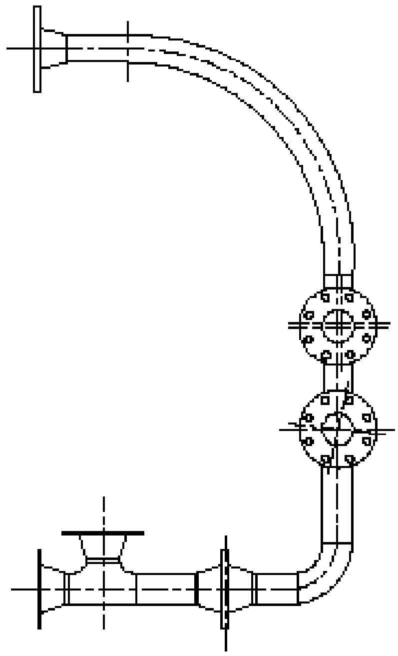


Fig. 1.7.42 Dimensional and alignment checks for piping assembly

1.7.7 Pipe Spool Fabrication

At the end of this exercise, you will be able to:

1. list the type of tools and equipment in common use in the pipe fitting application
2. identify and list the piping materials and fittings required for piping spools, fitting, assembly
3. carryout pipe fitup alignment and dimensional check.

Practical

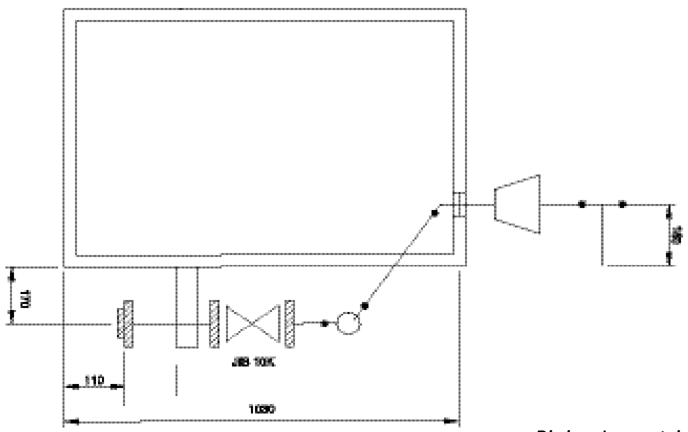
Requirement	
Tool/Instruments Measuring Tape – 1 No. Tri square – 1 No. Spirit level – 1 No. Bevel protractor – 1 No. C - Clamps, wire brush – 1 No. External alignment clamp – 1 No. Lever bar, file - flat – 1 No. Ball peen hammer – 1 No. Spark lighter – 1 No. Bench vice – 1 No. **Equipment / Machines** Personal protective equipment (PPE) Grinding machine – AG4 – 1 No. Beveling machine/cold cutting – 1 No. oxy acetyline cutting equipment – 1 No. With the relevant accessories	**Materials / Components** 1. ASTM 106 Gr B Carbon steel 2”ϕ pipe - 2 mtrs 2. ASTM A 106 GrB – 3 ”ϕ pipe - 1 mtr 3. ASTM A 105 N 2” – WNRF/SORF/Flange - 0.5 mtr 4. 2” – WNRF / SORF / Flange - 2 Nos 5. 150 class - 3 Nos 6. 2” – Elbow – CS – 90° - 1 No. 7. 2” – Elbow – CS – 45° - 1 No. 8. 2” x 3” – Reducer ECC - 1 No. 9. Bolt & nut M12 x 45mm - 8 set 10.Gasket (Spiral wound Gasket-SWG) - 50mm 11.Gate valve 2” ϕ - 1 No. 12.Fire extinghuser - 1 No. 13. First-aid kit - 1 No.

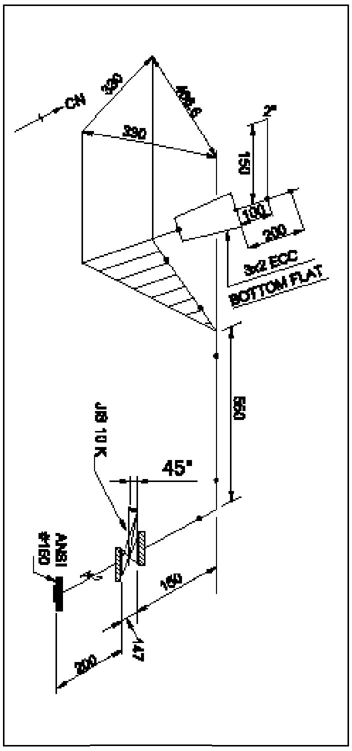
Tips

1. All dimentions are in mm.
2. With the materials given, trainee is required to fabricate the piping according to given dimensions.
3. Pipe fabrication and installation shall be in accordance with the relevent Indian standard / ASME standard / customer specification as applicable.

Pipe to flange, pipe fittings to pipe fitup and alignment

1. Flange must be centered with respect to the axis of the pipe and the face of the flange must be perpendicular to the axis.
2. Check the internal surfaces of the flange and the pipe.
3. Place a spirit level against the face of the flange.
4. Deposit first tack welded by the qualified tack welder.





Piping Isometric drawing

1.7.8 Pipe to Pipe Single 'V' Butt Joint Fitup

At the end of this exercise, you should be able to:

1. perform measuring, marking
2. carryout hacksaw cutting and cleaning (deburring)
3. perform edge preparation by grinding, filing as required.

Practical

Requirement	
Tool/Instruments Measuring Tape – 1 No. Vernier caliper – 1 No. Steel rule – 1 No. Bevel protractor, try square – 1 No. Ball peen hammer – 1 No. Scriber – 1 No. Flat file – 1 No. Hacksaw frame with blade – 1 No. Spirit level – 1 No. **Equipment / Machines** Personal protective equipment – 1 Set AG–4– Grinding machine – 1 No 200 Amps capacity – welding machine – 1 No with complete accessories	**Materials/ Components** 1. 2" ϕ SCh – 40 cs pipe 500 MM long – 1 No. 2. Grinding Disc – 4" ϕ – 1 No. 3. Face shield – 1 No. 4. Welding electrode 3.2 – 1 No. 5. Welding hand shield – 1 No.

- Use appropriate PPEs.
- Select the pipe materials as per requirement.
- Remove rust, mill scale and other contamination on either side of the pipe edges.
- Verify the squareness and perform grinding / filing, if needed to ensure squareness.
- Use spacer wire between pipes in order to maintain root gap.
- Align the pipe to pipe without any misalignment / hi-low.
- Position similar grade of bullet pieces within the groove space.
- Check the Diameter and thickness of the pipe using vernier caliper.
- Measuring and marking is to be done as per drawing by using measuring tape and scriber.
- Cut the pipe manually with the help of hacksaw and frame.
- Hold the pipe with bench vice and grind the edges 30° to 35° bevel angle, maintaining 1.5mm root face.
- Set the 2 pipes to form a single 'V' butt joint.
- Use a fixture or V-profile of an angle to align the pipes.
- Switch 'On' the welding equipment and select 3.15mm ϕ electrode for tacking and set current 100 Amps.
- Perform 4 tacks at equal intervals adjusting 2mm root gap.

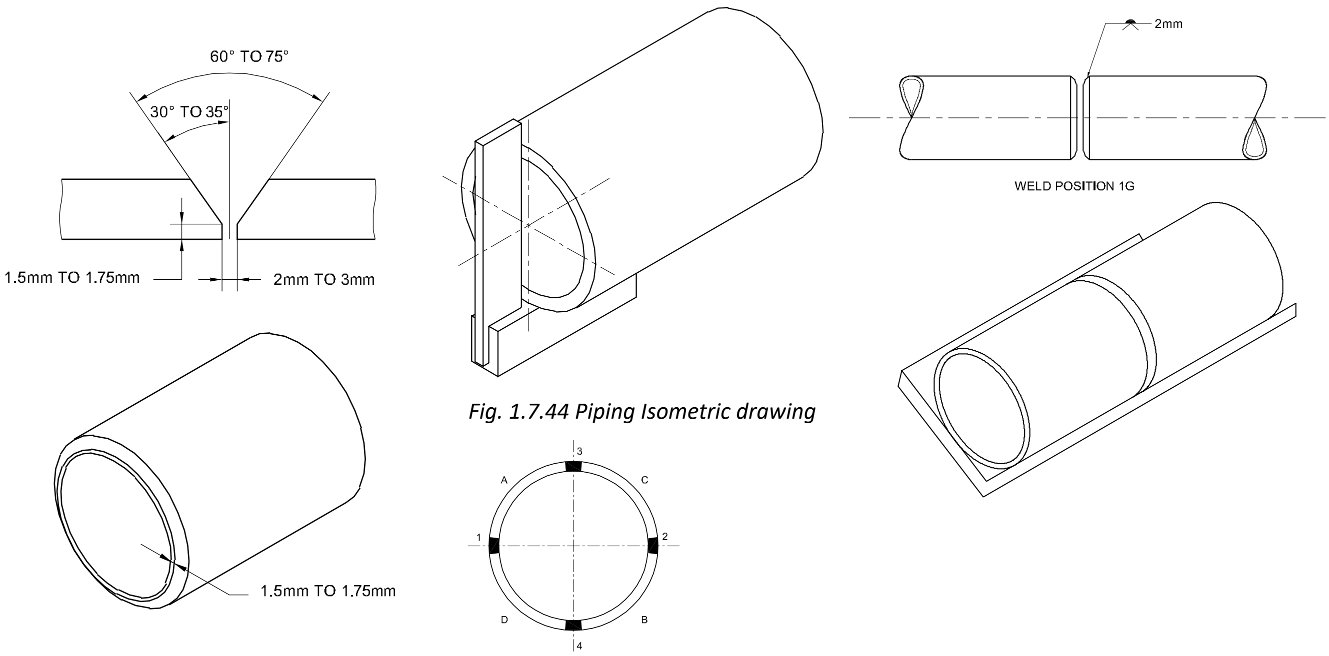


Fig. 1.7.44 Piping Isometric drawing

Safety: Wear appropriate PPE's (Personal protective equipment)

1.7.9 Pipe to Fittings Single 'V' Butt Joint Fitup

At the end of this exercise, you should be able to:

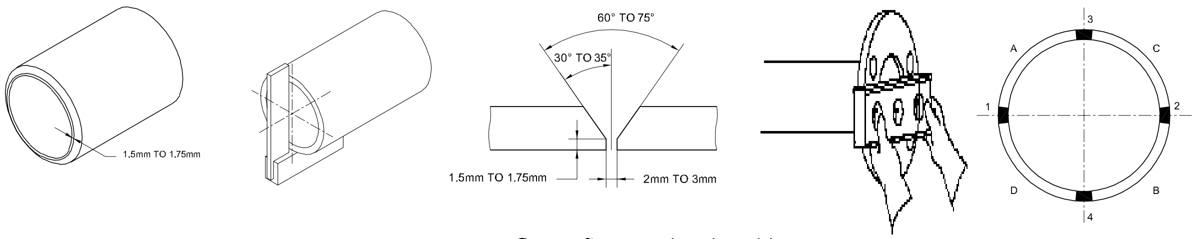
1. perform measuring, marking, cleaning
2. carryout pipe to fittings fitup and alignment
3. check root gap and perform tack weld as required.

Practical

Requirement	
Tool/Instruments Measuring Tape – 1 No. Vernier caliper – 1 No. Try square – 1 No. Spirit level – 1 No. Scriber – 1 No. Flat file – 1 No. Ball peen hammer – 1 No. Hacksaw frame with blade – 1 No. **Equipment / Machines** Personal protective equipment – 1 Set AG–4–Grinding machine – 1 No. 200 Amps capacity – welding machine – 1 No. with complete accessories	**Materials / Components** 1. 2" ϕ SCH – 40 cs pipe 500 MM long – 1 No. 2. 2" ϕ Class # 150 WNRF – 1 No. 3. Grinding Disc – 4" ϕ – 1 No. 4. Welding electrode 3.2 – 1 No. 5. Welding hand shield – 1 No.

- Use appropriate PPEs.
- Select the materials as per requirements (drawing).
- Check the diameter ϕ and thickenss of the pipe using vernier caliper.
- Check the size, ratings of the flanges.
- Measuring and marking is to be done as per drawing using measuring tape and scriber.
- Hold the pipe with bench vice and grind edges 30° to 35° bevel angle maintaining 1.5mm root face.
- Set the pipe with flange to form as a single 'V' butt joint.
- Use a fixture/vice and carryout pipe to flange alignment.
- Check the flange alignment/ off centre using spirit level and Try Square.
- Drilled hole shall straddle the pipe vertical axis centreline.
- Check the squareness of flange and carryout tack weld.
- Place a temporary protective cover on flange faces.





Pipe to flange fit up and tack weld

Safety:

Wear appropriate PPEs (personal protective equipments).

Never saw the welding with bare eyes.

Do not handle, touch hot job/stub end with bare hands.

Exercise

I. Answer the following questions.

1. What are the tools required for pipe fitup and alignment?

   ----

2. What are the cutting process to be used for SS, DSS pipe cutting?

   ----

3. Describe pipe to pipe fitup and alignment sequence.

   ----

4. Explain pipe to flange fitup and alignment sequence.

   ----

5. What are the parameters to be checked for piping assembly?

----

6. How will you protect piping spool end and flange surface?

II. State whether the following statements are True or False.

1. Pipe and fittings should be cleaned externally and internally for a distance of 25 - 50 mm, prior to welding.

   True ☐ False ☐

2. Stainless steel pipes should be cut by plasma cutting.

   True ☐ False ☐

3. For pipes of same nominal wall thickness, offset (hi-low) should not exceed 1.6 mm.

   True ☐ False ☐

Notes

1.7.10 Assembling, Dismantling of Piping Spools and subassemblies

At the end of this topic, you should be able to:

1. perform flanged piping spools assembling and dismantling
2. carryout safe handling of piping spools and their components
3. generate stagewise inspection record
4. return all tools and equipment to the store on completion of the pipe fitting activities.

Flanged piping spools assembling and dismantling

Cleaning: Before erection, all prefabricated piping spools pieces should be cleaned inside. The cleaning process should include removal of all foreign matter such as scale, sand, weld spatter and slag, etc., by wire brushes. Cleaning tools and blowing with dry compressed air may be done. Special cleaning requirements for some services like SS - piping requiring pickling should be used to remove oxidation and discolouring due to welding.

Fig. 1.7.46 Flanged pipe spools

Assembling: While fitting up mating flanges, care should be taken to assemble and align the flanged piping spools and check the flanges for trueness / flatness. Faces of the flanges can be pulled together, without inducing any stresses in the pipe and the sub assemblies. Extra care should be taken for flanged piping spools assembly and temporary protective cover should be provided on flange faces.

Flange bolt-up: In a flanged connection, all components must be correct to achieve a seal. The most common cause of leaky gasketed joints is improper installation procedures. Before beginning a bolting process, the following preliminary steps will help to prevent problems:

- Clean the flange faces and check for scars. The faces must be clean and free of defects (burrs, pits, dents, etc.).
- Visually inspect all bolts and nuts for damage or corroded threads. Replace or repair bolts or nuts, as necessary.
- Remove burrs from all threads.
- Lubricate the threads of the bolt or stud, and the surface of the nut face adjacent to the flange or washer. Hardened washers are recommended in most applications.
- Install new gasket and be sure that the gasket is properly centered. Do not reuse old gaskets not use multiple gaskets.
- Adjust the position of the nuts to ensure that 2-3 threads are visible above the top of the nut.
- Improperly bolted flange includes - bolts that are too short, and the nuts are not completely engaged on the bolts. This means that the joint may not be as strong as it should be. Flanges are designed so that the entire nut-bolt combination holds the forces on the flange. If the nut is only partially screwed onto the bolt, the connection may not be strong enough. This shall be avoided. Ateast one thread shall protrude the nut face.
- Flange leakage test including helium test, snoop test shall be performed as per approved procedure.

Fig. 1.7.47 Insufficient stud bolt length

Expansion joints installation

In general, expansion joints are not allowed in oil and gas piping. Instead, expansion loops are installed. If expansion joints are to be installed, the following instruction shall be followed:

- Check the expansion joint specification and manufacturer recommendations for special instructions.
- Verify to essure expansion joint matches the specified size, material, and capabilities for the application.
- Examine expansion joints including exterior, interior, and flange faces for cuts and gauges. Inspect for damage during shipment–dents, broken hardware.
- Use only designated lifting lugs.
- Review anchors, supports, and alignment guides to assure they meet system requirements. Assure anchors and guides can withstand expansion joint pressure thrusts and spring action rates.

- **Mating flanges:** Install the expansion joint flange against the mating pipe flanges and install bolts so that the bolt head is against the expansion joint flange. Bolts should be installed from the bellows side (so that the bolt heads are adjacent to the bellows) to ensure that the bolts do not interfere with the bellows during periods of compression. Flange-to-flange dimensions of the expansion joint must match the required opening.
- Examine pipe flange faces for roughness and damage. Make sure mating flanges are clean and are matched to the type supplied with the expansion joint. Gaskets of appropriate material, size and temperature ratings must be used in all flange-to-flange type installations.
- Position pipe flange faces to ensure axes are aligned to within 1/8 inch without using excessive force.
- Carefully install the expansion joint to ensure no damage occurs and align bolt holes.
- Install joint with arrow pointing in the direction of flow.
- Support the expansion joint until bolted in place.
- Insert bolts with washers through retaining rings on the arched side of the expansion joint and then through the mating flanges in a cross pattern.
- Attach and tighten nuts (with washers) until it is hand tight.
- Torque each bolt to full torque with the cross-bolt pattern until the outside edge of the expansion joint flange bulges slightly.
- **Bolt torque:** Tighten bolts by alternating around the flange in stages. Never tighten an expansion joint to the point that there is metal-to-metal contact between the expansion joint flange and the mating flange.
- Corrugated expansion joints shall be installed with the length extended or compressed for the ambient temperature condition at erection, depending on anticipated direction and magnitude of movement after the line reaches the operating temperature.
- Make a final check to see that shipping ties have been removed.
- Remove all shipping devices after the installation is complete and before pressure test of the fully installed system.
- Remove any foreign material that may have become lodged between the convolutions.

Installation of gaskets: Various types gaskets are available from different manufacturers. Appropriate gaskets shall be installed based on the purpose and service conditions. Fitter shall not make their own choice. Fitter shall refer to the drawings or consult the supervisor for installing the right gaskets. Joint integrity and tightness depend on gasket installation workmanship. Unless otherwise specific instruction is available, the following installation instructions shall be followed during gasket installation.

- Examine the flange surfaces, fasteners (bolts or studs), nuts and washers to ensure they do not have any defects or damages.
- Ensure the gasket is of the correct size. The inner diameter of the gasket should not be smaller than the inner diameter of the flange.

Fig. 1.7.48 Checking flange faces

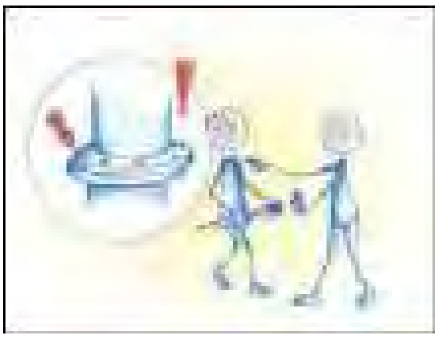


Fig. 1.7.49 Aligning bolt holes

Fig. 1.7.50 Installing gasket

- All types of gaskets should be handled with care. Carry gaskets carefully, ideally in some form of protective cover.
- Protect the surfaces and never bend or write on the gasket.
- Be sure to install the bolts that are designed for the flange are suitable for the given operating temperatures.
- Ensure that there is no corrosion on the bolts as this can affect the function of the bolt.
- Align the flange faces and bolt holes.
- Verify to ensure the gasket is of the specified size and material and ensure that it is free of defects.
- Carefully insert the gasket between the dry flanges.
- Make sure the gasket is centered between the flanges. This is extremely vital, especially, where raised faces are involved.
- Do not use joint compounds or release agents on the gasket or seating surfaces unless specified by the gasket manufacturer as this can lead to reduced surface friction.
- Bring the flanges together ensuring that the gasket is not pinched or damaged.
- Do not contaminate the gasket or the flange surfaces with lubricants.
- Gaskets shall never be reused, as it will not have enough resilience.

Bolt tightening sequence

- The pressure over the gasket shall be uniformly distributed in order to achieve satisfactory sealing. Always use the proper tools such as a calibrated torque wrench.
- Tighten all nuts, initially, by hand.
- Tighten two bolts diametrically opposite to each other to 30% of the required bolt stress.
- Tighten another pair of bolts approximately 90° further round the circumference. Continue until all bolts have been tightened to 30% of the required bolt stress.
- Torque each nut to approximately 60% of the required torque is same sequence is diametrically opposite sequence as the above step.
- Torque each nut to approximately 80% of the required torque is same sequence is diametrically opposite sequence as above.
- Torque each nut to full (100%) torque. Apply at least one final torque to all nuts in the clockwise direction until all torque is uniform.

Dismantling: After the completion of pressure testing, pressure should be reduced and released by opening the vents, till all draining is completed. After draining the piping system, the piping assembly should be dried by dry air and test blinds should be dismantled and the equipment is to be isolated.

Tips

Control valves and instrument should be dismantled. Prior to hydrotest and reinstated after hydrotest.

Check valves in lines 1.5 inch and below flapper or seat should be removed during pressure testing.

Pressure gauges which are part of the finished piping system should be removed.

Temporary protective covers should be retained on all open ends and flange faces until the piping is finally connected to avoid any foreign material.

Bolting should be protected by non-corrosive oil or grease to prevent rusting.

Safe handling of piping components and sub assemblies

1. There are many components that go into producing piping spools subassembly, and equipments. Many of them have critical machined surfaces such as flange faces.
2. Pipe and completed spools should be stored above the ground on wooden pallets.
3. Company / institute is responsible to protect all open ends of pipes and flanges with the use of suitable end caps.
4. Company / Institute should provide adequate and safe lifting slings or similar equipment during handling or lifting operations. When piping spools are lifted by their ends, soft faced hooks should be used.
5. All completed spools should be transported by a method which does not induce significant deformation or stress.
6. Pipe fitter should be familiar with the piping colour coding system.

Piping assembly installation and inspection

1. Pipe fitter may not perform all necessary checks for acceptance purpose. But, pipe fitter shall know all inspection and test requirements and ensure that the respective piping work has been completed as per AFC drawing, approved procedures and inspection and test plans. Pipe fitter shall check first before offering for QC or client inspection.
2. During pipe fit-up, welding, assembly / installation, all stage inspections shall be performed as per approved ITP and stage inspection reports shall be maintained.

Piping assembly / installation inspection include the following but are not limited to

a. Correct materials (quality, rating, size) have been used and installed.
b. Dimensional inspection that shall include length, size, thickness, position, orientation, level.
c. Ensure that all inline instruments / equipment have been installed and comply with AFC drawings.
d. During this check, flow direction is very important. All inline valves, instruments and equipment shall be checked for flow direction and ensure inlet and outlet connections have been made as per approved drawings.
e. Some piping works may require piping installation with slope. Hence, if applicable, pipe slope and direction of slope shall be checked and verified.
f. Ensure that all flanges have been bolted with required gaskets and bolts / studs and nuts. All bolts shall be tightened to the required torques.
g. Stud face shall be outside the nut face. Stud shall protrude at least two threads outside the nut face.
h. Ensure that adequate pipe supports have been installed as required by AFC drawing and specifications.
i. Visual inspection and all required NDT shall be completed and records maintained as required by approved ITP.
j. It shall be ensured that all weld repair works have been completed.
k. All required protective coating shall be completed.

Documentation: Documentation and records are used throughout the manufacturing process and as well as supporting process (quality control) they must meet the basic requirements.

The different types of documentation as per industrial needs include:

1. Material receiving inspection reports
2. Material release note
3. Piping spool fabrication reports (visual inspection report) and production reports
4. Stagewise Inspection Reports

Manufacturing stage inspection report

The format gives the details of the product being inspected showing the details.

Table - 3 Inspection report

Sl. No.	ISO Drawing No.	Weld Joint No.	Pipe Bevel			Pipe Fitup misalignment	Flange alignment	Visual Inspection	Remarks
			Bevel Angle	Root Face	Root Opening				
1.	DRG. No. ONGC / ML / 05 / 62	J1	35°	1.6	2.4 - 3.2	1 MM (max)	ACC	Fitup Accepted	

Return all tools and equipments to the store on completion of shop and field piping work and all subassemblies should be cleaned from the inside and outside by suitable methods ensuring that they are free from all loose foreign materials.

Carryout house keeping: Keep the workarea in a safe and tidy condition on completion of pipe fitting and installation activities.

Advantages of House keeping

1. Helps an Industrial organization to function efficiently. 2. Helps to prevent injuries and improve productivity.
3. Eliminates fire Hazards and controls dust.

Fig. 1.7.51 Good House keeping practice

1.7.11 Gasket Installation, Flange Bolting and Torquing

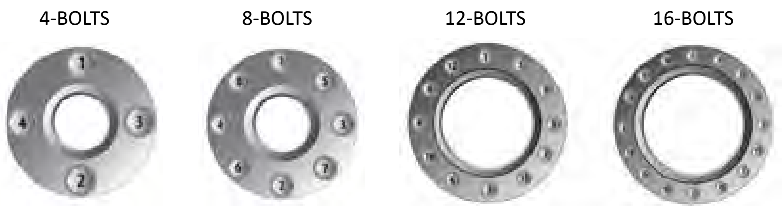
At the end of this exercise, you will be able to:

1. perform flanged piping spools assembling
2. install gaskets, bolt and nuts
3. perform flanged piping spools assembling and bolt tightening in sequence.

Practical

Requirement				
Tool/Instruments		**Materials / Components**		
Measuring Tape	– 1 No.	Pre fabricated flanged piping spools		
Try square	– 1 No.	Gaskets		– 1 No.
Spirit level	– 1 No.	**Equipment / Machines**		
Ball peen hammer	– 1 No.	Torque wrench	– (manual)	– 1 No.
Set of – open end spanners	– 1 No.	Torque wrench	– pheumatic	– 1 No.
Screw driver	– 1 No.	(With calibration certificate)		

- Clean the flange faces and ensure it is free from defects.
- Visually inspect all bolts and nuts for damaged threads.
- Lubricate the threads of the bolt and the surface of the nut.
- Align the flanges duly ensuring parallelity of the raised space. Use feeler gauges and ensure uniform gap is there.
- Ensure that all gaskets and bolting materials have been supplied as per AFC drawing.
- Install the new gasket and be sure that the gasket is properly centered. Do not reuse old gaskets.
- Adjust the position of the nuts to ensure that 2-3 threads are visible above the top of the nut.
- Tighten all nuts initially by hand.
- Tighten two bolts diametrically opposite each other to 30% of the required bolt stress.
- Tighten another pair of bolts approximately 90° further round the circumference. Continue untill all bolts have been tightened to 30% of the required bolt stress.
- Tighten another pair of bolts approximately 90° further round the circumference. Continue until all bolts have been tightened to 30% of the required bolt stress.
- Torque each nut to approximately 60% of the required torque is the same sequence is diametrically opposite sequence as is the above step.
- Torque each nut to approximately 80% of the required torque is the same sequence is diametrically opposite sequence as is the above step.
- Torque each nut to full (100%) torque. Apply at least one final torque to all nuts in the clockwise direction until all torque is uniform.



Tips

Safety

Use appropriate PPE.

Over torquing shall not be performed the it may damage the gasket.

Stud and nut shall not be shorter than the bolt space.

Exercise

I. Answer the following questions.

1. State the name of piping components that are not to be included during pressure testing.

   ----

2. Name the different methods used to protect bolting and flange faces from corrosion.

   ----

3. List the parameters to be checked by pipe fitter during and after fitup work.

   ----

4. Explain the piping assembly process in detail.

5. State the advantages of housekeeping.

II. State whether the following statements are True or False.

1. Piping spool end should be protected with suitable cap or cover.

   True ☐ False ☐

2. After completion of pressure testing, the piping assembly should be dried by dry air.

   True ☐ False ☐

3. Control valves and instruments should be dismantled prior to pressure testing.

   True ☐ False ☐

Notes

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=g191eS009Gg

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=y9Re2xPTM_8

2. Perform Pipe Laying and Joining Activity

HYC/N6110

Key Learning Outcomes

At the end of this module, you will able to:

1. practice safety ‘PPE”
2. read and interpret engineering drawing, work procedure and specifications
3. inspect, select suitable materials, tools and equipment
4. perform pipeline laying, fitup in construction site
5. explain different types of welding methods
6. describe petroleum products and their properties.

UNIT 2.1 Pipeline Layout for Petroleum Product Distribution

Unit Objectives

At the end of this unit, you will be able to:

1. read and interpret engineering drawing, procedure, specifications
2. select suitable jigs and fixtures, tools, equipment and accessories
3. inspect materials, tools, consumable, instruments and equipment
4. check cleaning of piping materials and identify the location for tack welding
5. verify that the assembled joints comply with the specifications and drawing.

2.1.1 Pipeline Laying Procedure in Oil and Gas Transmission System

At the end of this topic, you shall be able to:

1. identify pipeline route design and procedure approval
2. recognise in pipeline construction materials, procurement, manpower planning and equipment
3. state the regulations covering pipeline construction and pre-commissioning.

Pipeline route selection design documents reading and approval

The pipeline system is designed and installed in accordance with relevant sections of IS/BIS-15663- Part 1, 2, 3, 4 and international standards ASME B 31.4 ASME B 31.8 and ASME B 31.3 as applicable.

Pipeline construction materials and welding in accordance with API-5L-and API-1104. While selecting pipeline route, the following factors shall be considered:

1. Population and building densities
2. Topographical data, location of forest, rivers, including public roads
3. Records of any existing facility like buried pipeline and cables
4. Soil investigation
5. Environmental data

Pipeline procedure should include:

1. Safety and environment
2. Quality assurance
3. Survey
4. Right of way
5. Trenching, sand bedding
6. Stringing
7. Cold bending
8. Pipe fitup and welding
9. Testing and inspection including visual and NDT
10. Field joint coating /protection
11. Holiday testing
12. Lowering-in and tie-ins
13. Installation of valves inline instrumentation
14. Cathodic protection
15. Hydrostatic testing
16. Pre - commissioning
17. Preparation of built records and final documentation.

Safety and environment

During all stages of the pipeline fitup, alignment, dimensional check and welding, the pipe fitter should work to the highest achievable quality, safety, and environmental standards. The pipe fitter and team should ensure compliance with the relevant approved procedure with an awareness of potential hazards.

Pipeline routing

The pipeline routing philosophy is to minimise land acquisition, designate pipeline corridors and develop route for each pipeline. In planning pipeline route, access should be provided for construction and inspection, operation and maintenance.

Material procurement

Pipeline materials should be procured as per company procedure /instructor instruction.

1. The minimum radius for cold bend should be 20-Dia of the main pipeline or as specified in the drawing

- line pipes should be provided with a factory applied PE/PP/PPE coating
- each coated pipe should be left bare for a distance of 150 mm cut back from each end.

Carbon steel pipeline material grade

Table 3 API-5L Pipe Schedule Chart/Table							
Size & Pressure Rating	Service	Design Pressure	ISO 3183 Grade	API 5L Grade	ISO Wall Thickness (mm)	Corrosion Allowance included in WT (mm)	Remarks
3”-600#	Sour	9500 kPag	L290	X42	5.6	3	
3”-900#	Sour	13800 kPag	L360	X52	5.6	3	
4”-600#	Sour	9500 kPag	L360	X52	5.6	3	
4”-900#	Sour	13800 kPag	L360	X52	7.1	3	
6”-300#	Sour	4750 kPag	L290	X42	5.6	3	
6”-600#	Sour	9500 kPag	L360	X52	7.1	3	
6”-900#	Sour	13800 kPag	L290	X52	8.8	3	
6”-1500#	Sour	23800 kPag	L290	X52	10.0	0	
8”-300#	Sour	4750 kPag	L290	X52	5.6	3	

Pipeline materials handling and control

Materials handling includes but is not limited to Pipe handling and stacking.

Pipe Handling

Pipe and fittings, valves should not be allowed to drop or strike objects which may damage the pipe and the coated surface.

When lifting the pipe, non-abrasive wide “**nylon pipe slings”** or special lifting hooks should be used.

Temporary attachments for handling or lifting should not be welded to any pipe.

Trucks used to transport coated pipe / bare pipe should be free of any materials that might damage the pipe during transportation.

After loading, suitable non-metallic slings should be used to tie the pipes securely to the truck

Pipe ends should be protected with suitable end caps.

Fig. 2.1.1 Pipe Handling

Fig. 2.1.2 Pipe Stacking

Pipe handling includes receipt, Checking, Lifting, Loading, Transport, Unloading, Stacking, Storage.

Pipe stacking

Flat ground surface should be used for pipe stacking and movement should be prevented with berms of screened sand or non-metallic soft materials.

When stacked, the bottom layer of pipes should be wooden wedged.

Pipes of different diameters, wall thickness grades or manufacture should be stacked separately.

Epoxy coated pipe should be transported, stacked and stored using rubber separator strips.

Pipe should not be stacked higher than 3.5 metres.

Pipe should be stacked in such a way that water is not retained inside the pipe during storage.

Exercise

I. Answer the following questions.

1. What are the factors that are to be considered for selection of the pipeline route?

2. What are the procedures to be followed in pipeline construction?

3. Name the carbon steel pipeline materials used as per API 5L-Grade.

4. What are the steps to be followed in pipeline materials handling?

II. State whether the following statements are True or False.

1. Pipeline systems are designed and constructed in accordance with IS-15663 Part 1 and ASME B31.4.

   True ☐ False ☐

2. Pipeline routing should be followed as per approved drawing and specifications.

   True ☐ False ☐

3. The minimum radius of the cold bend should not be less than 20D of the main pipeline.

   True ☐ False ☐

4. Pipe ends should be protected with suitable end caps.

   True ☐ False ☐

Notes

2.1.2 Pipeline Construction Regulation

At the end of this topic, you shall be able to:

1. recognise pipeline construction that affect public
2. identify and list pipeline construction that affect drinking water sources and ecologically sensitive areas.

Pipeline pre-construction activities

Pre-construction activities need to be carried out by the pipeline design and installation company prior to the start of the pipeline construction activities. The activities include finalizing the pipeline route, detailed design finalization, setting up of geographic positioning station, populated area, agricultural area, drinking water sources, ecologically sensitive areas etc.

Safety risk assessment

A formal quantitative risk assessment should be carried out on all proposes of pipeline operations that could affect populated area, drinking water sources and ecologically sensitive areas. The assessment should ensure that the selected design factors, proximity distances to buildings, drinking water sources, etc., conform to safe design requirements.

Planning and approvals

The company should not commence pipeline work critical areas before obtaining approvals from the concern authorities and duly meeting all regulatory requirements and conditions of the permit issued by the authorities.

Below and above ground services

1. Existing pipeline, cables, tunnels are to be incorporated on the drawing and the contractor/company is fully responsible for protecting all existing facilities throughout the pipeline construction work.
2. River crossing **-** The minimum depth of cover at crossing of river and water sources, tarmac and graded roads are to be indicated on the drawing.

Livestock passageways

The livestock passageways should be constructed with a minimum of 1.5 m cover over the total pipeline length of 6.5 metre. Access barriers should be installed on the ends of the crossing to indicate safe crossing width of the livestock passageway for vehicles.

Overhead powerlines

The company should contact the local electricity authority to determine the minimum safe clearances allowed underneath overhead powerlines at each point where these cross the working strip or access roads. The company should provide goal posts at the agreed height on each side of the overhead lines.

Fig. 2.1.3 River crossing

Fig. 2.1.4 Overhead Powerlines

Road crossing

The pipeline should be installed with casings at road cross on all roads and highways without the installation of casings. The contractor company should install diversion road, when specifically permitted. Responsible authorities should provide adequate safe passage of vehicles.

2.1.5 Road Crossing

Procedure for constuction of pipeline

Preliminary planning/preparing work area is as follows:

1. Setting out
2. Ground investigation
3. Trench excavations.

The following steps are to be followed:

preparation of the area, land works, storage, temporary worker facilities.

providing drawings and procedure

preparation of detailed method statement of pipeline string yard setup, equipment storage requirements

preparation of specifications

preparation of welding procedures and plans

preparation of testing methods (NDT)

preparation of safety HSE plans (Health, Safety and Environment)

preparation of safe work procedure.

Route selection

The selection of the pipeline route should take full account of the associate risks, particularly safety and environmental risks.

Acquisition

Land acquisition is a necessity to lay down petroleum pipelines in the country, as per the procedure laid down under the Land Acquisition Act, 1962.

Soil boring - Testing

Soil testing is a geo-technical investigation for understanding the ground condition prior to undertaking works for pipeline construction. The investigation should provide information to the designers.

Pipeline design reading

The pipelines are to be designed taking into consideration the operating conditions and requirements over its entire life cycle, including final abandonment.

Fig. 2.1.6 Pipeline Route Image

Fig. 2.1.7 Soil Testing

Check for legal permit availability

Petroleum and Natural Gas Regulatory Board and (PNGRB), 2016 Survey of India - No Objection Certificate is to be obtained.

Work permit availability – PTW

PTW – permit to work system is a document which specifies the work to be done and necessary precautions to be taken. PTW form /record is an essential part of safe system of work for pipeline /piping construction activities.

Hot work permit is a work permit required for any work that develops spark, flames, or heat sufficient to cause ignition /fire/work at heights above 1.8 meter.

Cold work permit is a work permit used for work/activities that will not produce sufficient energy to ignite flammable atmosphere or materials.

Confined space entry permit is the most essential tool for assuring safety during entry in confined spaces with known hazards or without known or potentially hazardous atmosphere. Before each entry into a confined space, an entry permit will be completed by EHS/HSE department.

Exercise

I. Answer the following questions.

1. What are the pre-construction activities that are to be carried out prior to start of pipeline construction?

----

2. Name are the quantitative risk assessment that have to be carried out during risk assessment.

----

3. Name the type of pipeline crossing for route selection.

----

4. What are the stages of preliminary planning?

Notes

2.1.3 Pipeline Work Execution

At the end of this topic, you will be able to:

1. identify pipeline survey, right of way and trenching preparation
2. perform stringing, welding, coating and wrapping
3. perform pipe laying, testing, inspection
4. describe back filling and restoration of land.

Pipeline survey

The pipeline installation company will carry out pre-entry survey where required so as to record the condition of the land prior to the start of any work. The company should carry out the survey of the pipeline route and also prepare route maps to fix the centre line of the pipeline.

Right of way preparation (Row)

The right of way, in most cases, is laid near and parallel to the pipeline as access way / road and used to construct, maintain, operate, protect, inspect, and replace one or more pipelines.

Pipe stringing: Individual joints of pipe are strung along the right of way (row) adjacent to the excavated trench and arranged to be accessible to construction personnel.

Trenching: The trench should be excavated to provide a minimum depth of cover as specified in the drawings.

River crossing: River crossing pipeline should be installed to meet at all design requirments. Safety requirements and conditions should be followed as specified in the project specification and approved drawings. Rivers are prone to heavy erosion due to high velocity flow after heavy rains combined with the existence of large stones and boulders. River crossings, pipe may require continuous concrete protection.

Road crossing: The carbon steel pipeline may cross roads and highways. With or without the installation of casings, all road crossings should be made by open cut method when possible. The crossing shall be installed to meet the requirements and conditions set forth by the authority in the jurisdiction at all times. Contractor / company should provide sufficient and proper traffic aids such as warning signs and other safety requirements.

Microtunelling: At locations where open cut methods are impractical or not permitted for whatever reason, microtunelling trench–less techniques have to be implemented.

Horizontal Directional Drill (HDD) is a term used to define the method of installing a pipeline in long sections without land or road cutting.

Pipe fitup and alignment: The pipes ends should be cleaned thoroughly. Any coating, rust or other surface residues (contaminations) should be removed by power tools, wire brushes, or by grinding. The cleaning should be extended for at least 50 mm along the internal and external pipe surfaces from the edge of the bevel. The pipes should be fitup and aligned with the use of external or internal clamps as applicable. The maximum permissible misalignment between the surfaces of pipes of the same nominal diameter and thickness should be 1.6 mm (max/min value).

Welding: The welding of pipeline will commence after welding procedure qualification, welder qualification and pipe fitup are approved. The welding crew will weld pipeline of continuous lengths, between features such as roads, rivers, railways and other underground obstacles that prevent the pipeline from being continuously installed in the trench.

Testing and inspection

All welds on the pipeline are, generally, subjected to visual and radiography inspection. This is achieved on the main pipeline by an internal X-ray machine travelling along the length of the pipe carrying out X-rays at each weld for approximately 2 minutes exposure (may vary depending upon Pipe thickness.

Pipe joints coating and wrapping (Anti corrosion field – joint coating)

There are minimum requirements for the external /internal field joints coating of pipeline weld joints and repair of damaged coating. The type of field joint coating be applied shall be compatible with and have good adhesion to the mill applied/factory coating.

1. Fusion bonded epoxy (FBE) coated line pipe: The field joint coating to be used is fusion bonded epoxy coating only.
2. Polyethylene (PE) /polypropylene (PP) coated line pipe: The field joint coating should be coated with heat shrink sleeves.
3. Epoxy /polyurethane paints should be applied an the above ground pipelines to protect than against UV damage.

Pipe laying (lower and lay): The side booms will be positioned approximately 5 metres from the trench centreline and installed into the open unobstructed trench using a number of side booms.

As the pipe line is being lowered / installed, a coating crew will be present to conduct test to holiday detect damage/defect to the pipe coating prior to the pipe entering the trench. Any holiday damage detected will be repaired by a fast – setting repair coating.

Inspecting

Prior to the lowering and after lowering, every length of the coated pipe should be inspected visually and by spiral ring holiday detector and repaired.

Back filling

The trench should not be back filled untill inspected and accepted by the company inspector. The sand padding is around and above the pipe. Back filling should be performed as soon as possible after padding has been approved. The initial back fill should be placed in the trench to a level slightly above the surrounding ground. After initial back fill, the remaining excavated materials shall be neatly crowned over the trench. Except on river area on either side of road crossing, the windrow should be tapered from full height to the ground level to improve the visibility of drivers on the right of way.

Restoration of land (Reinstatement)

Company/contractor/employee should clean - up the working strip and all working areas used by the company, regularly and during the course of the work. The excess soil in the working strip should be levelled in a manner satisfactory to the company as per pipeline approved drawing.

Exercise

I. Answer the following questions.

1. List the sequence of oil and gas pipeline construction activities.

----

2. Define ROW.

----

3. Explain pipe stringing?

----

4. Explain pipeline trenching?

----

5. How many types of alignment clamps are used in pipe fitup?

----

6. What is the maximum permissible pipe fitup misalignment dimension / tolerance?

----

7. Which are the types of protective coating used in underground (UG) pipeline?

---

8. What type of coating materials are used in above ground UV exposed pipeline?

II. State whether the following statements are True or False.

1. The purpose of pipeline survey is to record the condition of the land.

   True ☐ False ☐

2. Right of way is used to construct and operate pipelines.

   True ☐ False ☐

3. If the river crossing area where heavy erosion is expected, portions continuous and concrete protection should be used.

   True ☐ False ☐

4. Pipe ends should be cleaned thoroughly at least 50 mm along internal and external pipe surfaces.

   True ☐ False ☐

5. Pipeline welds are generally inspected visual and radiography inspection methods.

   True ☐ False ☐

Notes

2.2 Oil and Gas Products

Unit Objectives

At the end of this unit, you will able to:

1. describe what refining is and how crude oil is converted into useful products
2. classify and specify different petroleum products and their propertied
3. define LNG.

2.2.1 Petroleum and Petroleum Refining

At the end of this topic, you will able to:

1. specify different petroleum products and their properties
2. define LNG.

Petroleum / Crude Oil

Hydrocarbon is a compound made of carbon and hydrogen. Petroleum is formed by hydrocarbons with the addition of certain substances, primarily sulphur. Petroleum in its natural form, when first collected, is usually called crude oil. Crude oil is a highly variable mixture of heavy and light hydrocarbons that need to be separated in a refinery to be converted into usable products.

Refining

Petroleum refining is the process of separating different parts of crude oil and converting the same into useful products such as gasoline or petrol, diesel oil, Liquid Petroleum Gas (LPG) kerosene oil, jet fuel, fuel oil, etc. Refining is a chemical engineering process performed in petroleum refineries.

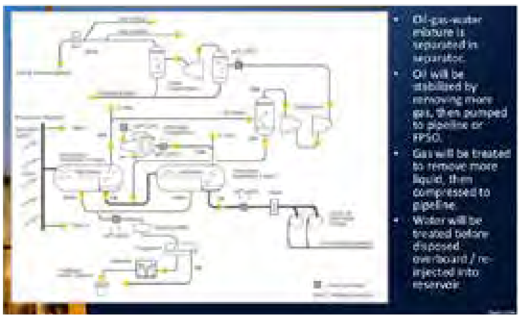
After crude oil is removed from the ground, it is sent to refineries for further processing. Crude oil is composed of hundreds of different hydrocarbon molecules, which are separated through the process of refining. One barrel of typical crude oil contains 42% Gasoline, 22% Diesel, 9% Jet Fuel, 5% Fuel Oil, 4% Liquefied Petroleum Gases, 18% other products. Petrochemical feedstocks, waxes, lubricating oils, and asphalt are also derived from crude oil.

1. Crude Oil Conversion Processes

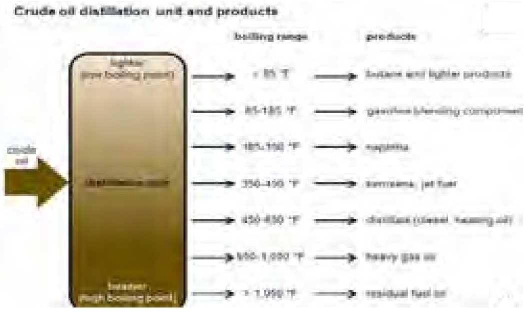
Separation

Separation begins with the process of distillation and then fractionation of crude oils into separate hydrocarbon groups. Modern separation involves passing crude oil through hot furnaces and towers. Most distillation products are further converted into more usable products by changing / modifying the size and structure of the hydrocarbon molecules through cracking, reforming, and other conversion processes.

In the first step, molecules are separated through atmospheric distillation (at normal atmospheric pressure), according to their molecular weight. During the process, known as topping (refining), the oil is heated at the bottom of a 60-meter distillation column, at approximate temperature of 350 to 400°C, causing it to vapourize. The vapours rise inside the column while the heaviest molecules, or residuals remain at the bottom without vaporuizing. As the vapours rise, the molecules condense into liquid at different temperatures in the column. Only the gases reach the top, where the temperature has dropped to 150°C. Crude oil is heated in a furnace so that hydrocarbons can be separated at their respective boiling points. Inside large towers, heated petroleum vapour is separated into fractions according to weight and boiling point. The lightest fractions, which include gasoline, rise to the top of the tower before they condense back to liquids. The heaviest fractions settle at the bottom because they condense early. The resulting liquid and vapour are discharged into distillation units. All refineries have atmospheric distillation units, while more complex refineries may have vacuum distillation units.



2.2.1 Typical oil and gas process facilities



2.2.2 illustration of crude oil products and their boiling range.

Inside the distillation units, the liquid and vapour separate into petroleum components called fractions according to their boiling points. Heavy fractions are at the bottom and light fractions are at the top. At successive higher points on the tower, various major products including naphtha, gasoline, kerosene, diesel and uncondensed gasses (which condense at lower temperature) are drawn off. The lightest fractions, including gasoline and liquefied refinery gases, vapourize and rise to the top of the distillation tower, where they condense back to liquid. Medium weight liquid, including kerosene and distillates, stay in the middle of the distillation tower. Heavier liquids, called gas oils, separate lower down in the distillation tower, while the heaviest fractions with the highest boiling points settle at the bottom of the tower.

2. Different Petroleum Products and their Properties

Gasoline

Gasoline is a refined as the most popular product, derived from petroleum. It Consists of a mixture of hydrocarbons, additives, blending agents duly constituting the largest fraction of product obtained per barrel of crude oil.

The typical composition of gasoline hydrocarbons (% volume) is as follows: 4-8% alkanes; 2-5%. alkenes; 25-40% isoalkanes; 3-7% cycloalkanes; l-4% cycloalkenes; and 20-50% total aromatics(0.5-2.5% benzene). The hydrocarbons in gasoline have a chain length of between 4 and 12 carbons.

Gasoline is mainly used as an engine fuel in vehicles. Internal combustion engines burn gasoline in a controlled process called "deflagration". Gasoline burns cleaner and meets air pollution control standards and requirements. Its boiling point is around 70˚C. In fact, the resistance to autoignition is the largest difference between gasoline and jet fuel as jet fuel is highly resistant to autoignition.

Octane levels are manipulated by the addition of a particular hydrocarbon called "octane". The higher the octane rating of the gasoline, the more the fuel can be compressed. Higher compression means higher temperature and pressure can be achieved inside the engine, which translates into higher power output/power.

Diesel

Diesel fuel consists of hydrocarbons of a chain length between 8 and 21 carbon atoms. It requires comparatively less refining than gasoline. Unlike gasoline engines, diesel engines do not rely upon electrically generated sparks to ignite the fuel. Its boiling point is around 200˚C.

Diesel is compressed to high degree along with air, creating high temperatures within the cylinder that lead to combustion. This process makes diesel engines highly efficient, achieving up to 40% better fuel economy than gasoline powered vehicles. Because of their similar distillation points, diesel and sulphur contaminants are removed from crude oil during refining. Diesel fuel is used as fuel in cars, power generation sets and irrigation pumps.

Fuel Oil/Furnace oil

Fuel oil is one of the "left-over" products of crude refining. It is in liquid form. It is used as industrial fuel. Because of its contaminants, fuel oil has a high flash point and is more prone to autoignition.

It also produces more pollutants when burned. Its boiling range is 700 to 1112˚F / (370 to 600 ˚C).

Jet Fuel

Jet fuel primarily being aviation gasoline is used in jet planes, requires specific characteristics. It must have a low flammability and must be able to be used in cold temperatures associated with high altitude without freezing. Its boiling point is around 120˚C. Jet fuel is based on kerosene, which is slightly heavier than gasoline. They are basically mixtures made up of kerosene and gasoline, special additives (1..2%), corrosion inhibitor, anti-icing, anti-fouling, and anti-static compounds.

Liquid Petroleum Gas (LPG)

LPG is a petroleum derivative mixture (gaseous at ambient temperature, but handled as liquids at their vapour pressure, 200..900 kPa), mainly constituted by propane, n-butane, isobutane, propylene, and butylenes. The composition varies widely from nearly 100% propane in cold countries to only 20–30% propane in hot countries. LPG is flammable mixture of hydrocarbon gases. LPG is heavier than air and liquefies under pressure. It is used as household cooking fuel in heating appliances / cooking equipment, and is also used as vehicle fuel.

Petroleum gas

It is in liquid form and is used for heating, cooking, making plastics. Its boiling point is around 20˚C.

Kerosene

Kerosene is a crude oil distillate similar to petro diesel but with a wider-fraction distillation. Kerosene is in liquid form, and is used as lamps illuminance and cooking fuel. It is used in industries as space heating fuel. It is also sometimes used as automotive and rail road diesel fuel.

Paraffin wax

Paraffin wax is a white or colourless soft solid, derived from petroleum, coal or oil shale. It consists of a mixture of hydrocarbons. It is solid at room temperature and begins to melt above 40 °C (99 °F) Its boiling point is >370 °C (698 °F) and its density is around 900 kg/m^3. It is insoluble in water, but soluble in ether, benzene and certain esters. Common applications for paraffin wax include lubrication, electrical insulation, and candles. Dyed paraffin wax can be made into crayons. Paraffin wax is an excellent electrical insulator, with a resistivity of between 1013 and 1017 Ohm metre.

Lubricating oil

Lubricating oil / motor oil consisting of grease and viscuous oil is in the liquid form. It is made from heavier, thicker petroleum hydrocarbon, derived from crude oil and added with some additives to improve certain properties. Its boiling point is around 300˚C. It is mainly used to lubricate moving parts in industry, automobile, rail engines and marine engines; used as motor oil, grease, lubricant.

Petroleum Naphtha

The generic name naphtha describes a range of different refinery intermediate products used in different applications. Naphtha is obtained in petroleum refineries as one of the intermediate products from the distillation of crude oil. It is a liquid intermediate between the light gases in the crude oil and the heavier liquid kerosene. Naphthas are volatile, flammable and have a specific gravity of about 0.7.

Naptha is used to make high additives, high octane petrol and to make polymeric plastics and urea, a nitrogenous fertilizer. Naphtha is used primarily as feedstock for producing high-octane gasoline component by the catalytic reforming process. It is also used in the petrochemical industry for producing olefins in steam crackers and in the chemical industry for solvent (cleaning) applications. Its boiling point is around 40˚C.

Liquefied Natural Gas (LNG)

LNG is a clear natural gas, colourless, non-corrosive and non-toxic in liquid forms, when natural gas is cooled to -162˚C (-260˚F) liquid state. The cooling process shrinks the volume of the gas 600 times smaller than its volume in the gaseous state, making it easier and safer to store and ship. In its liquid state, LNG will not ignite. It is flammable after vaporization into a gaseous state. The gas is then cooled down in stages until it is liquefied. LNG is, finally, stored in storage tanks and can be loaded and shipped. Key properties of LNG are:

Comprises mainly methane, colourless, cryogenic liquid, with an atmospheric boiling point of - 163°c to 160°c

1 m^3 of LNG at atmospheric pressure equals 600 m^3 of natural gas.

Exercise

I. Answer the following questions.

1. What are the petroleum products separated and converted from crude oil?

   ----

2. Explain the properties of gasoline.

   ----

3. Explain crude oil conversion process cracking.

   ----

4. Explain the ideal properties of lubricating oil.

   ----

5. Define LNG and explain the typical LNG processing system.

   ----

6. What are the key properties of LNG?

II. State whether the following statements are True or False.

1. Hydrocarbon is a compound made of water, carbon and hydrogen.

   True ☐ False ☐

2. In the refining process, separation begins with the process of distillation and then fractionation of crude oils into separate hydrocarbon groups.

   True ☐ False ☐

3. The higher the octane rating of the gasoline, the more the fuel can be compressed.

   True ☐ False ☐

4. Paraffin wax is an electrical insulator.

   True ☐ False ☐

5. LNG is a cryogenic liquid.

   True ☐ False ☐

6. LNG forms when natural gas is cooled at -162˚F.

   True ☐ False ☐

Notes

2.2.2 Pipeline Instruments Control and Gas Analysis Systems

At the end of this topic, you will able to:

1. define the principles of SCADA operation of typical pipeline instruments
2. explain the principles of operation of gas analysis systems.

Supervisory Control And Data Acquisition (SCADA) is a system of software and hardware elements that allow industrial organizations to :

- control industrial processes locally or at remote locations
- monitor, gather and process real-time data
- directly interact with devices such as sensors, valves, pumps, motors and more through human-machine interface software.
- record events into a log file.

The basic SCADA architecture begins with programmable logic controllers (PLCs) or remote terminal units (RTus). PLCs and RTus are microcomputers that communicate with an array of objects such as factory machines, sensors and end devices and then route the information from those objects to computers with SCADA software.

Pipeline Monitoring

An efficient oil and gas pipeline monitoring systems is based on wireless sensor networks. Wireless sensor networks are considered an effective technique to collect oil and gas transmission pipeline information.

- Pipeline monitoring systems are used:
- to evaluate corrosion and bacteriological control programs
- to collect samples without generating hazardous wastes
- to provide online analysis of chemical treatment programs
- to collect data that satisfies regulatory monitoring requirements and
- for pipeline risk evaluation and integrity monitoring.

Pipeline monitoring systems can be installed on new or existing lines both on and offshore. Permanent, portable, insulated and trailer mounted systems are available.

Gas Analysis

Gas analysis is used:

- to determine the composition of natural and industrial gases
- to control technological processes in the metallurgical, chemical, oil and gas industries and
- to detect toxic, highly inflammable or explosive gases in the atmosphere at production facilities.

Principle

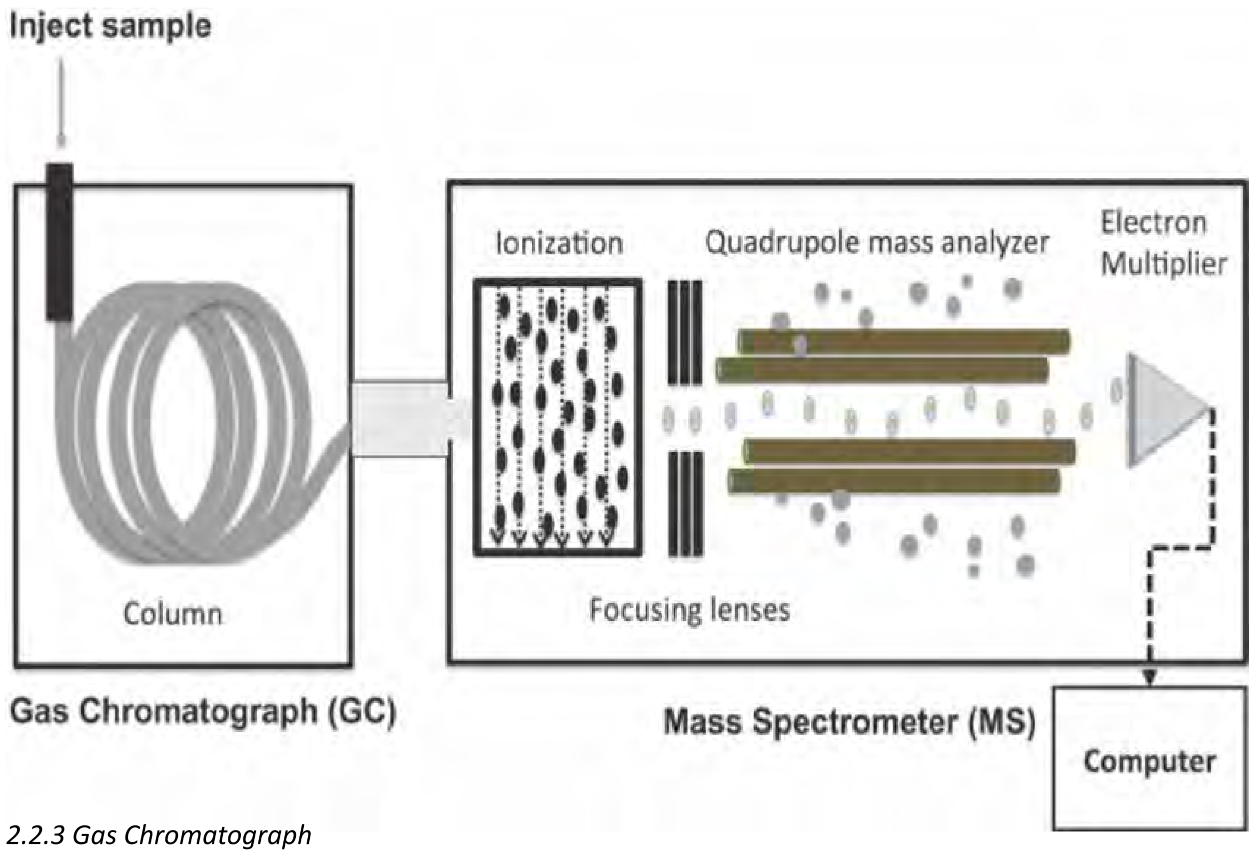
The chemical methods are based on the principle of the absorption of components of a gas mixture by various reagents. For example, carbon di-oxide is absorbed by an alkaline solution; oxygen, by an alkaline solution of pyrogallol; unsaturated hydrocarbons by bromide water.

Principle of moisture analyser

The moisture content determination is defined as the loss of mass that occurs as the material is heated. The sample weight is taken prior to heating and again after reaching a steady state of mass subsequent to drying.

Gas Chromatograph – Principle

The sample solution is injected into the instrument as a gas stream which transports the sample into a separation tube known as the 'Column' - (Helium or nitrogen is used as carrier gas). The various components are separated inside the column. Gas Chromatography is a technique used for the analysis and quantification of volatile compounds present in gas.



2.2.3 Gas Chromatograph

Density Meter

A density meter is a device that measures density. Many density meters can measure both the wet portion and the dry portion of a sample. The wet portion comprises the density from all liquids present in the sample. The dry solids comprise the density of the solids present in the sample. Density meters have many applications in various industries. Density meters are used to measure liquids that flow through the pipeline. Industries such as oil and gas have uses for density meters at various points during the processes.

Principle

Density meter is a process gas analyzer which exploits the principle that the resonant frequency of a thin-walled cylinder will vary according to the density of the gas that surrounds it.

Calorimeter

The Calorimeter is used to measure and control the calorific value of the sample gas. Calorie is a unit of energy or heat. The Calorie was originally defined as the amount of heat required at a pressure of 1 standard atmosphere to raise the temperature of 1 gram of water at 1° Celsius.

Exercise

I. Answer the following questions.

1. What are the instruments used to determine density?

----

2. How does a density meter work?

----

3. What is the purpose of calorimeter?

----

4. What is the principle of Gas - Chromatograph?

----

5. What is the use of gas analysis system?

----

6. What is SCADA?

----

7. What are the uses of pipeline monitoring systems?

----

8. What is the expansion of PLC and RTu?

----

9. What is the purpose of PLCs and RTus?

II. State whether the following statements are True or False.

1. Pipeline monitoring systems cannot be installed on new or existing lines.

   True ☐ False ☐

2. Density meter is a device that is used to measure gas density

   True ☐ False ☐

3. Calorimeter is a device used to measure the gas tempreture.

   True ☐ False ☐

Notes

2.3 Knowledge on Different Types of Joining in Piping and Pipeline

Unit Objectives

At the end of this unit, you will be able to:

1. identify and state various improper practices while working in a fabrication field
2. describe the importance of personnel protection
3. explain the important safety rules associated with all phases of welding
4. emphasize the safety standards requirements
5. explain the various regulations, acts and standards with respect to health, safety and environment.

2.3.1 Safety Hazards and Standards

At the end of this topic, you will be able to:

1. state various improper practices while working in the fabrication field
2. identify and list Indian and international safety standards.

General

Safety is an important consideration in all fabrication, cutting and related work. No activity is satisfactorily completed if someone is injured. Accidents cause pain to personnel, reduction in income, unnecessary expenses are incurred in treatment of injuries caused to personnel. The personnel are incapacitated when finally leads to loss of production. Hence, it is always wise to prevent such accidents.

Hazards

All workers engaged in production and construction are continually exposed to potential hazards. Accidents may result from falling, being hit by moving objects, working around moving machinery and exposure to hot metal. Normal precautions are required with regard to these hazards as well.

Tips

When working above ground make sure that scaffold, ladder or work surface is solid and properly secured.

Use a safety belt or lifeline when working in high places without railings.

Safety Standards

Safety standards are standards designed to ensure the safety of products, activities or processes, personnel, etc. They may be regulatory legislations, advisory or compulsory.

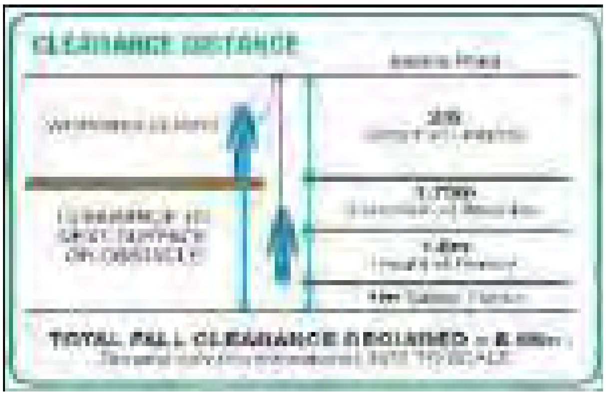


Fig 2.3.2. Wrong Anchoring / Clamping

Many safety standards and legislations exist to protect workers' rights, safety and health. Oil and gas pipe fitters need have knowledge, on applicable safety standards so as to implement, comply with and work safely without causing accident or any sort of damage.

Occupational accidents and diseases have an impact not only on the lives of individual workers, but also on the productivity and profitability of enterprises and, ultimately, on the welfare of society. Hence, safety standards are essential to ensure health and safety in oil and gas industry.

Salient Features and Provisions of Factories Act include

Special safety provisions relating to hazardous processes / operations, any process / operation or activity in relation to an industry, which can cause material impairment to the health of the persons engaged in or connected therewith, or result in the pollution of the general environment. Hence, it is essential to

ensure cleanliness of the workplace

make perform effective treatment and safe disposal of waste and effluent

suitable and effective provisions for adequate ventilation

provide sufficient and suitable illumination / light

make suitable arrangements to provide clean and easily accessible drinking water for all workers

Precautionary measures for working on machinery

maintain emergency devices for cutting power

maintain hoists and lifts.

Indian Standards on Safety

BIS has developed a number of standards on OSH for workplace safety beyond the legal requirements to develop and maintain safe and healthy work conditions. Here are some important Indian standards on safety and health:

a. General Standards

IS 18001-2000 – Safety Management

IS 5216 (Part 1) Recommendations on safety procedures

IS 8091-1976 – Code of safe practice for industrial plant layout

IS 5572-1994 – Hazardous Area Classification

IS 4014:1967 Code of practice for steel tubular scaffolding – 2 parts

b. Equipment and Operation Standards

IS 3016:1982 Code of practice for fire precautions in welding and cutting operations (first revision)

IS 6044 Code of practice for liquefied petroleum gas storage installations; Part 1: 1971 Commercial and industrial cylinder installations Part 2: 1972 Industrial, commercial and domestic bulk storage installations

IS1991:1987 Abrasive grinding wheels Safety requirements for the use, care and protection

IS 5903-1970 – Gas cylinders

IS 6044-2000 – LPG Storage and Installation

IS 2379-1990 – Pipelines colour codes

IS 1446-2002 – Hazardous Chemicals: Classification of Dangerous Goods

IS 4607:1968 Classification of hazardous chemicals and chemical products

IS 2190-1992 – Fire extinguishers

IS 2189-1999 – Fire detection and alarm system

Safety related International Standards and codes

NFPA 70E-2018 – NFPA 70E Standard for Electrical Safety in the Workplace, 2018 edition

BS EN 175:1997 – Personal protection. Equipment for eye and face protection during welding and allied processes (British Standard)

AWS C4.2/C4.2M:2017 Recommended Practices for Oxyfuel Gas Cutting Torch Operation

ANSI/ASSE A10.43-2016 – Confined Spaces in Construction and Demolition Operations

ANSI/ASSE A10.49-2015 – Control of Chemical Health Hazards in Construction and Demolition Operations

ANSI ASC A14.2-2017 – Ladders – Portable Metal – Safety Requirements

ANSI ASC A14.3-2008 (R2018) – Ladders – Fixed – Safety Requirements

ANSI/ASSE Z359 Fall Protection Code Package

BS OHSAS 18001 / ISO 9001 / ISO 14001 Occupational Health and Safety Requirements Package (Integrated management system)

ANSI Z49.1: 2012 – Safety in welding, cutting and allied processes

Exercise

I. Answer the following questions.

1. How should gas cylinders be stored when not in use?

   ----

2. What are the safety measures to be taken while working above the ground in high places?

   ----

3. List out any four safety standards related to welding works.

II. State whether the following statements are True or False.

1. Both oxygen and acetylene cylinders can be laid on the ground during use.

   True ☐ False ☐

2. A safe and healthy work environment is the basic right of every worker.

   True ☐ False ☐

3. Safety harnesses are uncomfortable and are not flexible to do what needs to be done on the job site.

   True ☐ False ☐

4. Factory act mandates to securely guarding all parts of dangerous machinery.

   True ☐ False ☐

Notes

2.3.2 Pipes and Classifications

At the end of this topic, you will be able to:

1. identify the material pipes are made of
2. classify and describe pipes.

Pipe

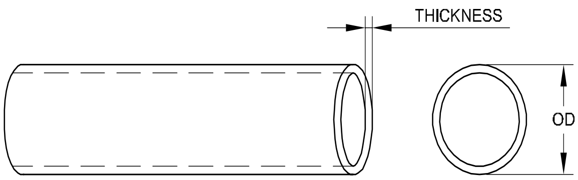
A pipe is a long, round, hollow object, usually made of metal or plastic, through which a liquid or gas can flow. They are available from small sizes to more than 60 inch diameter with a thin to thick wall thicknesses.

Types of Pipes

Pipes are manufactured as seamless, electric resistant welded and welded pipes.

Steel Pipe - Dimensions

Pipe sizes include inside and outside diameters, wall thickness, schedules and weight. Regardless of schedule number, pipes of a particular size have the same outside diameter. As the schedule number increases, the wall thickness increases. For example,



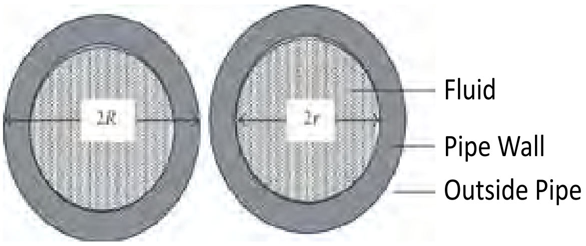


Fig. 2.3.3 Pipe

a 4 inches (100 mm) Schedule 40 pipe has an outside diameter of 4.500 inches (114.30 mm). and wall thickness of 0.237 inches (6.02 mm).

a 4 inches (100 mm) Schedule 80 pipe has an outside diameter of 4.500 inches (114.30 mm), and wall thickness of 0.337 inches (8.56 mm).

Tips

Standard steel pipe sizes are specified based on diameter and thickness (schedule). The schedule number on pipe products relates to the thickness of wall on the pipe.

Classification of Pipes

Pipes are classified in different ways based on the shape and the intended use. General classifications are:

a. Standard Pipe
b. Line Pipe: used for the transportation of oil, gas and water in cross country pipelines
c. Pressure Pipe: used to transmit fluids or gases at elevated temperatures or pressures or both
d. Structural Pipe: used for structural purpose

Tips

Oil country goods: Line Pipe is usually made of carbon steel or of low alloy, high - strength steel. Special pipe lines have been made of corrosion - resistant steels and stainless steels. Line pipe is made to API specifications.

Pipings and Pipelines

In the industrial world, the term piping is usually understood as a piping system comprising pipe with tubing, fittings such as tees, elbows, flanges and reducers, valves and headers.

The oil or gas extracted from wells is transported through pipelines. Pipeline is a system of pipes and other components used for the transportation of fluids between plants.

Guidance is provided by various codes and standards applicable to piping systems prepared by technical societies, trade associations and standardization bodies. The pipe and piping component materials conform to the following specifications:

- API Specifications
- ASME International Specifications
- ASTM International Specifications

Pipelines are usually built to the requirements of API Standard 1104, welding of pipelines and related facilities. It is also built with materials with chemical and mechanical properties that comply with one of the specifications.

Material Types

The material used for piping are: carbon steel, stainless steel, Cr-Mo alloy steels, cryogenic steels, Ni and its alloys, Cu and its alloys, Al and its alloys and Ti and its alloys.

Physical Characteristics

- Density
- Melting Point
- Thermal Conductivity
- Specific Heat
- Coefficient of thermal expansion
- Electrical conductivity

Identification of Metals

To produce a successful weld, it is necessary to know the composition of the metal being welded. If time permits, the best way to find the composition is, to take it to a laboratory for analysis. Since, the majority of the time that is not possible there are other methods to use which will give the fairly accurate identification of the metal. The following tests can be performed to help identify metals:

- appearance test
- dardness test
- magnetic test
- chisel test
- fracture test
- spark test.

Spark testing is a very popular and reliable test for the identification of different steels. It is quite accurate if the testing person is experienced. There are many different ways that metals are identified and specified. A material designation is the specific identification of each different metal by a number, letter or combination of the two. The chemical composition is by far the most widely used basis for metal designation. Mechanical properties are also occasionally employed.

Steel Pipe Specifications

In industrial applications, the material used to manufacture products is never selected by chance. During the design phase, engineers study the characteristics materials carefully and choose the material deliberately. Careful selection prevents subsequent complications when the product is put into use. It also helps to prevent incurring unnecessary costs. Only certified materials are to be used and all relevant certificates for supplied materials. are to be maintained.

For example: SA 106 Gr B, API 5L Grade, API 5L Grade X42, ASTM A 333 Grade 6, Duplex stainless steel 22% Cr. (Grade 2205).

Low- Carbon Steel Pipe

Common low carbon pipe steels are A 53, A 106, A 135, A 179, A 524, A 587 and API 5 L. It is favoured for its low cost and mechanical properties that make it suitable for many applications. While it is formable and durable, low carbon steel is resistant to mechanical stresses.

Carbon and carbon-manganese steels comprise the majority of offshore process piping.

High Strength Pipe

Higher strength steels can be used when it lets the use of a thinner wall pipe, which can reduce transportation costs and the amount of filler metal used to weld it. Higher strength also permits increasing operating pressure, which increases the pipe's carrying capacity. Hydrogen sulphide in gas or oil can be a source of corrosion cracking in the transport pipe. To guard against corrosion cracking, it is recommended that the pipeline operates at low stress levels. The wall thickness of soft pipe material such as X - 42 has to be increased to provide the suggested low stress level operations.

Corrosion Resistant Alloy (CRA) Pipe

Sour natural gas must be processed prior to its sale to remove the hydrogen sulphide that makes it sour, corrosive and, therefore, unusable. CRA clad, or lined, equipment and pipelines can be used in the construction of sour natural gas production and processing facilities when it is more economical to flow the contents of the well.

There is a distinct economic advantage in using ordinary carbon steel, protected from the effects of corrosion by a thin layer of CRA, to carry the loads. The raw natural gas is extremely corrosive due to the high Co_2 content which makes the selection of API 5L Grade 60 pipe internally clad with Type 316L stainless steel accessary. The 20 inch diameter seam welded pipe has a nominal 19 mm wall thickness of API 5L X 60 and an internal cladding of Type 316L stainless steel, 3 mm thick.

Stainless Steel Pipe

Stainless steel for cryogenic applications down to liquid helium temperatures are well established and play an important role in LNG ships and in piping systems and associated equipment. The standard grade of wrought stainless steel for general cryogenic applications is type 304L. Various additional grades have also been specified, including 304LN and 316LN. An important feature of the austenitic stainless steel is their very good weldability and corrosion resistance.

Offshore Piping

The use of austenitic stainless steel in process systems is limited to superaustenitic stainless steel for produced water systems. In piping applications, common applications for duplex stainless steel are gas and petroleum offshore platforms, where the pipelines are subjected to intense pressures and corrosive elements (salt water). Duplex stainless steel provides corrosion resistance and tensile strength. Duplex stainless steel fall into several categories, the most common of which involves UNS 31803 and UNS 32760. UNS 32550, UNS 32760 is made of 25% Cr duplex and super duplex stainless steel. UNS 31803 has 22% Cr duplex stainless steel. Use of materials such as duplex stainless steels and nickel alloys are prevalent on new or existing offshore installations. Nickel alloys are used for offshore process piping systems with UNS N 08825 and N 06625.

Exercise

I. Answer the following questions.

1. What is the expansion of CRA?

----

2. Describe duplex stainless steel.

----

3. Mention about stainless steel pipe designation.

----

4. Give examples on high strength pipe designation.

----

5. Write any three of steel pipe designation (specifications).

   ----

6. How are the pipe sizes (dimensions) specified?

   ----

7. What is a pipe? Give the examples of types of pipes.

   ----

8. What are the tests used in identification of material?

II. State whether the following statements are True or False.

1. In pipe dimensions, if the schedule number increases, the wall thickness decreases.

   True ☐ False ☐

2. Hydrogen sulphide, in gas or oil can be a source of corrosion cracking in the transport pipe.

   True ☐ False ☐

3. Pressure pipe is used to transport only oil and gas.

   True ☐ False ☐

4. Line pipe is usually made of carbon steel or low alloy steel.

   True ☐ False ☐

5. Spark testing is a very popular and reliable test for the identification of different metals.

   True ☐ False ☐

Notes

2.3.3 Pipe Joining Methods

At the end of this topic, you will be able to:

1. identify the types of pipe joining methods
2. describe the importance of pipe joints.

Joining Pipe Method

There are three main methods of joining pipes and attaching fittings to them – welded joints, Flanged joints, Threaded joints.

Pipe lines of 2 inch or larger are usually butt-welded, being the most economic, leak proof method. Smaller pipelines are, usually, joined by socket welding or screwing. Where large diameter piping is required to join up with flanged vessels, valves and other equipment, or where the line has to be opened for periodic cleaning, bolted flange joints are used instead of butt-welding.

Welded Joints – Piping

Butt welds

Butt welds can be used for all sizes, except for socket-welded joints.

Fillet welds

Fillet welds may be used to attach a reinforcing pad, saddle or structural attachments, slip-on flanges, small bore connections and socket-welding components. The fillet weld shall have fusion and melting of the edge and shall not reduce the throat thickness to below the specified amount of thickness.

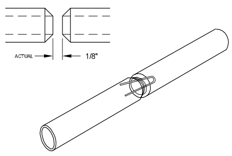


Fig. 2.3.4 Pipe to Pipe Fitup

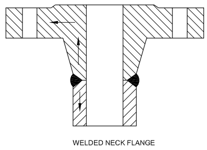


Fig. 2.3.5 Weld Neck Flange with Pipe Fitup

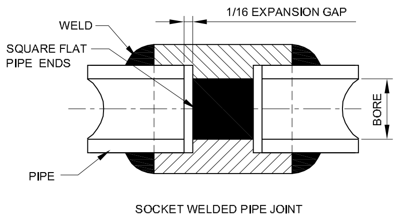


Fig. 2.3.6 Socket Welded Pipe Joint

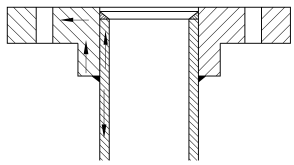


Fig. 2.3.7 Socket Welded Flange

Flanged joints

Flanged joints are used whenever the pipes, valves, vessels, fittings, etc., require to be connected together by bolting for ease of dismantling and reassembly. A flange and its bolting shall comply with a nominated standard.

Flange ratings

A flange shall be used within the pressure temperature rating specified in the drawing. For example: 150#, 300#, 600#, 900#, 1500# (# - class)

Where flanges of different ratings are bolted together, the rating of the flanged joint and the bolting torque shall be that of the lower rated flange.

Flange facings

Flange face shall be suitable for the intended service, the gasket and the bolting used. Flange facings may be flat face, raised face, 'O' ring grooved.

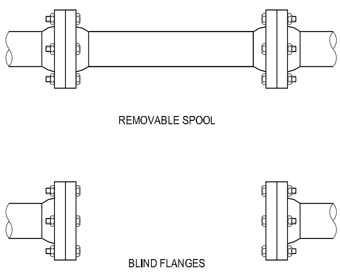


Fig. 2.3.8 Blind Flanges

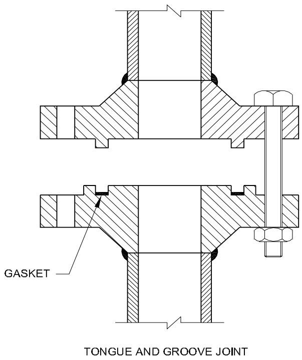


Fig. 2.3.9 Tongue and Groove Joint

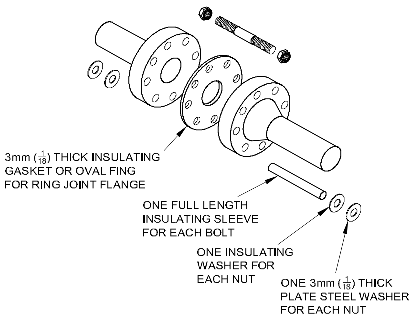


Fig. 2.3.10 Flanged joint

Gaskets

Gaskets are used to make a tight leak-proof seal between two joint surfaces. For pipe flanges, the common type of gaskets are the full face and ring types which are used for flat face and raised fare flanges respectively.

Spiral wound / A 316L / graphite filled gaskets should be used instead of spiral wound asbestos filled gaskets. Spiral wound gaskets shall not be used in sizes DN 1000 and larger.

Fig. 2.3.11 Gasket

For the installation of gaskets, the following shall apply:

A uniform distribution of the pressure over the gasket circumference shall be applied to achieve satisfactory sealing. To accomplish this, the bolts shall be tightened in the following sequence:

tighten all nuts by hand.

tighten two bolts diametrically opposite or diagonally opposite to each other to 50% of the required bolt stress.

tighten another pair of bolts approximately 90 degrees further round the circumference.

continue until all bolts have been tightened to 50% of the required bolt stress.

repeat steps 2, 3 and 4 to 80% of the required bolt stress.

epeat steps 2, 3 and 4 to 100% of the required bolt stress.

Gaskets used for the installation of orifice assemblies and between flanges located within the required straight length of pipe upstream and down stream of these assemblies shall not protrude into the free area of the pipe.

Tips

Gaskets shall never be re-used, since not enough resilience will be left in the gasket material to give a leak-proof joint when compressed for the second time.

Flange alignment

The flanges shall be lined up so that the bolts can be inserted without force. Nuts shall have a height equal to the bolt diameter. Hydraulic bolt tensioning provides more uniform bolt stress. It eliminates the variations due to different lubricants.

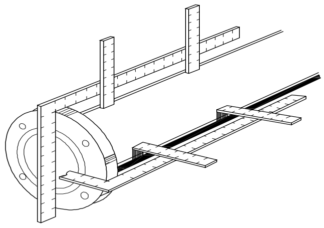


Fig. 2.3.12 Method of flange allignment

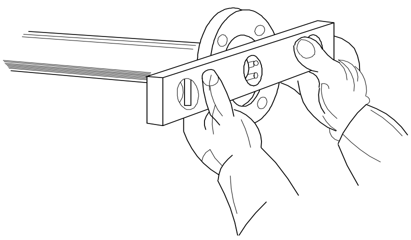


Fig. 2.3.13 Flange Alignment

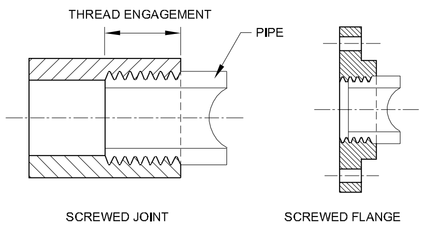


Fig. 2.3.14 Threaded Joints

Threaded joints

Threaded joints may be used for all fluid services. Threaded joints may be used only in galvanized piping (For example, fire water systems) DN 50 and smaller ones.

Threaded joints shall not be used in services where severe erosion, crevice corrosion, shock or fatigue are expected to occur and in process piping. Threaded instrument connections may be used in process piping in downstream of a piping valve. Sealing compound shall not be used when threaded joints are to be seal welded.

Exercise

I. Answer the following questions.

1) What are flange ratings?

----

2) Mention the steps to be followed while installation of gaskets.

----

3) Why should gaskets be never be re-used?

----

4) What are the main methods of pipe joining?

----

5) What are inflange facings?

----

6) Explain the method of pipe joining of welded joints.

II. State whether the following statements are True or False.

1. Hydraulic bolt tensioning provides more uniform bolt stress.

   True ☐ False ☐

2. Thread joints shall not be used in services like process piping.

   True ☐ False ☐

3. Smaller lines are usually joined by socket welding or threading.

   True ☐ False ☐

Notes

2.3.4 Welding Processes

At the end of this topic, you will be able to:

1. identify and state electric arc welding processes
2. state the applications of various welding processes.

Arc welding

The term arc welding applies to a large and diversified group of welding processes that use an electric arc as the source of heat to melt and join metals. The welding arc is struck between the workpiece and the tip of an electrode. The electrode will be either a consumable wire or rod or a non-consumable carbon or tungsten rod which carries the welding current. The electrode is manually or mechanically moved along the joint, or it remains stationary while the workpiece is moved. When a non-consumable electrode is used, filler metal can be supplied by a separate rod or wire, if needed. A consumable electrode, however, will be designed not only to conduct the current that sustains the arc, but also to melt and supply filler metal to the joint. It may also produce a slag covering to protect the hot weld metal from atmospheric conditions.

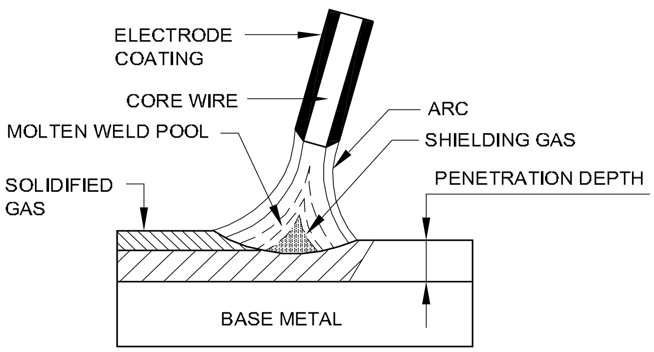


Fig. 2.3.15 Arc Welding

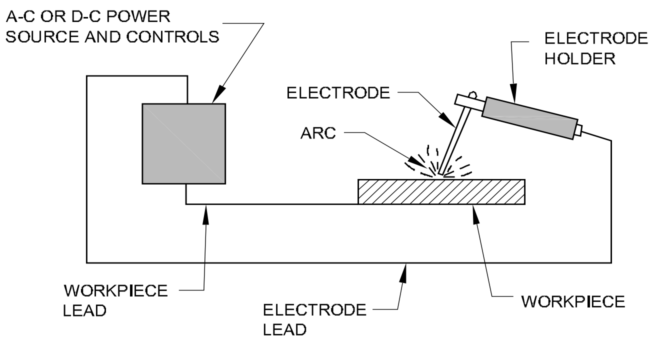


Fig. 2.3.16 SMAW

The most common welding processes are:

1. Shielded Metal Arc Welding (SMAW)
2. Gas Tungsten Arc Welding (GTAW)
3. Gas Metal Arc Welding (GMAW)
4. Flux Cored Arc Welding (FCAW)
5. Plasma Arc Welding (PAW)
6. Submerged Arc Welding (SAW)

There are approximately 50 distinct welding processes. The arc welding group of processes is the most popular, with 6 distinct arc welding processes and numerous variations. The standard practice in the fabrication field is to use these processes only.

Shielded Metal arc Welding (SMAW)

SMAW is an arc welding process with an arc between a covered electrode and the weld pool. SMAW is one of the oldest welding processes. It is also the simplest and perhaps the most versatile for welding ferrous base metals. More than 70% of the weld deposited, is by this process inspite of a large number of other sophisticated processes.

Gas Tungsten Arc Welding (GTAW)

GTAW is an arc welding process that uses an arc between a tungsten electrode (non-consumable) and the weld pool. The process is used with shielding gas and without the application of pressure. A commonly used gas is Argon (99.99%, vol.).

Filler metal may or may not be used. This process was developed in the late 1930s as heliarc or TIG welding. It was used to weld non-ferrous metals, particularly, stainless steel and aluminium and to join hard to weld metals. This process is also called as "TIG". TIG stands for tungsten inert gas welding. GTAW shall be used for all piping materials with a diameter equal to or less than DN 80. All GTAW machines are equipped with arc starting devices (high frequency, lift arc). Scratch starting shall not be used.

Gas Metal Arc Welding (GMAW)

GMAW is an arc welding process in which an electric arc is formed and maintained between a continuously fed consumable electrode wire and the workpiece. The arc and the weld pool are protected from atmospheric contamination by the shielding gas, supplied through the nozzle. GMAW process has been given many names, including MIG, MAG, CO_2 welding, depending on the type of shielding gas, the type of metal welded. The following gas mixtures are available: Argon CO_2 (85/15% vol. or 80/20% vol.)

These gases maintain a stable arc and give little spatter. The latter mixture is recommended when deeper penetration is required. CO_2 gas can be used. But procedure more weld spatter.

GMAW process can be used either in semi automatic machine welding or automatically. GMAW is welding for ferrous metals and aluminium has become popular.

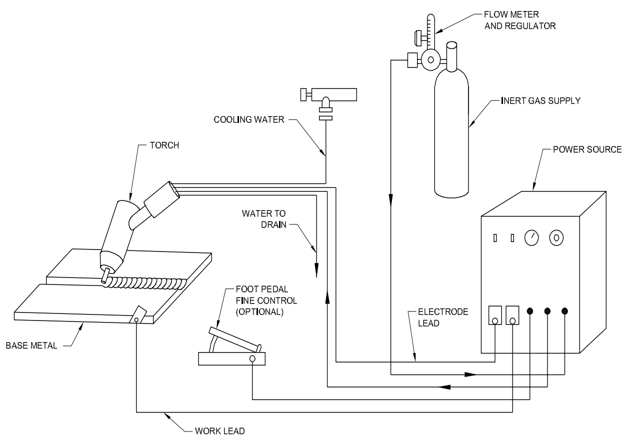


Fig. 2.3.17 GTAW

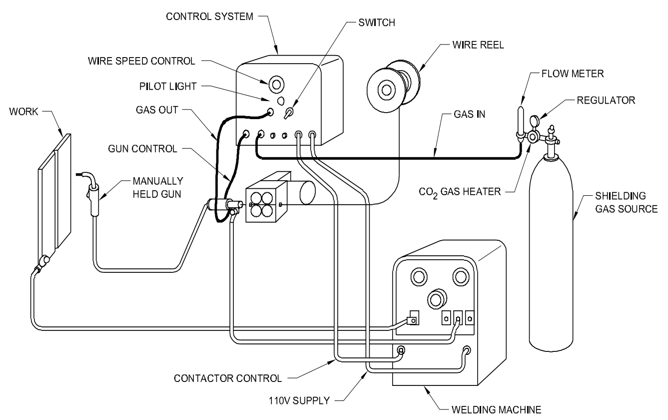


Fig. 2.3.18 GMAW

Flux Cored Arc Welding (FCAW)

FCAW is an arc welding process in which the heat for welding is produced by an arc established between the flux cored tubular consumable electrode wire and the workpiece.

FCAW is, normally, a semiautomatic process with combined characteristics of SMAW, GMAW and SAW processes. FCAW is almost identical to GMAW, except for the electrode filler wire which is a tubular wire filled inside the flux. During welding, an extensive slag cover is produced on the face of a weld bead. FCAW has found wide application in workshop fabrication pressure vessels / piping structural steel, storage tanks and field erection work.

Plasma Arc Welding (PAW)

The arc has very deep penetrating ability into the metals welded while the fusion takes place in a very narrow zone of the joint. PAW is similar to gas tungsten arc welding process except for the arc initiation.

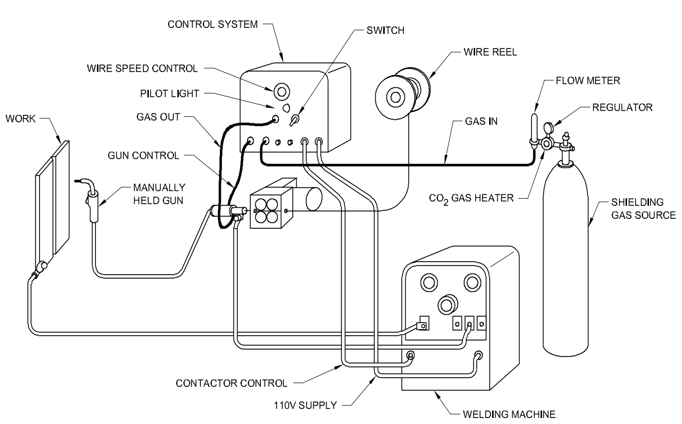


Fig. 2.3.19 Flux Cored Arc Welding

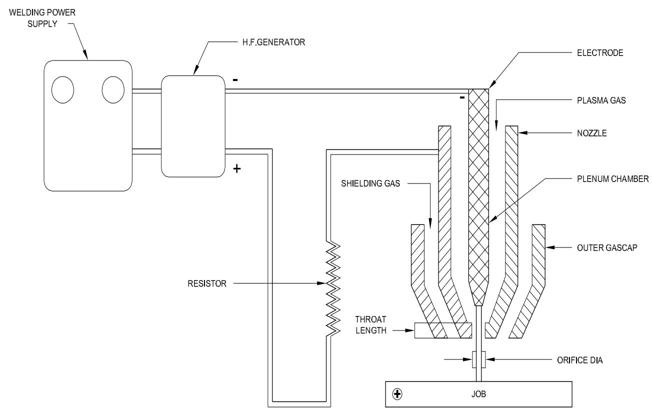


Fig. 2.3.20 Plasma Arc Welding

Submerged Arc Welding (SAW)

SAW also called 'Sub-arc' welding is an arc welding process where the welding arc is submerged under a granulated flux. The arc is initiated between the electrode wire and the weld joint under the medium of flux. The SAW process is used in both mechanized and semiautomatic operations, although the former is by far more common. Saw Welds can only be made in flat and horizontal positions. SAW shall not be used for repair welding of pipe lines. Welding fluxes shall be specified by manufacturer and type. Only fully mechanized SAW systems are to be used. SAW is widely recognized as a very productive welding process in the industry because of its inherent advantages:

a high deposition rate due to the use of high welding currents

deep penetration and a smooth bead

a high travel speed, high quality and reliability

no spatter, no fumes.

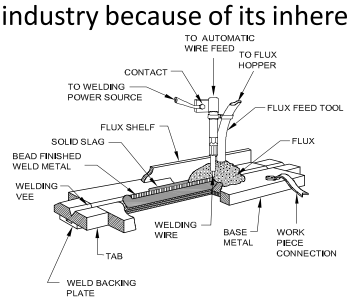


Fig. 2.3.21 SAW

8. Electron Beam Welding (EBW)

Electron beam welding is a process in which the heat required to produce fusion welds is obtained from the impact of a high velocity, high density stream of electrons on the workpiece. Upon impact, kinetic energy of the electrons is converted to thermal energy causing both vapourisation and melting. The vaporization of material immediately beneath the beam enables the beam to penetrate into or through the material to be welded, with the beam and vapour forming a hole. As the beam moves along the joint face, the molten material flows around the hole leaving the welded joint behind the beam.

EBW is an automatic welding process performed in vacuum without a shielding gas. Neither electrodes nor a filler rods are used.

9. Laser Beam Welding – (LBW)

'Laser' is an acronym for Light Amplification by Stimulated Emission of Radiation. Light is a source of energy which can be used for welding and cutting. But ordinary light is not useful since it is not 'coherent'. To get a coherent light (light waves in the same phase), different methods have been developed. As the concentration of energy or power density is quite high, it can weld very fast. Laser process can also be used for surfacing, cutting and scribing. The type of laser depends upon the lasing source. In the solid laser, some type of crystal such as ruby is used for lasing ability. LBW is most suited for thin job applications and, especially, for thermal sensitive jobs, which are difficult to weld by conventional arc welding processes. This is a method of welding in which the 'welding' heat is generated by sliding or rubbing together of two mating surfaces under pressure.

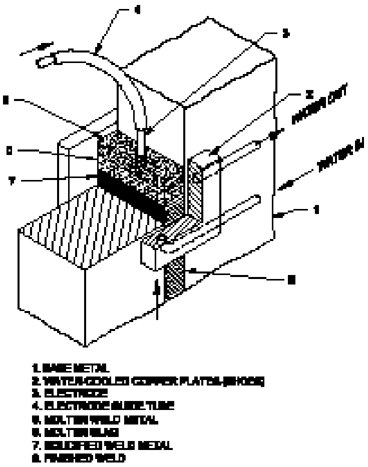


Fig. 2.3.22 Schematic of Electro-Slag Welding

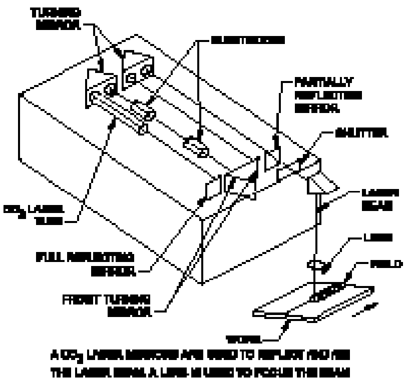


Fig. 2.3.23 Laser Beam Welding Process

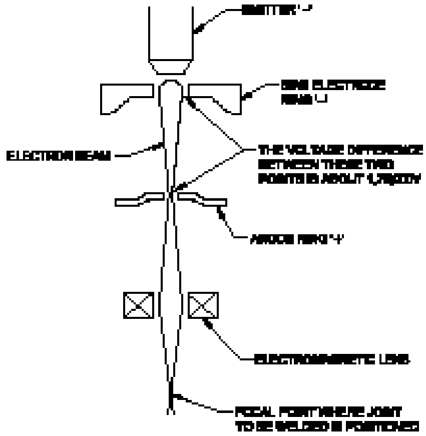


Fig. 2.3.24 Electron Beam Welding Process

Exercise

I. Answer the following questions.

1. What is the purpose of shielding gas?

----

2. List the most common arc welding processes.

----

3. Write a short note on GMAW process.

----

4. What are the advantages of submerged arc welding process?

----

5. Describe arc welding.

----

6. What are the arc starting devices that are used in gas tungsten arc welding process?

----

7. What is the expansion of LASER?

----

8. What is the classification of resistance welding process?

II. State whether the following statements are True or False.

1. Submerged arc welding can be made only in flat and horizontal positions.

   True ☐ False ☐

2. Plasma arc welding is similar to gas tungsten arc welding process except for the arc initiation.

   True ☐ False ☐

3. Flux cored arc welding is almost identical to gas metal arc welding except for the electrode filler wire.

   True ☐ False ☐

4. Thicker steel section can be welded in a single pass in the vertical position.

   True ☐ False ☐

5. EBW is performed in vacuum without sheiding gas.

   True ☐ False ☐

Notes

Weld Joint

At the end of this topic, you will be able to:

1. illustrate and name basic welding joints
2. explain the features of butt and fillet welds.

Importance of Joints

Pipes joined by welding offer major economics. Joint types and weld designs must be established. Loadings greatly influence the type of weld joint that should be employed, specifically, full-penetration welds. Fillet welds are the most widely used welds. Welds are made at the junction of all of the pieces that make up the weldment. Parts being joined to produce a weldment may be pipe, piping components or plate. The placement of these members creates the joints. All weld joints are either full or partial penetration joints. The strength of the weld joint depends on the size of the weld and the strength of the weld metal. The purpose of the weld joint is to transfer the loads and stresses between the members and throughout the weldment. The type of loading and service of the weldment have a great bearing on the joint design that should be selected.

At least three factors must be considered in designing a weld joint: strength requirements, the penetration requirements, and type of natural to be welded as dictated by loading and service.

Joint: A joint is “the junction of members or edges of members which are to be joined or have been joined”.

Types of Joints: There are only five basic types of joints**.** They can, however, be used in combinations.

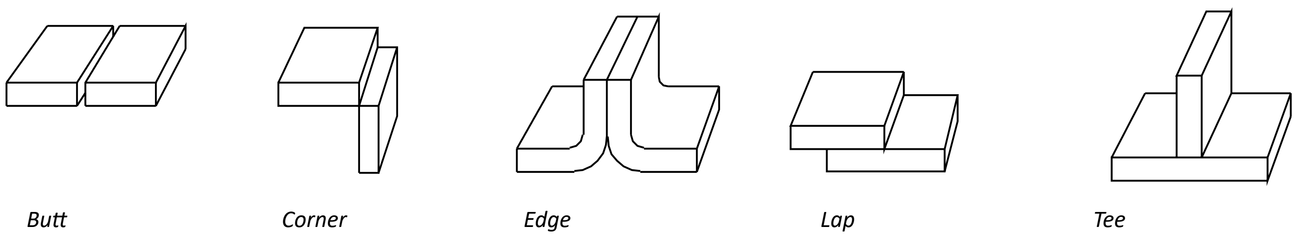


Fig. 2.3.26 Basic Type of Joints

1. The butt joint results when two members to be joined lie in the same plane and they are connected at their edges.
2. With a corner joint, the two members to be joined lie in perpendicular planes and their edges are connected.
3. The edge joint also has the two members lying in parallel planes.

4. In a lap joint, the two members lie in parallel planes, but not the same plane. The joint occurs where the two members overlap each other to form double thickness.
5. The T-Joint is similar in that the two members lie in perpendicular planes, except, now the edge of one member is joined to the planar surface of the other.

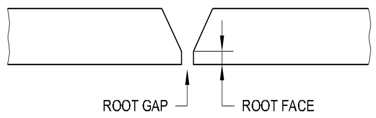


Fig. 2.3.27 Root Gap

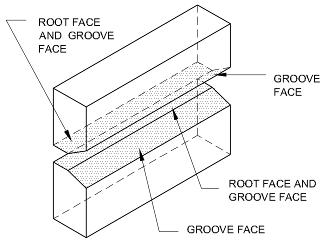


Fig. 2.3.28 Root Face

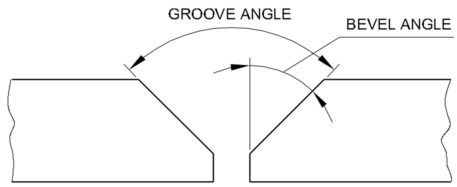


Fig. 2.3.29 Groove Angle

Root Gap

It is the separation between the members to be joined at the root of the joint.

Various features of a joint:

Some of these elements include root face, groove angle, bevel angle and groove face.

Root Face

Groove face adjacent to the root of the joint.

Groove Angle

The surface of a member is included in the groove.

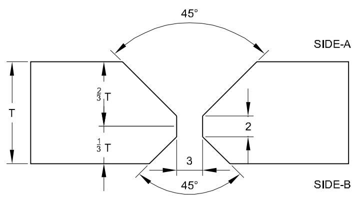


Fig. 2.3.30 Double 'V' butt Joint

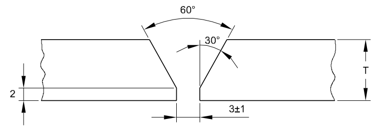


Fig. 2.3.31 Single 'V' butt Joint

Bevel Angle

It is the angle formed between the prepared edge of a member and a plane perpendicular to the surface of the member.

Groove Face

It is the total included angle of the groove between parts to be joined by a groove weld.

Types of Welds

There are numerous welds which can be applied to the various types of joints. Some of the basic types of welds include: square groove weld, bevel groove weld, V-groove weld, J-groove weld, U-groove weld, Fillet weld, spot weld.

All of these groove welds and fillet weld types can be applied to joints which are welded from a single side or on both sides. With this variety of groove weld geometries available, the pipe desinger can choose the one which best suits the need. This choice may be based on accessibility, type of welding process being used, method of joint preparation and adaptation to particular designs.

Exercise

I. Answer the following questions.

1. What are the five basic types of joints?

----

2. What are the types of welds?

----

3. Draw a simple sketch of a single -V- butt joint.

II. State whether the following statement is True or False.

1. Fillet welds are the most widely used welds.

True ☐ False ☐

Notes

2.3.6 Welding Procedure Specification

At the end of this topic, you will able to:

1. describe the procedure for welding
2. explain the importance of welding procedure specifications.

Introduction

Industries such as oil refineries, gas plants, chemical plants, power plants and those that operate cross-country pipelines, have created a great demand for pipe fitters and welders who are capable of producing high quality pipe welds consistently.

Importance of welding procedures

Only high quality pipe welds are acceptable in modern industry. The failure of a pipe weld can not only disrupt the operation of a plant, but can alone the cause of serious accident with the possible loss of life and property. For this reason, a pipe fitter must be a thoroughly qualified person in this craft. The pipe fitter (tack welder) will be tracked to do his job correctly with all the related information.

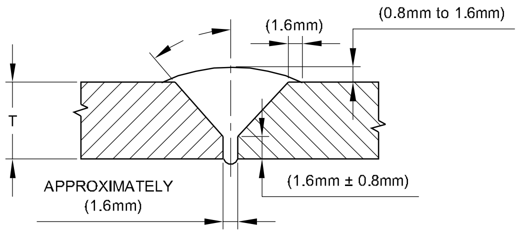
Welding procedures should be written whenever it is necessary to:

- comply with specifications and codes
- maintain dimensions by controlling distortion
- reduce residual or locked up stresses
- minimize detrimental metallurgical changes, etc.

Welding procedure specification (WPS)

The welding procedure specification is the primary tool used to communicate to the pipe fitter, welder, supervisor and inspector about how a specific weld is to be made. A WPS is a written welding procedure prepared to provide direction for making production welds to code requirements.

No welding shall be carried out until welding procedures, welders and tack welders (pipe fitter) are qualified according to the design code and approved by the client. Welding procedures shall be standardised and approved before performance qualification of welders.



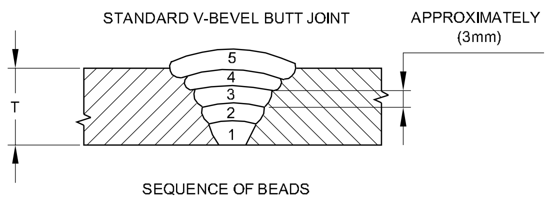


Fig. 2.3.32 joint design and sequence of weld beads in WPS format

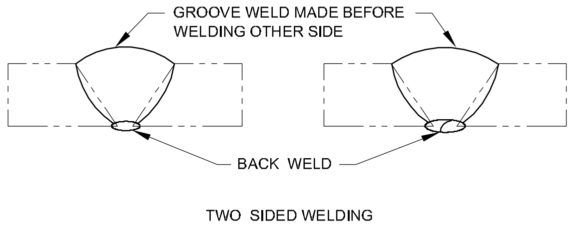
Basic steps

The basic steps in the qualification of a welding procedure is as follows:

1. Written preliminary welding procedure specifications are submitted by the contractor to the client for content approval.
2. Once the content of a written procedure has been approved, a weld is made in accordance with the requirements of that procedure.
3. The weld is inspected and tested and to satisfy the non destructive testing and mechanical requirements of the relevant specification.
4. If these tests meet the minimum requirements, the document becomes the procedure qualification record (PQR).
5. Prepare welding procedure specification from the approved PQR.

Tips

Tack welder and welder performance qualification testing shall be carried out in accordance with the design code, WPS and / or as specified by the client.



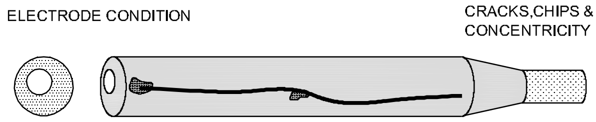


Fig. 2.3.34 Damaged Electrode

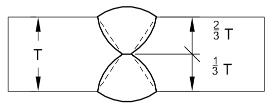


Fig. 2.3.33 Sequence of Beads

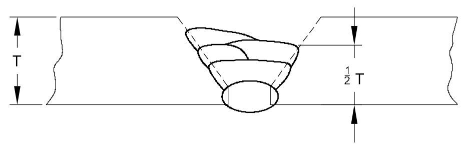


Fig. 2.3.35 Weld Interruption

Job Instructions Site survey by fire & safety officer

- No welder, tack welder pipe fitter is allowed to perform on the job, unless he is successfully qualified by passing the required tests.
- It is the manufacturer's responsibility to ensure that welding operations are carried out in accordance with the parameters as specified on the qualified welding procedure specification.
- WPS will be applicable equally for plate, pipe and tube joints.
- Two sided welding shall be carried out whenever possible / whenever allowed.
- All welding consumables shall have specified or actual mechanical properties equal to or greater than the material being welded, unless otherwise specified.
- A welder who is qualified with an E6010 is not necessarily permitted to use a low hydrogen electrode E7018. If he is qualified with a E7018, it is possible for him to use an E6010 if the job permits.
- Electrodes shall not be baked more than twice.
- Electrodes that show signs of damage or deterioration, for example, cracked or flaked coating, rusty or rusted / damaged core wire, shall be discarded.
- Irrespective of the base material, root runs shall be made without interruption other than for changing electrodes or to allow the welder to reposition himself. Welds shall not be allowed to cool until at least half the wall thickness has been welded.
- Scale and slag shall be removed from each bead and groove.

- When semi-automatic or machine welding is used, surface porosity clusters, bead starts and high points shall be removed by grinding before weld metal is deposited over them.
- Thorough inter-run cleaning and slag removal shall be carried out.
- No welding or hot work shall be carried out on post weld heat treated job.
- The contractor shall maintain the list of WPS, PQR, qualified welders tack welders, and the qualification records. The list and records shall be agreed by the client prior to production welding.

Instructions to be followed for any welding job:

- Collect safety equipment and tools such as safety glasses, helmet with correct lens shade, heavy duty gloves, wire brush, chipping hammer and pliers on welding table
- Clean the working table
- Collect materials for the job
- Set up welding power source
- switch the Power OFF and clean work area when the job is completed.

Welding procedure specification number ____________________________________

For _________________________________Welding of ______________________ Pipe and fittings

Process ____

Material ____

Pipe outside diameter and wall thickness ____

Joint design ____

Filler metal and number of beads ____

Electrical or flame characteristics ____

Position ____

Direction of welding ____

Number of welders ____

Time lapse between passes ____

Type and removal of line up clamp ____

Cleaning and / or grinding ____

Preheat /post weld heat treatment ____

Shielding gas and flow rate ____

Shielding flux ____

Speed of travel _________________________________ Plasma gas flow rate _____________________________

Plasma gas composition____

Plasma gas orifice size____

Sketches and tabulations attached____

Tested by ____

Welder____

Approved by ____

Weldingsupervisor____

Adopted____

Chief engineer____

Exercise

I. Answer the following questions.

1. What is the importance of welding procedures?

   ----

2. List out the instructions to be followed for any welding job.

   ----

3. What is welding procedure specification?

   ----

4. Give the expansion of the following:

   WPS, PQR

   ----

5. When is it permissible to interrupt the pipe joint weld once welding is started?

II. State whether the following statements are True or False.

1. The position of the welding is to be done as stated in the welding procedure.

   True ☐ False ☐

2. Coated electrodes shall not be baked more than twice.

   True ☐ False ☐

3. No welding or hot work shall be carried out on post weld heat treated job.

   True ☐ False ☐

Notes

2.3.7 Preparation of Pipe Joint

At the end of this topic, you will be able to:

1. select appropriate methods for the preparation of pipe
2. identify different tools and equipment used for preparation of pipe.

Introduction: The basis for the fabrication of piping will be as per the approved drawings, welding procedure specifications and other additional information. The type and grade of pipe, flanges, pipe fittings, branch connections and the extent to which welded joints are applied will be indicated on the drawings.

Prior to installation, all spools, shall be visually inspected for damage and cleaned of all foreign particles.

Contact between stainless steel parts and carbon steel parts shall be prevented in order to prevent oxidation and contamination. If there is any doubt, the stainless steel shall be chemically cleaned before any further work is carried out. Open ends of the pipe work shall be plugged, when not being worked on, to prevent ingress of foreign particles.

Preparation and Cutting

Cutting and bevelling of pipe may be done either by mechanical means or by flame or plasma cutting, when the following is taken into account:

a) For carbon steel, flame cuts shall be reasonably smooth and all oxides shall be removed from the surface by grinding to bright metal.

b) For low alloy steel, after flame cutting approximately 2 mm of material shall be removed from the cut surface by grinding.

c) For stainless steel, flame cutting shall not be used but plasma arc cutting may be used. The surface shall be cleaned or ground to bright metal after plasma cutting.

Non destructive test, including ultrasonic lamination checking and magnetic testing shall be carried out on all site (field) cuts and bevels if required.

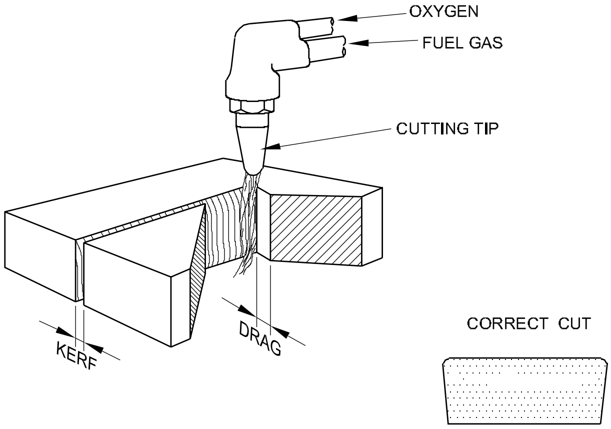


Fig. 2.3.36 Oxy-Fuel Gas Cutting

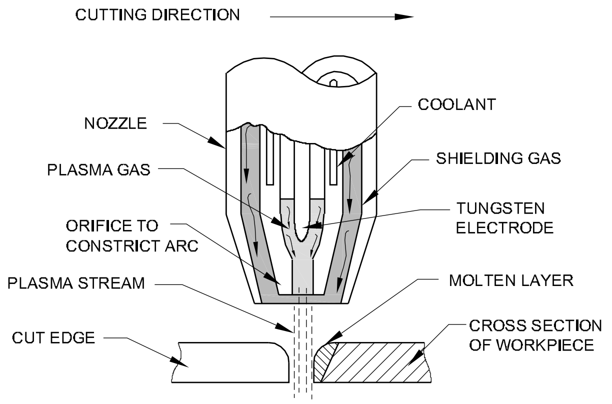
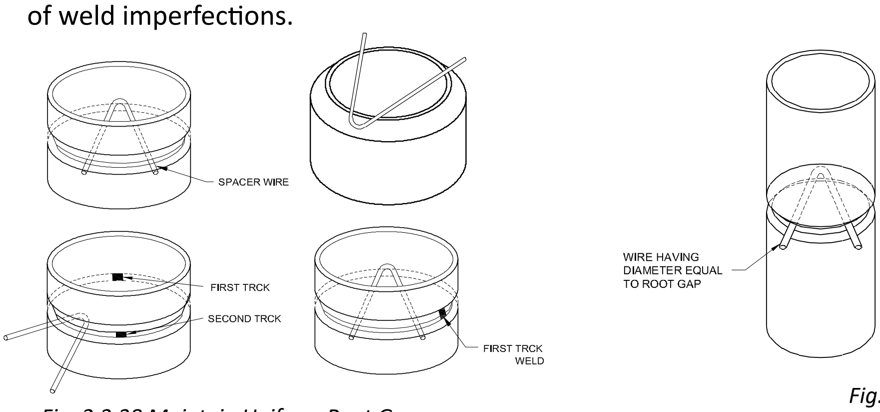


Fig. 2.3.37 Plasma Arc Cutting

Mitre joints shall not be permitted. Pipes for socket weld joints shall be cut square. Pipes for insertion into slip on flanges and socket welds shall be cut square and ground, if necessary. Cut edges which are to be incorporated into the weld shall be free from notches, sudden changes of shape, or imperfections which could be the cause of weld imperfections.



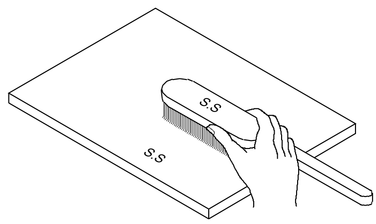


Fig. 2.3.39 Stainless Steel Wire Brush

Fig. 2.3.38 Maintain Uniform Root Gap

Assembly of piping components

All welded joint preparations shall be in accordance with the relevant details of the construction drawing and welding procedure specification. Prior to assembly, all weld preparations shall be free of rust, scale, moisture, grease and any other substance which could affect the integrity of the deposited weld metal. To achieve this, grinding or scratch brushing may be used. Stainless steel wire brushes are exclusively used for stainless steel fabrication.

For butt welding of all piping components (pipe ends, fittings and weld neck flanges) a uniform root gap shall be provided as specified in the relevant welding procedure specification. To maintain the specified alignment and gap during welding, the parts to be welded shall be securely held in position by mechanical means, for example, welded on bridge pieces, bars, jacks, clamps or tie rods or tack welding.

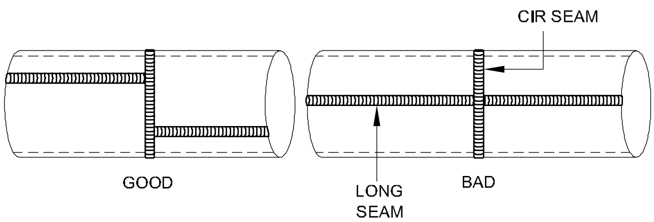
Where tack welds are used to maintain the specified alignment and gap on joints that require preheating, the preheat shall be applied and maintained.

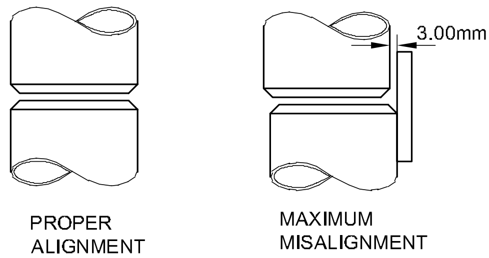
Pipe orientation

Seam orientation of welded pipe shall be selected to ensure that at the circumferential welds, the longitudinal welds are staggered over the top of the pipeline by a minimum angle of 90° or 250 mm, whichever is lesser.

The minimum allowable distance between girth welds shall be D (Diameter) or 500 mm whichever is larger. The alignment of abutting ends shall minimize the offset between surfaces. For pipe ends of the same specified thickness, the offset should not exceed 3 mm. Hammering to the pipe to obtain proper line up should be kept to a minimum.

A minimum distance between welds seams is often specified.





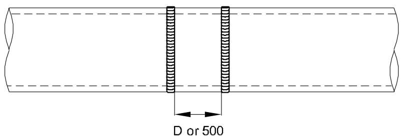


Fig. 2.3.40 A Weld Seam Orientation

Fig. 2.3.41 A Minimum Distance Between Welds Seams is often Specified

Line up clamps

Line up clamps are used to align the pipes and to hold them in place while welding. Line up clamps can be Internal line up clamp and external line up clamp.

Tack welds shall only be used where it would be impracticable to use an internal or external line up clamp.

Use of line up clamps

Line up clamps shall be used for butt welds in accordance with the welding procedure specification. When it is permissible to remove the line up clamp before the root bead is completed, the completed part of the bead shall be in approximately equal segments spaced approximately equally around the circumference of the joint.

Lineup clamps shall not damage the pipes and shall achieve the specified fit up. Non-welded fit up clamps shall be used for alignment of all pipe, pipeline and equipment work.

1. Internal line up clamp

An internal lineup clamp shall be used for all line circumferential welds except at tie-ins and other points where it would be impractical. In such instances, an external clamp shall be used. The use of internal line up clamps for all nominal pipe sizes of 6 inches and larger is mandatory. However, when an internal line up clamp is used and conditions make it difficult to prevent movement of the pipe or if the weld is unduly stressed, the root bead shall be completed before clamp tension is released. In other words, an internal line up clamp shall not be removed until the root bead is 100% complete.

2. External lineup clamp

Root bead segments used in connection with external clamps should be uniformly spaced around the circumference of the pipe and shall have an aggregate length of at least 50% of the pipe circumference before the clamp is removed.

In other words, an external line up clamp shall not be removed until the root bead is at least 50% complete and is equally distributed around the joint.

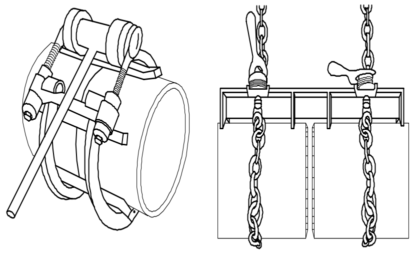


Fig. 2.3.42 External Pipe Clamp

Fig. 2.3.43 Internal Clamp

Weld fitup

Pipe ends should be field beveled by machine tool or machine oxygen cutting. Manual oxygen cutting may also be used. All surfaces to be welded shall be thoroughly cleaned to remove oxide, scale, oil or other foreign matter and be dry. The cleaned surface shall extend at least 25 mm beyond the substrate surface touched by the arc.

Tack welding shall be carried out by qualified welders in accordance with the same requirements and parameters as for the root pass of the base material. The minimum number of passes (root and hot) to be deposited before the pipe is lowered off shall be maintained. Temporary tack welds shall be removed by grinding or chipping and the area ground shall be smooth without reduction of wall thickness, followed by MT or PT inspection to confirm the absence of linear indications.

Clearance

When the pipe is welded above the ground, the working clearance around the pipe at the weld should not be less than 400 mm.

When the pipe is welded in a trench, the bell hole shall be large enough to provide the welder or welders(s) with ready access to the joint.

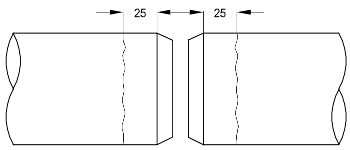


Fig. 2.3.44 Cleaning of Pipe Ends

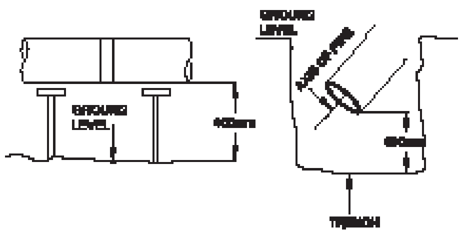


Fig. 2.3.46 Temporary Tack welds on plate pipe

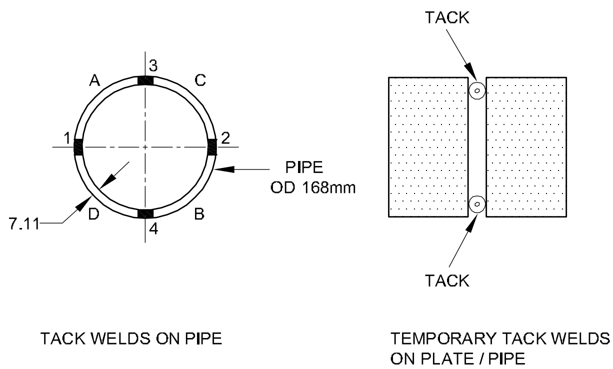


Fig. 2.3.45 Take Welds on Pipe

Exercise

I. Answer the following questions.

1) When is it permissible to remove an external line up clamp before the root bead is completed?

----

2) Why stainless steel parts are fabricated in separate or designated workshop areas?

----

3) Describe the methods of cutting and bevelling of steel pipes.

----

4) How are tack welds performed during the assembly of piping?

----

5) What are the uses of line up clamps?

----

6) What are the two types of line up clamps?

----

7) When is it permissible to remove an internal line up clamp before the root bead is completed?

----

9) What makes plasma arc cutting different from oxy fuel cutting?

II. State whether the following statements are True or False.

1. The working clearance around the pipe at the weld should not be less than 400 mm.

   True ☐ False ☐

2. For pipe ends of the same specified thickness, the offset should not exceed 1.6 mm.

   True ☐ False ☐

3. Stainless steel wire brushes are exclusively used for stainless steel fabrication.

   True ☐ False ☐

Notes

2.3.8 Welding Power Sources

At the end of this topic, you will be able to:

1. state the necessity of an arc welding machine
2. name the different types of an arc welding machines.

Necessity of the welding machine

The welding process requires enough electric current (measured in amperes) to produce melting of the work and the metal electrode and the proper voltage (measured in volts) to maintain the arc. Depending on their size and type, electrodes require 18 to 45 volts and approximately 50 to 500 amperes. The current can be alternating or direct, but it must be provided through a source that can be controlled to meet the many conditions encountered on the job.

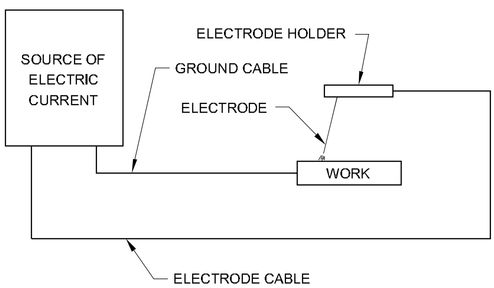


Fig. 2.3.48 Simple Welding Circuit

Fig. 2.3.49Pipeline Truck for field welding

The voltage supplied for industrial purposes is too high to use directly in arc welding. Therefore, the welding plant must convert the high voltage low current main supply, to the low voltage high current characteristics required for welding. Alternatively, the welding plant may provide an independent supply.

Welding machines are available in a wide variety of types and sizes to suit the demands of different welding processes, operations and types of work. The selection of a particular machine may also depend upon cost, portability and personal preference.

Selection of a Power Source

Selecting the power source is based on:

1. Process selection: It will generally determine the output characteristics of the power source required.
2. Welding current: Most arc welding processes use direct current. Some process use either direct or alternating current.
3. Machine rating: This helps to determine the size or capacity of the arc welding power sources.
4. Duty cycle: It measures the amount of work that the power source can do.
5. Availablity of Power: Location and whether electric power is available or gas or diesel power has to be used.
6. Auxiliary devices: Auxiliary devices and controls might be necessary for some work.

Classification

Welding power sources are also known as power supplies and welding machines. All machines may be classified by 1)Output slope, whether constant current or constant voltage and Power source type such as transformer, rectifier, inverter or generator.

Power sources for welding may be grouped under four main headings.

1. Transformers – for a.c welding
2. Rectifiers – for a.c /d.c. welding
3. Generators – for d.c. welding
4. Inverter – a modern type of power source, a.c/d.c

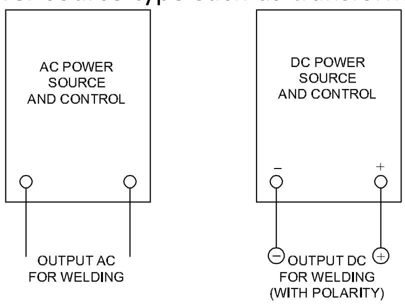


Fig. 2.3.50 AC and DC Welding

Pipeline Welding

It is necessary to find and change the best welding equipment, for appropriate welding process. The welding of the root pass is the most critical portion of a pipe weld. In many cases, the root pass is made with traditional SMAW or GTAW and the fill and cap passes are made with one of the wire-fed processes GMAW, FCAW-G, SAW.

The welding machines used for the wire-fed processes are different than the standard, constant current (CC) units. The power source would have to provide the CC output for SMAW/GTAW of the root, but would also need to provide a constant voltage (CV) output, as well as withstand the field environment on the pipeline.

The gas shielded flux cored process, FCAW-G secured is to present the best overall solution. It provided good deposition rates and it could be used with basic wire feed equipment.

FCAW-G process has considerable success on large diameter pipeline projects. Further, it is necessary to have a way to supply electrical power to the welding power source. This is accomplished by assembling a support tracktor. Generator on tractor is used for providing three-phase electrical power and an air compressor along with enclosures and boxes for the welding power source and all of the other various tools needed at the welding location.

Engine drives generate direct current for constant current or constant voltage applications. Most engine drives have an automatic feature to conserve fuel for field work. This makes arc starting difficult on some machines, because the engine delivers only about 50 volts of open circuit voltage for arc initiation.

Transformers and rectifiers can provide alternating current or direct current. Direct current is preferred for most welding application.

Inverters are the most versatile power sources because they can output constant current and constant voltage. Inverters use solid state components used to boost incoming 60 Hertz power to very high frequency current in the range of 18 to 100 kilohertz. An inverter based machine is a portable one which is small, of light weight and is often used for field welding. A plasma cutting power source is also mounted on the tractor.

While it is typical that electrical grinders are used on pipe lines, it is determined that air-powered grinders are faster and tougher on the job.

Duty Cycle

Power sources are rated by duty cycle. Duty cycle is the percentage of time the machine can operate at rated output during a 10 minute period. Welding grounds shall be connected directly to the work as close as possible to the working area and in such a manner as to provide the best welding circuit possible.

Exercise

I. Answer the following questions.

1. What is duty cycle?

----

2. Is the SMAW power source constant current or constant voltage?

----

3. What makes inverters versatile?

----

4. Name the four basic types of arc welding machines.

----

5. What does 60% duty cycle mean?

----

6. How is the output of an arc welding machine indicated ?

----

7. What are the factors to be considered while selecting the power source?

II. State whether the following statements are True or False.

1. Alternating current (A.C) is preferred for most welding applications.

   True ☐ False ☐

2. There is no difference between open circuit voltage (OCV) and arc voltage.

   True ☐ False ☐

Notes

2.3.9 Shielded Metal Arc Welding

At the end of this topic, you will be able to:

1. identify state the fundamentals of shielded metal arc welding
2. identify entry level skills in SMAW (MMAW)
3. describe the SMAW process equipment and applications.

Introduction

Shielded metal arc welding (SMAW) is also known as manual metal arc welding (MMAW) and stick electrode welding. Shielded metal arc welding (SMAW) process uses an electrical circuit that supports a welding arc to convert electric line power or fuel into heat. The heat from the welding arc is intense, extremely concentrated, and immediately melts a portion of the workpiece and the end of the electrode. The welder maintains the arc length by holding a consistent space between the electrode and the weld pool that forms on the workpiece. As the arc is removed, the liquid fuses and the metal solidifies into continuous metal.

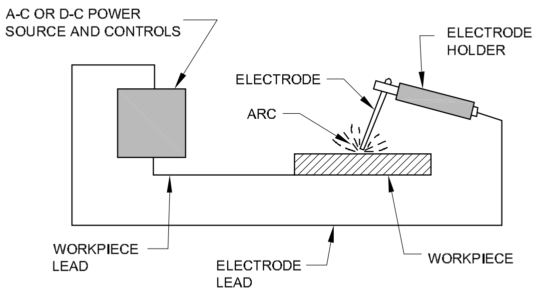


Fig. 2.3.51 Elements of a typical welding circuit for shield metal arc welding

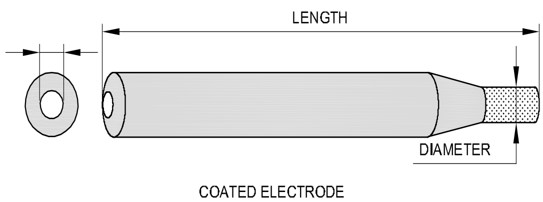


Fig. 2.3.52 Electrode

Figure, 2.3.51 shows the power source connected into a circuit with the electrode and workpiece in series. The welding cable used in the circuit, the electrode holder, and the connection between the cable and the workpiece are also important elements of the circuit. The power source has two distinct output terminals. From one terminal, a connection is made to the workpiece and from the other, a connection is made to the electrode.

Metals welded

The SMAW process is used in joining and surfacing applications on a variety of base metals. Electrodes are also available for the application of wear impact or corrosion resistant surfaces on the same base metals.

Welding procedure

A suitable electrode diameter is chosen depending on the thickness of the material to be welded, type of joint, position of welding, groove design and, finally, the experience of the welder.

A suitable power supply is chosen. Depending on the electrode, the amperage to be used is selected and set on the equipment. During welding, the welder maintains a normal arc length by uniformly moving the electrode toward the work as the electrode melts. At the same time, the electrode is moved uniformly along the joint in the direction of welding to form the bead. After welding, the slag should be completely removed before the next layer is deposited. Proper grounding is required to avoid arc blows.

Weld quality

Discontinuities are, sometimes, encountered in welds made by SMAW process that include porosity, slag inclusions, incomplete fusion, incomplete penetration, undercut, cracking, etc.

Process advantages

1. The equipment is relatively simple, inexpensive and portable.
2. The process is less sensitive to wind and draft than the gas shielded arc welding processes.
3. The process is suitable for most of the commonly used metals and alloys.

4. The process is flexible and can be applied to a variety of joint configurations and welding positions.

Process limitations

1. Metals with low melting temperatures such as lead, tin, zinc and their alloys are not welded with SMAW.
2. The SMAW process yields lower deposition rates than the gas metal arc and flux cored arc welding processes because the maximum used current is limited.
3. Another drawback is stub loss. The stub is the grip end of the electrode that is discarded. Longer stub losses translate directly into lower deposition efficiency.
4. The operator factor (arc time as a percentage of the welder's total labour time) for SMAW is usually lower than that for a continuous electrode process.
5. The weld cost is relatively high.

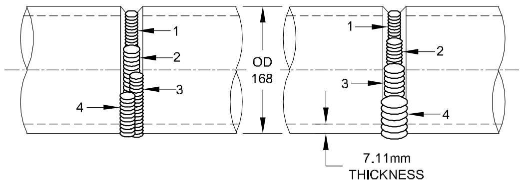


Fig. 2.3.55 Pipe Weld bead Sequence

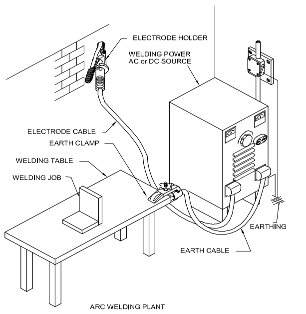


Fig. 2.3.53 Welding Power Sources (Machine)

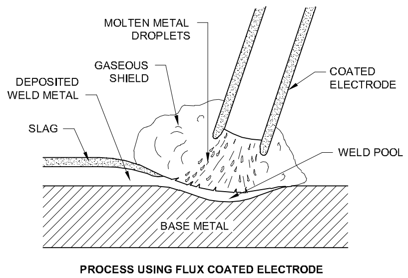


Fig. 2.3.54 Process Using Flux Coated Electrode

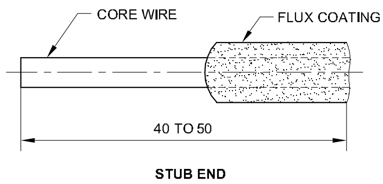


Fig. 2.3.55 Stub End

Exercise

I. Answer the following questions.

1. In what direction does the current flow in the SMAW (MMAW)?

----

3. List any three advantages of SMAW.

----

4. What is the device used to hold the electrode?

----

5. What is the function of a electrode in SMAW?

----

6. What is the length of the electrode stub end?

----

7. What is arc length?

II. State whether the following statements are True or False.

1) Manual metal arc welding is also known as shielded metal arc welding.

True ☐ False ☐

2) The SMAW process yields higher deposition rates than the gas metal arc and flux cored arc welding processes.

True ☐ False ☐

Notes

2.3.10 Electrode Classification

At the end of this topic, you be will able to:

1. explain the necessity of coding electrodes
2. describe the electrode coding as per AWS.

Introduction

The primary element of the shielded metal arc welding (SMAW) process is the electrode itself. It is made of a solid metal core wire covered with a layer of granular flux held in place by a bonding agent. Since the electrode is an important feature of the process, it is necessary to understand how various types are classified and identified.

AWS specifications

American Welding Society (AWS) specifications A5.1 to A 5-34 describe the requirements for various electrodes, filler wires, flux, gas. They describe the various classifications and characteristics of these electrodes.

Most of the industrial countries issue filler metal specifications. In the United States, the AWS provides filler metal specifications. They are approved by ANSI (American National Standards Institute) and have become an American national standard.

The American Society of Mechanical Engineers (ASME) in its "Boiler and pressure vessel code" issues filler metal specifications that are identical to AWS specifications. ASME adds the prefix letters SF to the specification number.

ASW A 5.1/ASME SFA 5.1

Many countries use specifications of the industrialized countries (American, European, Canada) All welding consumables (filler metals and fluxes) shall conform to one of the following specifications:

AWS

A 5.1, A 5.20, A 5.2, A 5.23, A 5.5, A 5.28, A 5.17, A 5.29, A 5.18

Consumable that do not conform to the specification above may be used provided the welding procedure specifications involving their use are qualified and approved.

AWS Codification (Classification)

The American Welding Society has a classification system to identify SMAW electrodes for mild steel, low alloy steel, stainless steel and cast iron. AWS classifications for filler metals provide valuable information to welders about their usability. It includes what the materials are best suited for and how to use them maximizes performance. They also offer insight into the mechanical properties that a given filler metal will provide.

A simple numbering system is used for electrode classification. The welding electrodes are classified according to: type of current, type of covering, and welding position, mechanical properties of the weld metal in the welded condition.

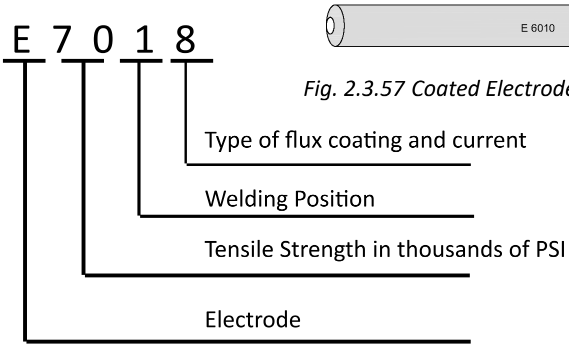


Fig. 2.3.57 Coated Electrode

Fig. 2.3.56 SMAW Electrode codification system

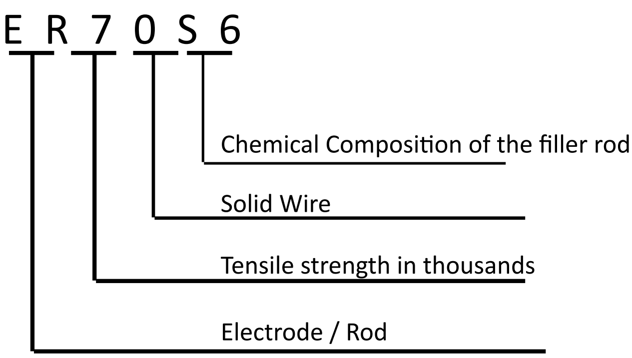


Fig. 2.3.57 GMAW filler wire

The AWS classification such as E 6010, E 7018 is printed on the flux coating near the end of the electrode. It indicates that the electrode manufacturer has qualified the electrode to the AWS specification for mechanical and chemical properties. The identification consists of an ‘E’, which stands for electrode, followed by four or five digits.

The first two or three digits refer to the minimum tensile strength of the deposited weld metal. These numbers state the tensile strength in thousands of pounds per square inch. For example, ‘70’ means that the tensile strength of the deposited weld metal in at least 70,000 psi. The next digit refers to the positions in which the electrode can be used. A ‘1’ denotes that the electrode is suitable for use in any (all) positions. A ‘2’ means that the electrode can be used only in the flat or horizontal fillet positions. The last digit describes the usability of the electrode by the type of flux coating and recommended current conditions (AC, DCEP or DCEN). The electrodes ending in ‘8’ are classified as low hydrogen types and are used in AC or DCEP. The electrodes ending in ‘O (Zero)’ are classified as cellulose coating, deep penetration used in DCEP (E6010).

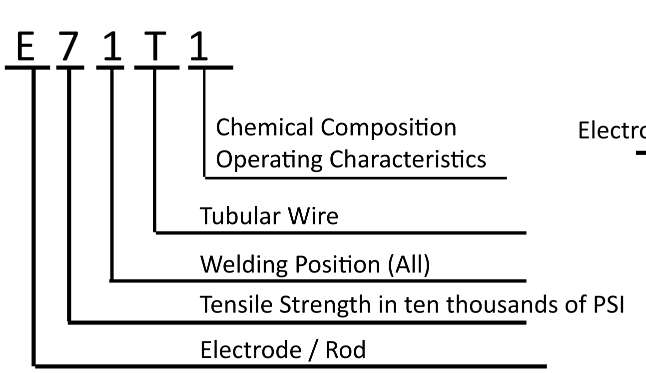


Fig. 2.3.58 FCAW filler wire

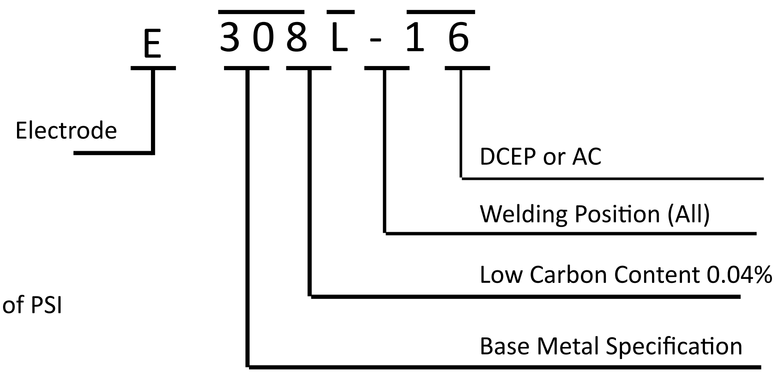


Fig. 2.3.59 SMAW Stainless steel electrode

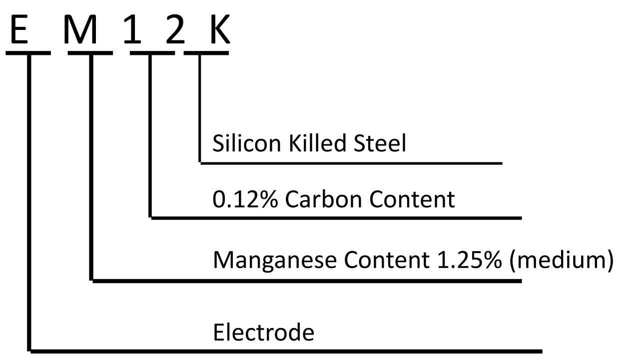


Fig. 2.3.60 SAW Filler wire

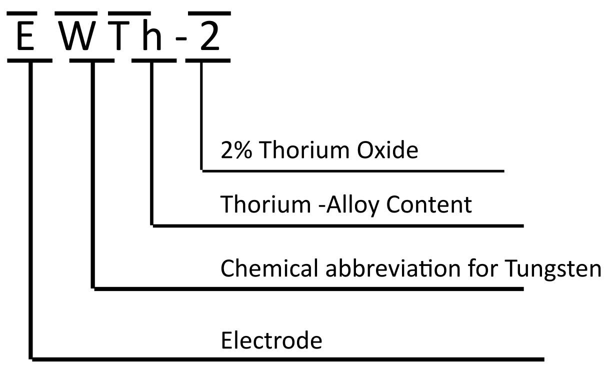


Fig. 2.3.61 GTAW electrode - Tungsten

Electrode identification

The electrode classification number is imprinted or stamped on the electrode covering filler wire within 65 mm of the grip end of the electrode.

Tips

All manual electrodes shall be properly identifiable upto the time of usage, each electrode being distinguishable by a coding marked near the grip end. Electrodes without a code marking shall not be used.

Electrode storage

Electrodes, filler wires and fluxes shall be stored in a dry storage room in accordance with the manufacturer’s instructions. Basic low hydrogen electrodes, after removal from the containers, shall be baked in ovens. The baking ovens and the holding ovens shall have automatic heat controls and a temperature read-out display.

Exercise

I. Answer the following questions.

1. What is the minimum tensile strength of an E6010 electrode?

----

2. Write several different electrode classifications (codifications).

----

3. What do the first two numerical digits of a SMAW process electrode mean?

----

4. Give the expansion of AWS.

----

5. Write any three AWS specifications numbers of welding electrodes.

----

6. How are welding electrodes classified?

----

7. Explain E7018 codification system.

----

8. How are welding electrodes identified?

II. State whether the following statements are True or False.

1. 'W' on a tungsten electrode designates 'welding'.

   True ☐ False ☐

2. According to the AWS electrode codification, the letter 'E' stands for 'electric current'.

   True ☐ False ☐

Notes

2.3.11 Electrode Angle

At the end of this topic, you will be able to:

1.describe the electrode angle and its effects on the quality of welds.

Shielded Metal Arc Welding

SMAW is one of the oldest welding processes. It is also the simplest and, perhaps, the most versatile one used for welding ferrous base metals. The welding arc is produced by bringing the electrode close to the work and touching it. The touching of the electrode causes resistance, heating of the arc at the contact spot thereby igniting the arc.

Electrode

The electrode is consumed in the arc and provides the filler metal for the joint. The electrode consists of a straight piece of solid metallic wire called core wire which has a concentric covering / coating of flux.

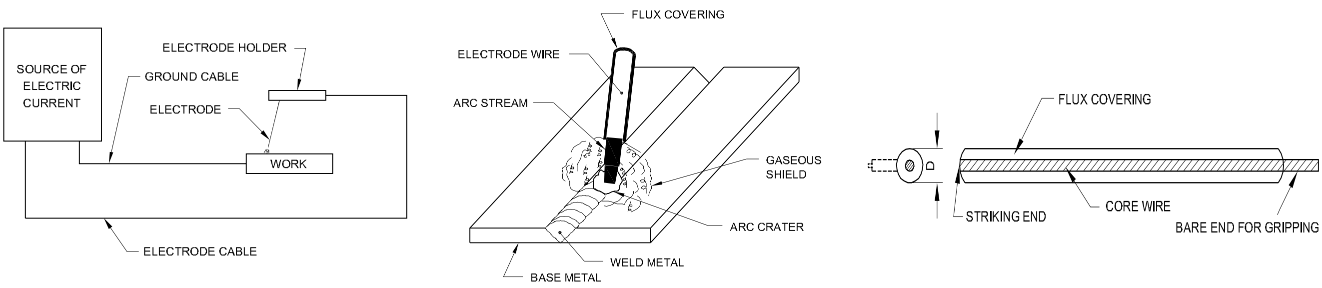


Fig. 2.3.62 Simple Welding Circuit *Fig. 2.3.63 SMAW Electrode* *Fig. 2.3.64 SMAW Electrode During Welding*

Electrode Angle

The angle of the electrode with respect to the weld puddle is very important while welding. Improper electrode orientation causes slag entrapment, undercuts and porosities. The type and the size of the electrode and the welding position combinable decide the angle of the electrode to be kept with respect to the work and the weld joint.

Electrode travel angles (both pushing angle in case of forehand welding and pulling angle in case of back hand welding) is to be kept correctly. The travel angle is the angle between the joint and the electrode along the axis of the weld.   push angle exists when the electrode points in the direction of travel. The push angle reduces heat input because the arc is pointing away from the puddle.

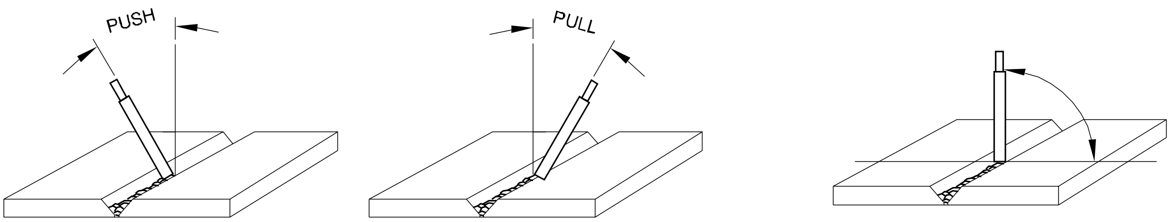


Fig. 2.3.65 Push Angle *Fig. 2.3.66 Pull Angle* *Fig. 2.3.67 Work Angle*

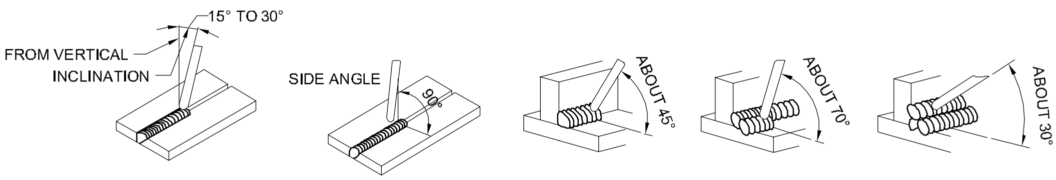


Fig. 2.3.68 Electrode Angle

A pull (drag) angle points away from the direction of travel. The pull angle increases heat input because the arc is pointing into the puddle. Also, the work angle (the angle of the electrode to work surface toward sideways), is equally important to avoid under cutting or lack of side wall fusion.

A large travel angle may cause a convex shaped weld profile with insufficient penetration, whereas a very small travel angle can cause slag entrapment. This is more so in vertical and overhead welding and in girth welding of pipes.

Welders should receive training under experienced welding instructors in controlling the electrode angle and other aspects of electrode manipulation to attain the standard demanded by important specification.

The angle of electrode should be held at 90° to the base metal surface and at 5° to 15° to the direction of the weld in overhead position. The correct angle for welding of pipe in 5G-up position. The electrode is brought back to the 6.30 position which is the actual starting position for the root bead. The angle is especially critical in pipe welding since it changes constantly as the weld progresses around the pipe.

Exercise

I. Answer the following questions.

1. What is the difference between a push and pull travel angle?

----

2. Define work angle.

----

3. What are the possible consequences of an incorrect work angle?

----

4. Explain the electrode angle in 5G up hill position.

II. State whether the following statements are True or False.

1. Correct electrode angle is not so important to make good welds.

   True ☐ False ☐

2. The angle reduces the heat input.

   True ☐ False ☐

Notes

2.3.12 Striking the Arc

At the end of this topic, you will be able to:

1. recognise the method of striking the arc and its effects on the quality of welds.

Striking the arc

In shielded metal arc welding, the coalescence is provided by the electric arc that is struck between the electrode and the work. Striking the arc is the operation of touching the work with the electrode and taking it back from the work to a proper distance in order that the arc is sustained and not extinguished. Striking the arc is a basic action throughout the entire welding operation. It occurs everytime an electrode is changed or the weld is started. In shielded metal arc welding with coated electrodes, the arc is 'struck' in the following two ways:

'touch and retract' method

'scratch' method.

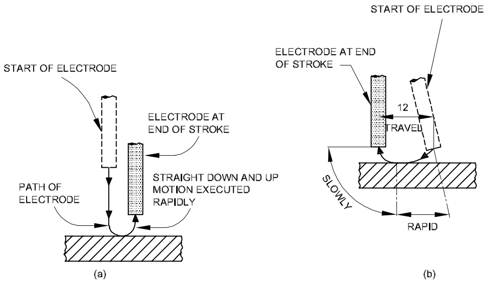


Fig. 2.3.69 Striking the Arc

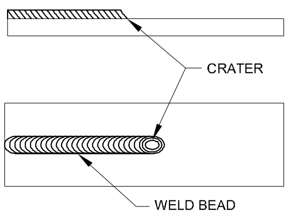


Fig. 2.3.70 Weld Crater

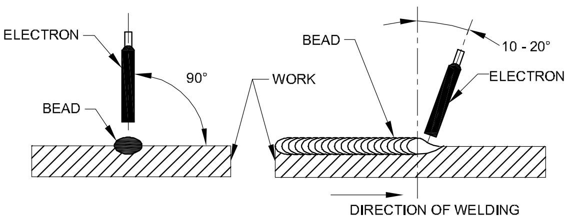


Fig. 2.3.71 Electrode Position when making flat beads

The ‘touch and retract’ method helps to

- ensure personal protective equipment are worn
- put on the welding helmet or bring the welding shield in front of your eyes
- hHold the coated electrode in the electrode holder
- strike the arc by moving the electrode down to touch the job surface lightly
- brought down the electrode almost vertically to touch the plate and then swiftly retract or withdraw through a short distance to ignite an arc

move down the electrode safety once the arc is struck, as the electrode is being consumed, and at a uniform rate so as to sustain the arc

Tips

The touch start method is mostly recommended as it does not put pit marks on the job surface.

2. The ‘scratch’ method helps to

- strike the arc by dragging the electrode quickly and softly across the welding job using wrist movement only
- withdraw the electrode approximately 6mm from the surface for a few seconds and then lower it to approximately 3 mm distance to maintain the arc
- ensure that the arc has been properly struck producing a ‘burst of light with a steady sharp cracking sound’
- break the arc quickly and withdraw the electrode up.

The welder will have to, in the beginning, practice this ‘striking’ till adequate experience is obtained in striking (without sticking) to maintain a stable arc.

Maintaining the arc

Once the arc is struck, it is necessary to maintain and sustain it. The experience gained and the skill of the welder play a vital role in the maintenance of a stable arc. However, stability of the arc is also dependent on the electrode and the power source employed.

The type of coating also influences the arc length to a large extent. While it is easy to maintain an arc with ‘touch’ electrodes, it is less easy with ‘rutile’ (E6013) electrodes. Cellulosic type of electrodes (E6010) are even more difficult, while the basic coated (E7018) variety requires deft control.

Stopping the arc

When the arc is to be extinguished, the electrode is to be lifted so that the gap between the electrode and the work is too large for being bridged by the flow of electrons and ions.

Crater

When the arc is extinguished abruptly, there is a likehood of a crater being left in the puddle as it solidifies. Such craters could give rise to increased stress levels and often are likely to develop cracks. Such cracks are more predominant in low alloy steels and stainless steels. As crater cracks are undesirable, it is necessary to avoid crater cracks or deep craters by filling up the crater before the arc is extinguished. This is done by retracting the electrode as the weld is about to be completed, to obtain a longer arc length and tracing back the weld in the opposite direction of travel for a short distance when extinguishing it. This will provide for metal transfer through the ‘long’ arc which will fill the crater cavity.

Tack welder

During fit up of the piping components, tack welding shall be carried out by qualified welders in accordance with the same requirements and parameters as for the root pass of the base material. A welder cannot be engaged for only tack welding. So, the pipe fitter will be qualified as a tack welder by visual inspection and bend testing of fillet weld prior to commencing production welding.

2.3.13 Straight Line Beads on M.S. Plate

At the end of this exercise, you will be able to:

1. select the electrode, current and polarity for depositing the weld beads
2. maintain constant arc length, electrode angle and travel speed
3. deposit straight line beads.

Practical

Requirements	
Tool/Instruments	**Materials / Components**
Welding helmet – 1No.	M.S. Plate – 10mm x 100mm x 150mm – 1No.
Chisel – 1No.	Electrode E6013 / E7018 ϕ 3.15mm each– 1No.
Wirebrush – 1No.	Grinding Disc 4” dia – 1No.
Chipping hammer – 1No.	
Equipment/Machines	
Welding Machine with accessories – 1No.	
Grinding Machine AG4 – 1No.	
Personal protective equipment – 1 Set	

Bead on plate welding

The pipe fitter would be able to deposit straight line bead upon completion of this exercise. This consists of laying weld beads on a plate in the flat position. The exercise involves the following steps:

i) Take a plate of suitable dimensions – length (150) x width (100) x 10MM thickness. Usually, a mild steel plate is selected.

ii) Grind lightly the surface of the plate, clean the surface wire brush to be free of dust, rust, oil, grease, etc.

iii) Using a chalk, a ruler, centre punch and hammer lay out parallel lines on the face of the plate.

iv) Connect the ground or earth connection to the plate. Check for proper connections to the electrode holder and polarity.

v) Set proper current.

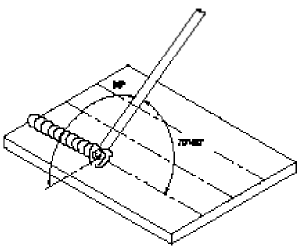
vi) Strike the arc a little away from the edge near the operator.

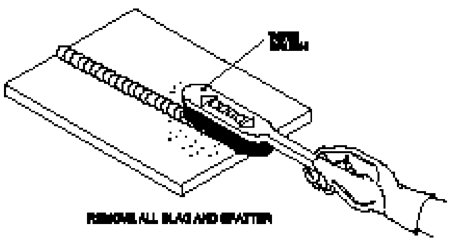
vii) Move the electrode maintaining the arc, along the line drawn on the plate, slowly across away from the operator.

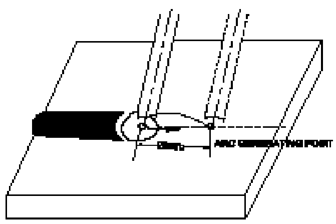
viii) Do not allow the arc to get extinguished except for changing the electrodes.

ix) When one bead is completed, repeat the same process on the other lines.

x) Repeat the exercise till adequate steadiness is obtained in laying straight string beads and uniform beads that could be produced consistently.







Exercise

I. Answer the following questions.

1. How is the welding arc started? Explain the usual methods for striking an arc.

----

2. How can the crater at the end of the weld bead be eliminated?

----

3. What are the tests to be conducted to qualify a pipe fitter for tack welding?

II. State whether the following statements are True or False.

1. The electrode angle is not critical in pipe welding.

   True ☐ False ☐

2. A welder cannot be engaged for only tack welding.

   True ☐ False ☐

Notes

2.3.14 Welding Sequence

At the end of this topic, you will able to:

1. prepare proper joints
2. explain how to improve the fitup condition.

Introduction

The preparation of the pipe joint is an essential part of pipe fit up and welding as the quality of the weld is affected by the care used in preparing the joint. Indeed in many instances, the failure of the pipe joint can be attributed to faulty joint preparation. The pipe fitter must understand and then assemble the parts required to prepare the joint properly for welding. This is the first step in making a successful pipe weld.

Four steps to check the weld joint conditions are:

prepare the edges 2. clean the joint surfaces 3. fitup and align the pipes 4. Tack weld the pipes together with temporary supports to control the distortion.

Conditions for welding

Prior to and during welding of piping, the following shall be observed:

The joint surfaces shall be cleaned and aligned, as required. Fitting up pipe is one of the basic skills of pipe welding. In simple terms, fitting up means to position the pipes in the correct location as specified is the drawing.

Joint preheat for inter pass temperature and arrangements for delayed cooling when required shall be in accordance with the qualified welding procedure for the respective joints.

Tips

No fit up and welding shall be carried out when the parts to be welded are wet.

When the base metal temperature is below 20°C, both sides of the weld preparation shall be preheated to a temperature of approximately 50°C or the preheat temperature prescribed in the WPS, whichever is higher.

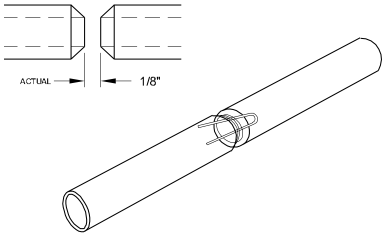


Fig. 2.3.72 Pipe Fitup Steps

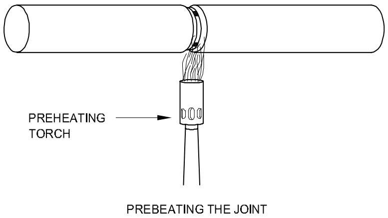


Fig. 2.3.73 Preheating the Joints

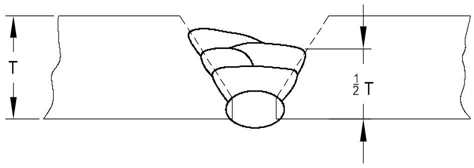


Fig. 2.3.74 Minimum 3 Layers (Passes)

Ambient air movement should be limited to that covered by the qualified welding procedure.
No welding shall be performed unless the welder and the work are properly protected from weather conditions including but not limited to rain, snow, air, moisture, blowing sands and excessive wind and preferably from sub-zero air temperatures. Such conditions shall be observed, in particular, for site fabrication.

Tips

Wind shields may be used when practical. Wind shields or tents shall be required when the wind is strong enough to affect arc stability or shielding gas coverage or when deemed necessary. The wind velocity in the weld area for GTAW, GMAW or FCAW shall not exceed 8 kph.

All welding procedure variables shall be maintained in accordance with the qualified welding procedure.The minimum number of passes before the joint is allowed to cool to ambient temperature shall be followed. The minimum shall be three layers or one third of the joint or qualified WPS, whichever is greater.

Distortion caused by welding can seriously affect the alignment and the locational accuracy of a pipe installation unless preventive measures are taken to avoid these problems.

On the job, the pipe fitter must always be aware of the distortion and must take those steps required to prevent this from affecting the quality of work. The following methods may help:

use of line up clamps to align the pipes and hold them in position

use of a strong back to add to the stiffness of the header pipe

plan to weld the branches in the correct sequence in order to minimize the effect of distortion

welding the root beads in all pipe joints in the correct sequence

using a temporary support to maintain the correct alignment of a right angle pipe joint

make allowance for the contraction of the weld lengths of pipe welded together.

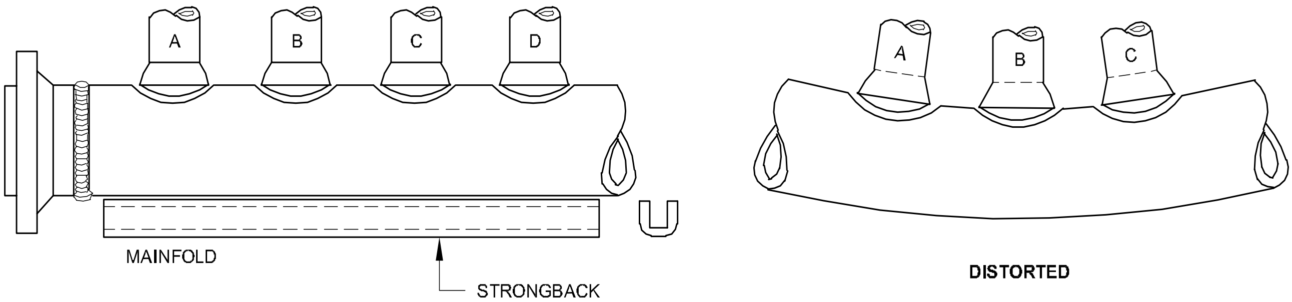


Fig. 2.3.75 (Top) Use of a strongback to prevent distortion (Bottom) Pipe distorted (Bent) As A Result Of Welding

Exercise

I. Answer the following questions.

1. What are the practical methods to minimize distortion during fabrication?

----

2. Why is preheating prior to welding required?

----

3. Mention the four steps to check the weld joint conditions for pipe fitter activities.

----

4. Why are wind shields or tents required during field welding?

II. State whether the following statements are True or False.

1. No fitup and welding shall be carried out when the parts to be welded are wet.

   True ☐ False ☐

2. The pipe fitter must always be aware of distortion and how to control it.

   True ☐ False ☐

Notes

2.3.14 Welding Techniques 5G Vertical Up and Down Hill Position

At the end of this topic, you will be able to:

1. perform edge preparation of pipes
2. tack weld the fit-up
3. weld a joint in vertical up (5G) position, uphill and 5G down hill position.

Basic Pipe Welding Procedures

Before starting to learn pipe welding, a pipe fitter should be proficient in welding in the four basic positions: flat, horizontal, vertical and overhead.

All of these positions are used to weld pipes. Since the pipe has a round shape, there is usually a gradual transition from one position to another.

When the pipe is in the 5G position, with its horizontal axis in position on the pipe, it can readily be identified by their likeness to the numbers on the face of a clock.

Pipe axis shall be horizontal and pipe is fixed in horizontal. Rotation of pipe is not possible in 5G fixed position. Welding is to be accomplished in the vertical position. Two different welding procedures are used when the pipe is in the horizontal position: downhill and uphill pipe welding.

Tips

Before proceeding with this exercise, review the procedures and figures for vertical downhill in the next exercise.

Practicing for vertical up (5G)

Prepare a pipe with diameter 168 mm OD (ϕ 6”), 7.11 mm thick, 100 mm long and mark lines at a pitch of 20 mm. Tack weld the pipe in its axis in the horizontal.

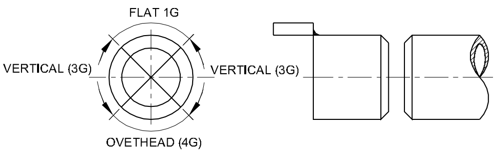


Fig. 2.3.76 Pipe Horizontally Fixed Position - 5G

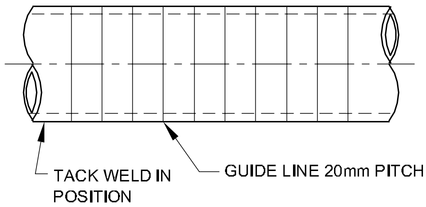


Fig. 2.3.77 Practicing for Fixed Position

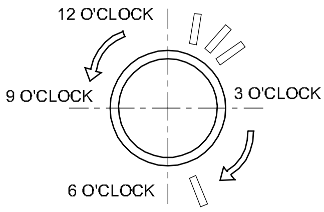


Fig. 2.3.78 Movement of Electrode

Strike the arc at the 5’o clock position and maintain the correct electrode angle and arc length. Move the electrode towards the 11’o clock position (anticlockwise).

Do not support or rest your hand on the pipe or the table. Break the arc at the 11’o clock position.

Move the arc from the 5’o clock to the 11’o clock position (clockwise).

Repeat the steps several times, till the pipe welder is able to produce uniform weld beads using the arc, restarting and merging techniques.

Preparation of pipe joint

Tips

Follow the procedures as stated in the next exercise on downhill welding, for the edge preparation of pipe joint and fit-up.

Make sure that the bevel angle conforms to the welding procedure specification. The groove angle must be large enough for the electrode to fit into the groove.

Welding Technique

Perhaps the most difficult position in which to weld pipe is in the 5G position. Once this is mastered, welding pipe in other positions is less difficult to learn. For this reason, it is best to start by learning how to weld in the 5G position.

Pipe size : OD 168 mm, 7.11 mm thickness
150 mm long - 2 nos.

Electrode : E 6010 - ϕ 3.20 mm

Welding current : 80 - 110 amperes

Vertical up welding uses lower current and slower travel speed to produce a joint with fewer but heavier beads.

The slower travel speed of vertical-up welding and the high liquid pool melts out gas holes more effectively than vertical down welding.

Tips

Vertical up welding requires a larger root opening and bevel angle than vertical down does. The best way to weld an open root is to use a deep penetrating electrode like E 6010.

Pipe Clamps

One difficulty encountered in assembling pipe to be fabricated / installed, is the positioning of the pipe before tacking. External line up clamps are made to hold virtually any type of pipe joint. The use of clamps to secure proper alignment is highly recommended. The pipe joint should be clamped using the external line up clamp.

Deposition of Root Pass

The root pass is the most important weld that must be made in completing this joint. Start the root pass at either the 5 o'clock or 7 o'clock position and proceed across the bottom to the top of the pipe joint. Stop either at the 11 o'clock or 1 o'clock position.

When welding a root pass, the keyhole is necessary in order to obtain the required weld penetration. While welding the root pass, the welder must pay careful attention to the keyhole and watch for changes in size.

The same sequence is followed on the other side.

Remove the external line up clamp after 50% completion of root bead equally distributed around the joint. After the entire root bead has been completed, it should be thoroughly inspected for visible welding defects.

T. – Thickness, A – 60° – 70°, B – ±5mm, C – 1 – 5 ± 0.75mm

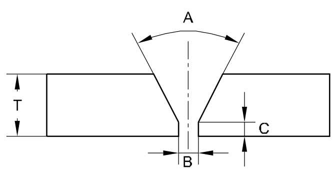


Fig. 2.3. 79.Typical single V butt joint

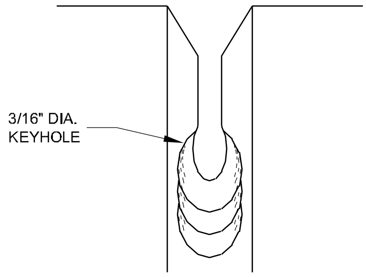


Fig. 2.3.80 Key Hole

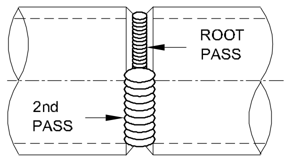


Fig. 2.3.81 Second pass

Second (HOT) Pass

Second pass is also called " hot pass" Select ϕ 3.20 mm electrode and a current setting of 100 - 120 amperes.

Deposit the second (hot) pass in the same sequence as in root pass.

Time lapse between completion of root and commencement of second pass is to be maximum 5 minutes.

Inspect the root side for any burn through defect which will be occur if the root pass thickness is less.

Deposition of 3rd and 4th (Final) Pass

Clean and wire brush the welds thoroughly.

The electrode should at all times be pointed towards the centre of the pipe's circumference or should be perpendicular to the pipe surface.

Deposit the third pass using slight side to side movement.

Fill the crater at the end of weld.

Remove the slag, spatters and clean the weld bead.

Welding Technique 5G Down Hill Position

Pipe joints are often used in industries which include pipeline projects, refineries, tanks, etc.

In butt joints the letter 'G' is used to signify a groove joint (edges are beveled) and a number is assigned to signify the welding position. In 5G-Multiple positions (flat, vertical and overhead) pipe is fixed, groove weld, pipe axis is horizontal and is not rotated. Welding shall be done without rotating the pipe.

Shielded Metal Arc Welding (SMAW)

SMAW is one of the popular methods for welding pipe both in the shop and in the field. Standard welding power sources which produce direct current such as a rectifier, inverter or an engine driven machine may be used. Welding may be done in 5G position and the direction of welding may be downhill or downward.

Pipe Welding Electrodes

E6010 – This type of electrode is frequently selected for joining pipe and are generally capable of welding in the vertical position with either uphill or downhill progression.

2.3.15 Welding Techniques 5G Vertical, Up and Down Hill Positions

At the end of this exercise, you will be able to:

1. prepare pipe bevel
2. fitup and tack weld the pipe
3. weld a joint in vertical up (5G) position.

Practical

Requirements			
Tool/Instruments		**Materials / Components**	
Welding helmet	– 1No.	M.S. /CS Pipe ϕ 6" sch 40, 150mm long	– 4 Nos.
Chisel	– 1No.	100mm long	– 2 Nos.
Wirebrush	– 1No.	Welding Electrode E 6013 / E7018, ϕ 3.15 mm	– 2 Nos.
Chipping hammer	– 1No.	Grinding Disc 4" dia	– 1 Nos.
Equipment/Machines			
Welding Machine with accessories	– 1 Set		
Grinding Machine - AG4	– 1No.		

Practice for 5G position

Prepare a pipe with diameter 168mm OD (ϕ 6"), 7-11mm thickness, 100mm long and mark lines at a pitch of 20mm. Tack weld the pipe in its axis in the horizontal.

Strike the arc at the 1'o clock position and maintain the correct electrode angle and arc length. Move the electrode towards 6'o clock position (clockwise).

Do not support or rest your hand on the pipe or the table. Break the arc, at the 7'o clock position above (anticlockwise).

Repeat the steps several times, till the pipe fitter is able to produce uniform weld beads using the arc, restarting and merging techniques.

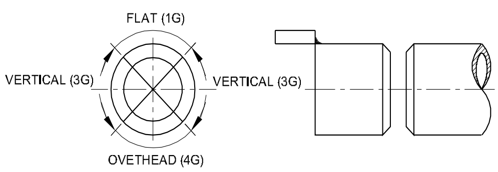


Fig. 2.3.82 Pipe Horizontally fixed Position - 5G

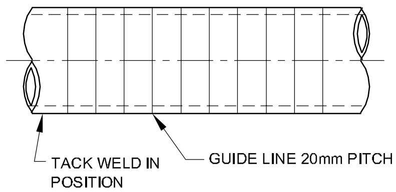


Fig. 2.3. 83 Practicing for horizontal fixed position

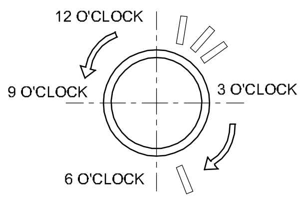


Fig. 2.3.84 Movement of electrode in horizontal fixed position

Preparation of pipes

Clean the bevel face and the pipe surface atleast 1 inch from the edge of the welding groove to remove rust, scale, paint, oil and grease. Grind or file the bevel surfaces smooth to remove all traces of scale and any cutting irregularities (Fig. 3-a, b, c).

Make sure that the bevel angle conforms to the welding procedure specification. The groove angle must be large enough for the electrode to fit into the groove.

Tack Welding (Fit-up)

A tack weld is a weld made to hold the parts of a weldment in proper alignment until the final welds are made.

A tack weld is generally a short weld made at intermittent points to hold abutting edges together.

Tack Welds are an important phase in fabrication. They should not be treated as negligible elements, but should

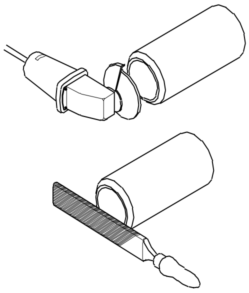


Fig. 2.3.85 Bevel Preparation

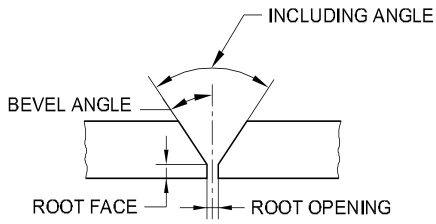


Fig. 2.3.86 Weld Joint Definition

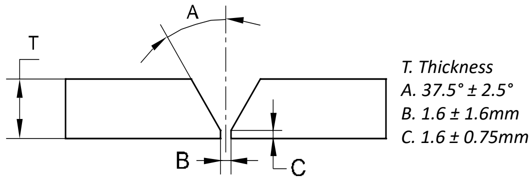


Fig. 2.3.87 Typical Single -V- Butt Joint

be deposited with the same concern for quality as ''final'' welds.

Make sure that the proper root opening between the pipe ends has been set up. The simplest way to secure and maintain an accurate root opening is to use a 3.2 mm gas welding wire of the proper size. By crossing the wire, accurate spacing at four points along the circumference of the joint is available. The pipe fitter should align the pieces of pipe then tack weld them to ensure that they do not shift during welding.

The best method for tacking the pipe depends upon its size. It can usually be done with four 1-inch (25 mm) long tack welds.

Make sure that the faces of the welds are flat. Good fit-up always improves results.

Welding Technique – 5G Position

Vertical down welding is a cross-country pipe line technique. Welding is from the top to the bottom. Vertical down welding requires higher welding current and faster travel speeds than vertical up so that the joint is made with several smaller beads. Root openings are less than those required for vertical up welding or there may be no root openings at all.

The vertical down method requires 50 to 75 more amperes than the vertical up method. Larger electrode sizes are specified for vertical down.

For the joint design shown, the travel speed for vertical down is more than twice that for vertical up.

Deposition of Root Pass

Root Pass is the basis for the success or failure in making a pipe weld. It is also the basis of a sound weld.

Electrode – E 6010, ϕ 4.00 mm

Current setting – 150 - 200 amps

Electrode Angle – 30 to 45° from the horizontal center line.

Start the root pass at 11'o clock or 1'o clock position. Weld across the top of the pipe and downward past the 6'o clock position to the 7'o clock or 5'o clock position.

Make the stringer bead with a drag technique. Rest the electrode coating on the bevel as you drag the electrode downhill around the pipe.

Maintain a small visible keyhole at all times to obtain adequate penetration on the inside of the pipe.

After the root pass is completed on one side of the pipe, weld the other side in the same manner.

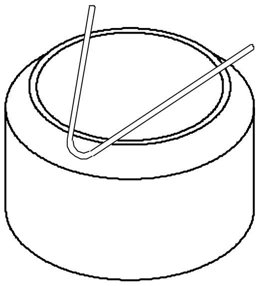


Fig. 2.3.88 Spacer Wire in V-Form

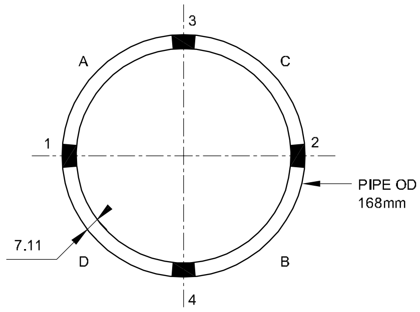


Fig. 2.3.89 Tack Weld

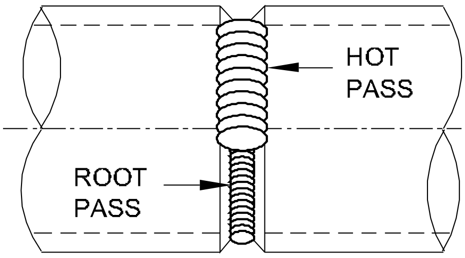


Fig. 2.3.90 Hot Pass (Welding Sequence)

Second (Hot) Pass

Remove all slag before making the hot pass (second pass).

Electrode – E 6010, ϕ 4 mm or ϕ 5 mm

Current setting – 150 - 190 amps

Electrode angle – 30° to 45°

The hot pass should be started within 5 minutes.

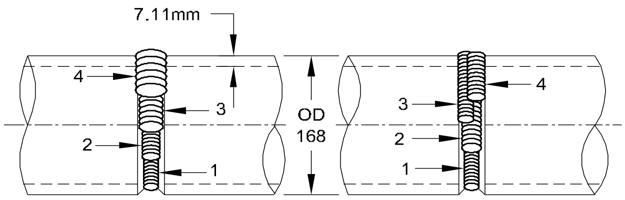


Fig. 2.3.91 Welding Sequence in 5G Down Hill Position

Welding should start at the top of the joint outside of the area of the previous starting point. Proceed downhill and stop at the bottom outside the area of the previous stopping point.

Fill Passes

The filler passes should be made with a 5 mm electrode and a current setting of 160 - 200 amps. Use a slight side to side weave and make sure that the weld deposit fills the groove and fuses into the side walls.

Final Pass

This pass is also referred to as a cover pass or capping pass. The final pass is made with a 4 mm electrode and a current setting of 120 to 160 amperes. A weave motion with some hesitation at each is used to prevent undercut. Take enough care and maintain the same electrode angle and travel speed as practiced earlier.

The completed weld should be 1.0 mm to 1.5 mm higher than the pipe wall and should overlap the groove by 1.5 to 3 mm on each side. Remove the slag and clean thoroughly. Visuallly inspect the weld. The pipe joint welded by SMAW in 5G position depends upon the V-groove width.

Requirement

Before any production welding is performed, the individual shall be qualified according to the applicable requirements. The specified minimum preheat shall be applied before any tack welding. Root tack welding shall be performed in accordance with the root pass parameters of the approved WPS. Tack Welders shall be qualified to weld with the WPS.

Dollymix welding Technique

Dollymix welding is a term used to define the progression of welding technique for pipeline welding. In Dollymix, the root pass is welded in uphill progression and the remaining passes are in downhill welding progression.

Safety

The electrode holder must be effectively insulated and properly maintained.

Exercise

I. Answer the following questions.

1. Briefly explain how a root pass weld is produced.

----

2. Describe root and final pass welding in 5G position a pipe joint.

----

4. What is the type of electrode to be used for downhill welding of pipe joints?

----

5. Should rust or oil be removed before welding?

----

6. Draw the sketch of a single-V-butt joint with details before welding (fitup stage).

----

7. Explain 'tack welding'.

----

8. State any three instances of a pipe welding.

II. State whether the following statements are True or False.

1. During 5G position, welding may be done with or without rotating the pipe.

   True ☐ False ☐

Notes

2.3.16 Welding Defects

At the end of this topic, you will able to:

1. list different weld defects in welded joints
2. define weld defect
3. describe the repair procedure.

Defect: If a weldment is to have the required reliability throughout its life, it must have a sufficient level of quality or fitness for purpose. A weld that does not meet any or all of the specific requirements of a particular specification or code is considered a defective weld. In the correct sense of the word, a defect is a rejectable discontinuity or a flaw of rejectable nature.

Type of defects

Defects in weldments, in general, can be classified as:

1. Defects involving inadequate bonding
   - lack of fusion
   - incomplete penetration

2. Foreign inclusions
   - slag
   - tungsten
   - oxide films

3. Geometric defects
   - undercut
   - excessive reinforcement
   - burn through or excessive penetration
   - distortion
   - Improper weld profile

4. Metallurgical defects
   - cracks
   - gas porosity
   - arc strikes

General reasons for defects

Defect are generally occurs because of:

- lack of know-how and experience
- welding process characteristics

- Base metal composition

- defective welding consumables
- joint design
- welding environment (wind, fitup, temperature)

Defects acceptance levels

Defect acceptance levels are included in certain client/project specifications or respective standards containing acceptance criteria or cross reference. Some specifications contain defect acceptance tolerances which are stricter than others, depending on the criticality rating of the structure or application to which the specification applies.

Effects of weld defect

- effective thickness of the base metal is reduced
- strength of the weld is reduced
- joint will break, when loaded, causing accidents
- properties of base metal will change
- weld appearance will be poor.

Identification of weld defects

Weld defects may be indentified during visual inspection or non – destructive testing.

1. Inadequate Penetration (IP): Inadequate penetration is defined as the incomplete filling of the weld root. One or both root faces may be inadequately filled in the inside surface.

2. Lack of Fusion (LF): LF is defined as a surface imperfection between the weld metal and the base metal that is open to the surface. It is also an imperfection between two adjacent weld beads or between the weld metal and the base metal that is not open to the surface.

3. Root concavity or suck back Bead that is properly fused to and completely penetrates the pipes wall thickness along both sides of the bevel but whose center is somewhat below the inside surface of the pipe wall.

4. Burn through: A burn through is defined as a portion of the roof bead where excessive penetration has caused the weld puddle to be blown into the pipe.

5. Slag inclusion: A slag inclusion is defined as a non – metallic solid entrapped in the weld metal or between the weld metal and the parent material.

6. Undercut: Undercut is defined as a groove melted into the parent material adjacent to the toe or root of the weld and left unfilled by weld metal.

7. Porosity and gas holes: This refers to the entrapment of gases evolved during weld metal solidification. Porosity is usually spherical in shape.

8. Cracks: These are grouped as metallurgical defects. Cracks are with a sharp tip and linear ruptures of the metal under stress. Cracks are dangerous defects and most of the manufacturing codes do not accept cracks irrespective of their dimensions. Crack shall not be repaired. When cracking is observed the weld shall be cut out entirely.

Rectification of weld defects (Repair welding)

Fig. 2.3.92 Inadequate Penetration

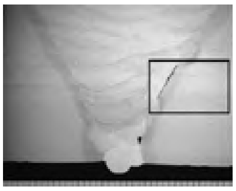


Fig. 2.3.93 Lack of Fusion

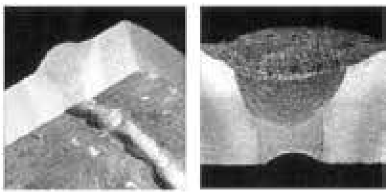


Fig. 2.3.94 Root Concavity

Fig. 2.3.95 Arc Strike

Fig. 2.3.96 Burn Through -1

Fig. 2.3.97 Burn Through -2

Fig. 2.3.98 Slag Inclusion

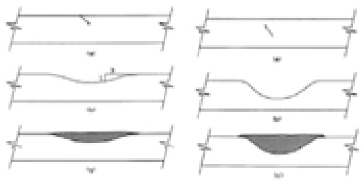


Fig. 2.3.99 Repair Welding Steps

Fig. 2.3.100 Under Cut

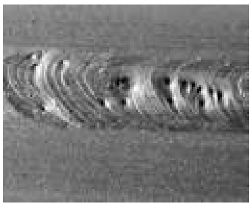


Fig. 2.3.101 Porosity

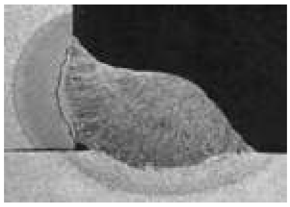


Fig. 2.3.102 Crack (HAZ)

Tips

Once the decision has been made to make a weld repair, it is necessary to review why the part failed or is worn out. There is no guarantee that a repair weld produces a more sound joint than the first one.

Defects may be rectified with prior client authorization. A qualified repair procedure shall be required whenever a repair is made by welding. The Welding Procedure Specification (WPS) may be supported by an appropriate pipe butt weld Procedure Qualification Record (PQR).

The repair weld shall be made by a qualified welder who has experience in methods used for repair of a defective weld. A repair procedure, as a minimum, shall include:

a) locating the defective portion.

b) excavation by grinding. (It shall be done in such a manner that the adjacent weld metal or base metal is not nicked or removed.)

c) after excavation, penetrant test or magnetic test shall be performed to confirm defect removal.

d) At the ends and the sides of the excavation there shall be a gradual taper from the base of the excavation to the surface of the weld metal. The profile shall be such that adequate access for welding is achieved.

e) cleaning the surfaces thoroughly before welding.

f) depositing of weld metal to compensate for any deficiency in size.

g) after completion of the repair welding, the full extent of the repair shall be visually inspected and non – destructive testing done to a length extending 50 mm beyond each end of the repair.

h) the repaired or replaced weld shall be retested by the method originally used. The same technique and quality acceptance criteria shall be applied.

Arc strikes

Arc strikes outside the area of permanent welds should be avoided on any base metal. Cracks or blemishes caused by arc strikes shall be ground to a smooth contour and checked to ensure soundness.

Exercise

I. Answer the following questions.

1. What is an unfilled groove along the toe of the welding called?

   a) Overlap   b) Undercut

   ----

2. What are the common defects encountered in arc welding?

   ----

3. What is root concavity?

   ----

4. List out the general reasons for the occurrence of defects.

   ----

5. What are the effects of weld defect?

   ----

6. List out geometric defects.

   ----

7. How are the weld defects identified?

   ----

8. What is slag inclusion? How is it caused and how can it be prevented or avoided?

   ----

9. What non–destructive testing method is performed to confirm defect removal after excavation?

II. State whether the following statements are True or False.

1. Testing of all repair welds should be as per the same non–destructive testing method previously used.

   True ☐   False ☐

2. Defects may be rectified without prior client authorization.

   True ☐   False ☐

3. When cracking is observed, the weld shall be entirely cut out.

   True ☐   False ☐

Notes

2.3.17 Knowledge of Non - Destructive Testing (NDT)

At the end of this topic, you will be able to:

1. describe fundamentals, principles and processes of different NDT methods
2. determine the applicable NDT and the required surface preparation
3. prepare the weld and parent metal surfaces to perform the required NDT works
4. coordinate NDT works.

Introduction and purpose of NDT

All NDT works shall be performed with written and approved procedure and inspected with respect to applicable acceptance criteria. All NDT shall be performed only by trained, qualified and certified personnel in the respective NDT method. Though pipe fitters do not perform any NDT, they need to know about the basics of NDT to

- perform surface preparation for NDT and offer for NDT inspections
- perform visual inspection themselves
- Perform preliminary penetrant examination without waiting for NDT technician
- coordinate NDT works, where required
- be aware that some standards / specifications require NDT on materials and material edges, prepared for welding

Tips

Though NDT shall have been done for all pipe fittings, if edges are trimmed or cut to suit site condition, or bevels are modified, appropriate NDT shall be performed before commencing fitup / assembly works.

- welds are repaired, surface NDT should be performed to ensure the defect removal.
- be aware that ascertain that if weld repairs are more in a joint or cut and re-weld is required, then cut edges shall be prepared again and tested by appropriate NDT methods, prior to fitup.

Visual Examination

Visual examination, also called Visual Testing (VT), is a primary non-destructive testing. All types and methods of NDT require visual examination. Visual examination is a non–destructive examination method used to visually inspect / examine:

i. raw material, cut edges, weld edge preparations, joints, fitup, alignment, tack welds, welds and welding works (prior to welding, during welding and after welding) , weld heat affected zones, etc.

ii. evaluate an item by observation, such as the correct assembly, surface conditions, or cleanliness of materials, parts such as bolts and bolting works, nuts, gaskets, flanges, fittings, and piping and pipeline components used in the fabrication and construction of piping and pipeline works.

Visual examination can be performed with natural or auxiliary lighting. Minimum light intensity required at examination surface is 1000 lux. Lux (lx) is a unit of illumination equal to the direct illumination on a surface that is everywhere one meter from a uniform point source of one candle intensity or equal to one lumen per square meter. Visual inspection can be either direct visual examination, remote visual examination, or translucent examination.

Direct Visual Examination

Direct visual examination is a visual examination technique performed by eye and without any visual aids (excluding light source, mirrors, and/or corrective lenses), for example,magnifying aids, borescopes, video probes, fiber optics, etc.

Visual inspection may usually be made directly, when access is sufficient to place the eye within 24 inches. (600 mm) of the surface to be examined and at an angle not less than 30 degree to the surface to be examined.

Mirrors may be used to improve the angle of vision, and aids such as a magnifying lens may be used to assist examinations.

The minimum light intensity shall be 100 fc (1 000 lx). The light intensity, natural or supplemental white light source, shall be measured with a white light meter prior to the examination or a verified light source shall be used.

Remote Visual Examination

Remote visual examination is a visual examination technique used with visual aids in conditions where the area to be examined is inaccessible for direct visual examination. Remote visual examination may have to be substituted for direct examination where inaccessibility prevents effective visual examination. Remote visual examination may use visual aids such as mirrors, telescopes, borescopes, fiber optics, cameras, orother suitable instruments. Such systems shall have a resolution capability at least equivalent to that obtainable by direct visual observation.

Borescopic examination is a remote visual examination aided by a mechanical or electromechanical device to examine the inside diameter and inaccessible welds.

Translucent Visual Examination

Translucent visual examination is a supplement of direct visual examination. Translucent visual examination is a technique using artificial lighting intensity to permit viewing of translucent laminate thickness variations (also called candling). The method of translucent visual examination uses the aid of artificial lighting, which can be contained in an illuminator that produces directional lighting. The illuminator shall provide light of an intensity that will illuminate and diffuse the light evenly through the area or region under examination.

The ambient lighting must be so arranged that there are no surface glares or reflections from the surface under examination and shall be less than the light applied through the area or region under examination. The artificial light source shall have sufficient intensity to permit “candling” any translucent laminate thickness variations.

Liquid Penetrant Examination

The liquid penetrant examination method is an effective means for detecting discontinuities which are open to the surface of materials and welds. Typical discontinuities detectable by this method are cracks, seams, laps, cold shuts, laminations, porosity, cold laps, incomplete fusion, lamination on the edges, etc.

Penetrant Testing Methods and Techniques

Either a colour contrast (visible) penetrant or a fluorescent penetrant shall be used with one of the following three penetrant processes: water washable, post-emulsifying, solvent removable.

The visible and fluorescent penetrants used in combination with these three penetrant processes result in six liquid penetrant techniques.

Surface temperature limits: As a standard technique, the temperature of the penetrant and the surface of the part to be processed shall not be below 40°F (5°C) nor above 125°F (52°C) throughout the examination period.

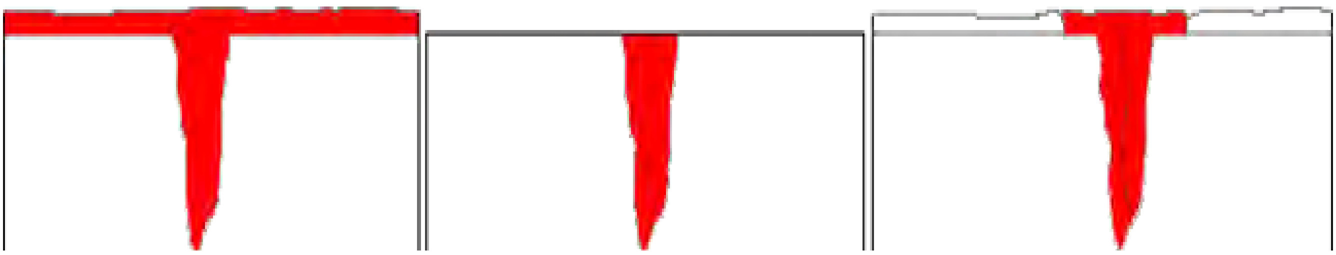


Fig. 2.3.103 Stages of Penetrant Testing

Penetrant Testing Procedure

a. Precleaning and Cleaning

Surface preparation by grinding, machining or other methods may be necessary where surface irregularities, heavy scales / rusts, etc., could mask indications.

Prior to each liquid penetrant examination, the surface to be examined and all adjacent areas within at least 1 inches (25 mm) shall be dry and free of all dirt, grease, lint, scale, welding flux, weld spatter, paint, oil and other extraneous matter that could obscure surface openings or otherwise interfere with the examination.

b. Application of Penetrant

The penetrant is then applied to the surface of the item being tested after precleaning and evaporation of solvents. The penetrant is allowed to remain in the inspection surface for a period called “dwell time” to soak into any flaws (generally 5 to 30 minutes).

c. Excess Penetrant Removal

The penetrant removal method is controlled by the type of penetrant used. The remaining traces shall be removed by wiping the surface with cloth or absorbent paper, lightly moistened with solvent. To minimize removal of penetrant from discontinuities, care shall be taken to avoid the use of excess solvent.

Application of Developer

The developer draws penetrant from defects out onto the surface to form a visible indication, commonly known as bleed out. Any areas that bleed out can indicate the location, orientation and possible types of defects on the surface.

The developer shall be applied as soon as possible after penetrant removal. Insufficient coating thickness may not draw the penetrant out of discontinuities. But, excessive coating thickness may mask indications.

Developing time for final interpretation begins immediately after the application of a dry developer or as soon as a wet developer coating is dry.

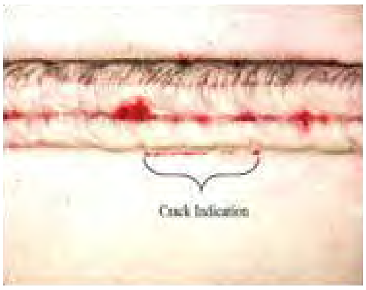


Fig. 2.3.104 HAZ Crack

Fig. 2.3.105 Cluster Porosities

Fig. 2.3.106 Cold lap

Fig. 2.3.107 Transverse Crack

Penetrant Testing – Inspection, Interpretation and Evaluation

Inspection of the test surface should take place after 10 to 30 minutes development time, depending upon product kind. This time delay allows the blotting action to occur.

The inspector may observe the sample for indication formation when using visible dye.

All indications shall be evaluated in terms of the acceptance standards of the referencing code section.

Magnetic Particle Inspection

The magnetic particle examination / inspection method (often abbreviated MT or MPI) is a non–destructive inspection method, applied to detect cracks and other discontinuities on the surfaces and near surfaces of ferromagnetic materials.

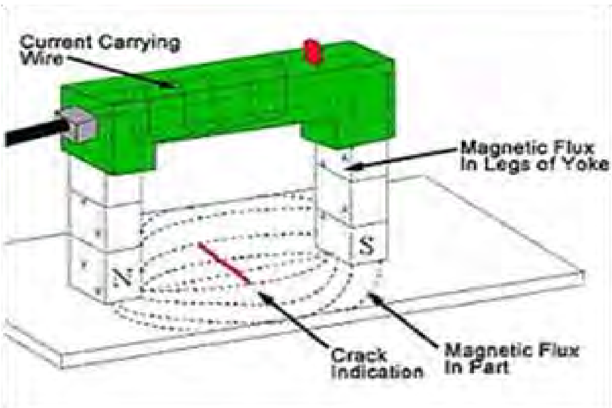
The sensitivity is greatest for surface discontinuities and diminishes rapidly with increasing depth of discontinuities below the surface.

Typical types of discontinuities that can be detected by this method are cracks, laps, seams, cold shuts, laminations, lack of sidewall fusion in welds, etc., in magnetic materials.

Magnetic Particle Examination Methods / Techniques

A ferromagnetic material can be magnetized either by passing an electric current through the material or by placing the material within a magnetic field originated by an external source. One or more of the following five magnetization techniques shall be used: prod technique, longitudinal magnetization technique, circular magnetization technique, yoke technique, multidirectional, magnetization technique.

The most versatile technique is using a 110v AC handheld electromagnetic yoke magnet, a white strippable paint as contrast background and a magnetic "ink" composed of iron powder particles in a liquid carrier base, normally in aerosol cans for portable techniques.



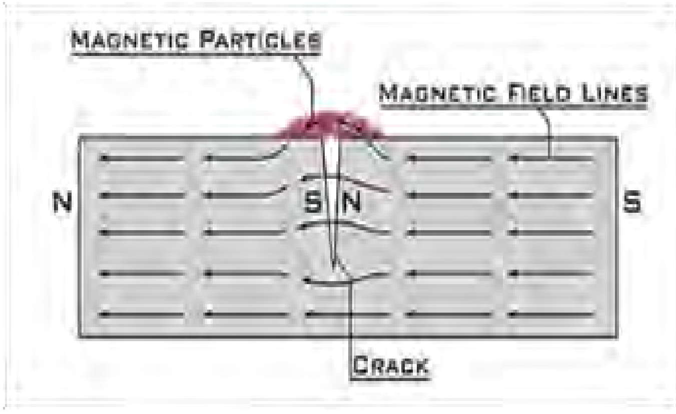


Fig. 2.3.108 Magnetic field application and discontinuity formation mechanism

Fig. 2.3.109 Flux lines flowing past perpendicular& parallel defect

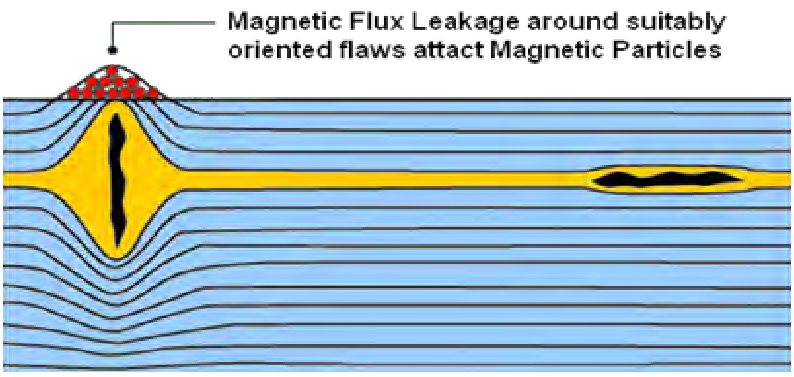


Fig 2.3.110 MPI indication formation

Magnetic particle inspection is performed in four steps:

induce a magnetic field in the specimen

apply magnetic particles to the specimen's surface

after stopping field application, view the surface, looking for particle groupings that are caused by defects.

demagnetize and clean the specimen.

The magnetic ink is applied and the iron powder particles bridge the gap caused by the defect giving a visible indication against the white contrast background.

Magnetic Particle Inspection – Interpretation, Evaluation and Recording

Interpretation shall be carried out to identify the locations of indications and characterise the indication.

All indications shall be evaluated in terms ofthe acceptance standards of the referencing code section.

Rejectable indications shall be recorded. As a minimum, the type of indications (linear or rounded), location and extent (length or diameter or aligned) shall be recorded.

Radiographic Testing

Radiographic Testing (RT) is non-destructive testing (NDT), exposing test object / specimen and radiography film to X-ray or Gamma rays. Gamma rays are produced by radioactive isotopes such as Iridium 192, Cobalt-60, Selenium 75, etc.

RT is usually suitable for testing welded joints that can be accessed from both the sides.

By radiography method, detects such as porosity, cluster porosity, slag / oxide inclusions, tungsten inclusions, cracks, voids, lack of fusion, incomplete penetration, undercut, etc., can be identified and inspected.

Radiographic testing provides a permanent record in the form of a radiograph and provides a highly sensitive image of the internal structure of the material. This film is then processed under dark room conditions and the various degrees of radiation received by the film are imaged by the display of different degrees of black and white. This is termed the film density and is viewed on a special light emitting device.

Fig. 2.3.111 Gamma Ray Equipment

Fig. 2.3.112 X-Ray Equipment

Radiographic Techniques

A single-wall exposure technique shall be used for radiography whenever practical. When it is not practical to use a single-wall technique, a double wall technique shall be used. In double wall technique, one of the following double wall viewing techniques shall be used:

Single Wall Viewing: For materials and for welds in components, a technique may be used in which the radiation passes through two walls and only the weld (material) on the film side wall is viewed for acceptance on the radiograph.

Double Wall Viewing: For materials and for welds in components 31/2 inches. (89 mm) or less in nominal outside diameter, a technique may be used in which the radiation passes through two walls and the weld (material) in both walls is viewed for acceptance on the same radiograph. For double wall viewing, only a source-side Image Quality Indicator (IQI) shall be used.

Placement of IQIs: Source-Side IQI(s): The IQIs shall be placed on the source side of the part being examined, except for the condition described in (b).

Once film exposing is completed is the film shall be unloaded inside the dark room, processed at the dark room under controlled temperature conditions (normally, 20˚C to 24˚C), dried and made ready for interpretation.

Radiography Film Interpretation, Evaluation and Reporting

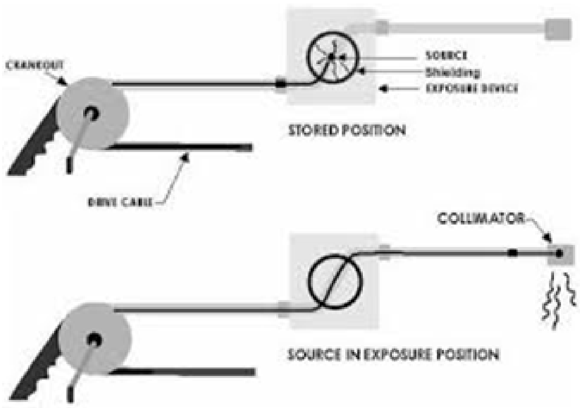


Fig. 2.3.113 RT Exposure equipment set-up

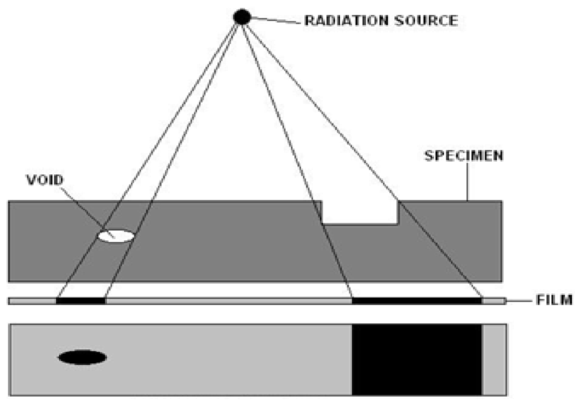


Fig. 2.3.114 RT film set-up and image formation

Radiography film shall be checked for any artefacts and film processing marks. If more artefacts and process marks are noticed in area of interest, then, it shall be reshot (to be radiographed again). Radiographic sensitivity is a measure of the quality of an radiography image in terms of the smallest detail or discontinuity that may be detected in exposed and processed radiographs.

Radiography films' density shall be between 1.8 and 4.0. In general, RT film sensitivity shall be 2% or less than 2%. However, applicable code / standard requirements shall be followed. Once sensitivity and density are checked and found to be within the acceptable limit, then the film shall be interpreted for any discontnuities present. Inclusions of low density, such as slag will appear as dark areas on the film, while inclusions of high density, such as tungsten will appear as light areas. Discontinuities shall be evaluated with respect to the acceptance criteria. Defects shall be recorded and reported.

Ultrasonic Testing

Ultrasonic non–destructive testing, also known as ultrasonic NDT or simply UT, is a method of characterizing the thickness or internal structure of a test piece through the use of high frequency sound waves. The sound wave frequencies used for ultrasonic testing are many times higher than the limit of human hearing, most commonly in the range from 500 KHz to 20 MHz.

In industrial applications, ultrasonic testing is widely used on metals, plastics, composites and ceramics. A wide variety of weld defects, cracks, voids, disbonds, inclusions and similar problems that affect structural integrity can all be located and measured with ultrasonic flaw detectors. It is possible to perform UT when access is available from one side only.

UT equipment and calibration blocks

UT Equipment:

An ultrasonic flaw detector is an instrument that generates and processes ultrasonic signals (longitudinal wave and transverse waves) to create a waveform display that can be used by a trained operator to identify hidden discontinuities, if any, in a test piece.

Calibration blocks:

Ultrasonic equipment shall be calibrated using appropriate calibration blocks such as V1 block, V2 block, flat bottomed hole sets. Basic calibration block and simulated calibration blocks having appropriate calibration reflectors shall be available for calibration.

Ultrasonic Testing Procedure

Surface Preparation: The surface to be subject to ultrasonic testing shall be free from the presence of any lubricants, dirt, residue, rust and sharp edges. Surface preparation shall include the areas to be examined, heat affected zones and skip distances.

Examination coverage (scan overlap): Each pass of the search unit shall overlap minimum 10% of the transducer (piezo-electric element) dimension perpendicular to the direction of the scan.

Ultrasonic Testing – Interpretation, Evaluation and Reporting

Fig. 2.3.115 Calibration using V1 block

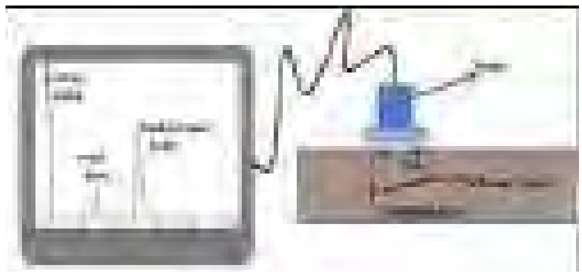


Fig. 2.3.116 Typical UT testing set up and screen pattern

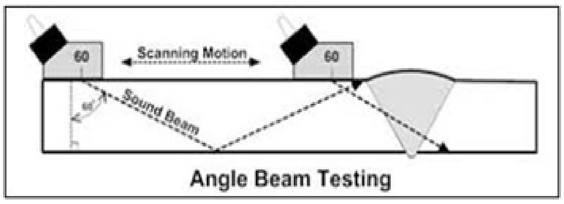


Fig. 2.3.117 UT scanning motion and sound beam bath

Evaluation: Any imperfection which causes an indication in excess of 20% DAC (Distance Amplitude Correction Curve) shall be investigated to the extent that it can be evaluated in terms of the acceptance standards of the referencing code.

Acceptance standard: All imperfections that produce an amplitude greater than 20% of the reference level shall be investigated to the extent that the operator can determine the shape, identity and location of all such imperfections and evaluate them in terms of respective / applicable acceptance standards. Imperfections that are interpreted to be cracks, lack of fusion or incomplete penetration are unacceptable regardless of length.

Reports: A report of the examinations shall be made. The report shall include a record indicating the welds or volume examined (this maybe marked-up in sketches) the location of each recorded reflector, and the identification of the operator for having performed the examination.

Ultrasonic Thickness Measurement

Equipment: Ultrasonic thickness gauge is used to measure thickness of a metallic and non–metallic material from one side applying nondestructive test technique. Access from one side of the object / test specimens is sufficient to measure the thickness, whereas micrometer and caliper need access from both side to measure the thickness.

Working Principle:

An ultrasonic thickness gauge also known as "D-Meter" is an instrument that generates sound pulses in a test piece and very precisely measures the time interval until echoes are received.

Having been programmed with the speed of sound in the test material, the gauge utilizes the sound velocity information and the measured time interval to calculate the thickness through the simple relationship [distance] equals [velocity] multiplied by [time].

Thickness, Tk = (V) x (t/2)

where

Tk = the thickness of the part

V = the velocity of sound in the test material (This velocity will be different for different materials.)

t = the measured round-trip transit time (Sound travelling time from thickness measuring probe to reach the backwall and return to the thickness measuring probe.)

Accuracy of Thickness Measurement

Ultrasonic gauges have measuring accuracies as high as +/- 0.001 mm, on common engineering materials. Accuracy of thickness measurement depends on

a. uniformity of sound velocity in the test material, b. the degree of sound scattering or absorption

b. the surface condition and accuracy

c. and care with which the instrument has been calibrated for the respective application.

Exercise

I. Answer the following questions.

1. Why should a pipe fitter have knowledge on NDT?

----

2. Define lux What is the minimum light intensity required the visual examination surface?

----

3. Describe the principle and processes of penetrant testing.

----

4. What are different penetrant testing methods and techniques?

----

5. What are the type of developers available and how are they applied while performing penetrant testing?

----

6. What are different Magnetic Particle Testing methods and techniques that are normally employed?

----

7. How do magnetic particles get accumulated and defect the image formed?

----

8. What are the three main steps of magnetic particle examination procedure?

----

9. What are the weld defects that can be detected by Radiography Testing?

II. State whether the following statement True or False.

1. Liquid penetrant examination method is suitable for detecting subsurface discontinuities.

   True ☐ False ☐

2. NDT shall be performed only by trained, qualified and certified personnel in the respective NDT method.

   True ☐ False ☐

3. "Dwell time" is the period on the developer remains in the inspection surface.

   True ☐ False ☐

4. The minimum light intensity required for visible dye penetrant examination is 1076 lux.

   True ☐ False ☐

5. In magnetic particle testing, maximum sensitivity will be to linear discontinuities that are oriented parallel to the lines of flux.

   True ☐ False ☐

6. Gamma rays are produced by radioactive isotopes - Iridium 192, Cobalt-60, Selenium 75.

   True ☐ False ☐

7. Ultrasonic thickness gauge is used to measure thickness of metallic and non-metallic materials.

   True ☐ False ☐

Notes

2.3.18 Welding Methods

At the end of this topic, you will be able to:

1. list the different methods of welding
2. explain about automatic pipe welding
3. describe the advantages of automatic welding process.

Introduction

The piping industry is roughly divided into three major categories – pressure piping, transmission and distribution piping, non–critical piping.

Transmission and distribution pipelines transmit oil, gas and petroleum products from the producing fields to the consumers. Welding this type of piping necessitates special techniques and procedures.

The cross-country transmission pipeline welding techniques have become extremely sophisticated. Welding procedures and techniques vary based on the diameter of the pipe.

Welding methods

There is more than one method of applying welding and some require manipulative skills. The methods of applying welding are defined:

1. **Manual welding:** Welding with the electrode holder, torch or gun held and manipulated by hand. For example : SMAW, GTAW processes.
2. **Semi-automatic welding:** In semi-automatic welding, the wire feeder maintains the arc and feeds the wire. The welder's job is to manipulate the arc along the joint. For example; GMAW, FCAW, SAW processes.
3. **Automatic welding:** All the welding parameters are preset and the entire operation from start to finish is accomplished by the equipment. The operator's role is nil / negligible.

Fully automatic welding demands expensive sophisticated controls and perfect fitup and alignment of the joint, which are beyond the capability of an average fabrication shop. For example; SAW, GMAW, FCAW processes.

Automatic welding without filler metal additions shall be done using the flash-butt welding process.

4. **Machine (Mechanised) welding:**

It is an intermediate step between semi-automatic and automatic versions. In machine welding, the wire feeder maintains the arc and feeds the filler wire, and a travel device provides the relative motion between the arc and the joint.

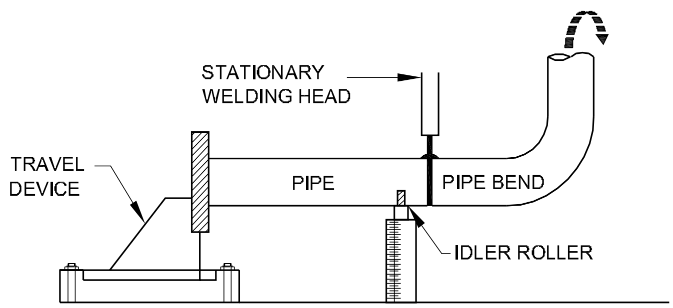


Fig. 2.3.118 Universal Positioner

In general, the design of weldments are made keeping the following factors in mind:

- achieving the highest joint efficiency
- improving the accessibility to the weld area
- minimizing cost of edge preparation and reducing the amount of weld metal deposited
- visualizing after effects like distortion, etc.

Automatic Pipe Welding

Automatic welding uses the same basic elements of machine welding plus a welding cycle controller. In arc welding, the electrode or welding rod is fed automatically into the arc to compensate for its melt-off to maintain the correct length of arc. Granulated flux or shielding gas, when called for by the specific process, is also fed automatically through the welding head.

The shielded metal arc welding process has been used and still is the predominant welding process for field girth welding. However, the use of semi–automatic and automatic gas metal arc welding is increasing steadily. Self – shielding and gas shielding flux cored arc welding is also used. In some cases, automatic welds are made on the inside diameter of the pipe.

Welding Operator

One who operates the machine or automatic welding equipment. Each welding unit and each operator shall be qualified by producing an acceptable weld using the qualified welding procedure.

Each operator be adequate by trained in the operation of the equipment prior to the start of welding and shall be thoroughly familiar with the equipment they operate.

Welder

Welder is one who performs manual or semi-automatic welding.

Advantages of Automatic Welding

Successful application of automatic welding offers the following advantages:

- Consistent weld quality
- Reduced welding costs through predictable weld time
- Increased productivity through higher deposition rates
- Increased productivity through higher operator factor
- Minimized operator skill and reduced training requirements
- Operator away from the welding arc area for safety and environmental reasons
- Better weld appearance.

Fig. 2.3.119 Auto Weld bead appearance

Exercise

I. Answer the following questions.

1. What are the four methods of welding?

----

2. Can more than one welding process be used to make a pipe weld?

----

3. Can gas metal arc welding be used on pipelines?

----

4. What are the advantages of automatic pipe welding?

----

5. What method of application requires the least manipulative skill?

----

6. Explain the difference between the welder and the welding operator.

II. State whether the following statement True or False.

1. GMAW process can be done by semi-automatic and automatic welding methods.

   True ☐ False ☐

Notes

2.3.19 Design Data

At the end of this topic, you will be able to:

1. define and differentiate various terms related to pressure and temperature of piping system
2. list the causes and reasons for pressure drop / pressure losses in fluid carrying piping / pipelines
3. define velocity and its unit
4. explain hydrostatics and hydrostatic test pressure.

Pipe fitters should understand the different design and installation data briefly to have idea about the piping / pipeline operating conditions and for participating in hydrotest. Installation data including the required hydrotest pressure, will be available in approved drawings / drawing package. Pipe fitter shall go through the drawing packages to know the installation data. In piping / pipeline design, the three major factors that need to be considered are pressure, temperature and nature of process / transmitting fluid.

1. Pressure

a. **Absolute pressure:** It is measured relative to absolute zero on the pressure scale, which is a perfect vacuum. Absolute pressure can never be negative. Absolute pressure decreases with elevation, just as water pressure increases with depth.

b. **Operating pressure (OP):** It is the actual gauge pressure which prevails inside equipment and piping during any intended operation. Operating pressure is the pressure at which the piping / pipeline is going to be operated or being operated at normal conditions.

c. **Maximum Operating Pressure (MOP):** The MOP is the highest gauge pressure which provides sufficient flexibility for the control of the intended operation. This is the maximum operating pressure the piping system can encounter during the operation.

d. **Maximum Allowable Operating Pressure (MAOP):** This is the maximum possible safe pressure the pipe / pipeline walls can withstand. This is different from MOP.

Design pressure (DP)

The DP is the gauge pressure at the top of the equipment / piping, in its operating position. It is used as the basis to determine the minimum thickness of equipment parts / pipes.

Maximum Allowable Working Pressure (MAWP)

The MAWP is the maximum gauge pressure permissible at the top of the equipment or the weakest point of equipment operating position at a designated temperature.

2. Temperature

Operating Temperature (OT): The OT is the temperature which prevails inside the equipment and piping during any intended operation.

Design Temperature (DT): It is the highest temperature at which equipment / piping / pipeline may be subjected to. The DT shall not be lower than the MOT. The DT is used for mechanical design (determination of minimum wall thickness and other physical characteristics) of equipment and piping.

Minimum Design Metal Temperature (MDMT) - It is the minimum metal temperature used in the design of a pressure vessel.

3. Pressure Drop / Pressure Loss and Frictional Losses

- Pressure drop is defined as the difference / decrease in total pressure between two points of a fluid carrying network / fluid flow system. Pressure drop occurs when frictional forces caused by the resistance to flow act on a fluid as it flows through the pipe.

Pipe Elevation Changes and Effect on Pressure Loss

As fluid flows through a piping system, where pipes rise and fall, changing elevation, the pressure at a particular point in a pipe is also affected by the changes in elevation of the fluid that flows.

For example, consider a single vertical pipe where the fluid is flowing upwards, gaining elevation height as it goes. The weight of fluid acting 'on top' of the fluid at a point in the pipe reduces as we consider points higher up the pipe, since there is less fluid above it. Therefore, there is a loss of pressure in the pipe as the fluid rises.

Conversely, at the bottom of the vertical pipe there is full weight of fluid in the pipe 'pushing down' on that point. due to this, the pressure at that point increases (in comparison to the pressure on the fluid at the top of the pipe). Therefore, there is a gain in pressure in the pipe as the fluid falls.

4. **Velocity**

   Velocity is a measure of how fast something moves in a particular direction. Its unit is distance travelled per unit time (for example, m/sec). The flow velocity of a fluid is the distance the fluid travels in a given period of time.

5. **Hydrostatics:** is the branch of fluid mechanics that studies "fluids at rest and the pressure in a fluid or exerted by a fluid on an immersed body". Hydrostatics is categorized as a part of the fluid statics, which is the study of all fluids.

6. **Hydrostatic Test Pressure**

Pipe fitter shall understand hydrotest pressure clearly. In construction sites, pipe fitters also will be involved in hydrotesting to install blinds, valves, bolts / studs, pressure gauges, pressure and temperature recorders, install vents and drains and assemble hydrotest manifold.

Hydrotest pressure is a leak test to be performed to check the tightness and integrity of the pipeline. Water is the preferred fluid for hydrotest.

For process pipeline as per ASME B31.3, the hydrostatic test pressure at every point in a metallic piping system shall be not less than 1.5 times that of the design pressure.

For liquid hydrocarbons and other liquids pipeline transportation systems as per ASME B31.4, the hydrostatic test pressure shall be not less than1.25 times that of the internal design pressure.

For gas transmission and distribution metallic piping system as per ASME B31.8, the pipe shall be hydrostatically tested. It shall be at least 1.25 times the maximum allowable operating pressure if installed in a Class 1 location. It shall be at least 1.5 times the maximum allowable operating pressure if installed in a Class 2, 3, or 4 locations that include offshore pipelines. However, the test pressure stated in approved construction drawings shall be followed.

Exercise

I. Answer the following questions.

1. Differentiate operating pressure and maximum operating pressure.

   ----

2. Explain the term "Maximum Allowable Working Pressure".

   ----

3. What are the factors that contribute to pressure drop / pressure loss.

   ----

4. Describe frictional losses, which contribute pressure drop.

   ----

5. Explain the effect of pressure loss that is likely to occur due to pipe elevation changes.

   ----

6. Write short notes on hydrostatic and hydrotest pressures.

II. State whether the following statement True or False.

1. MDMT stands for "Maximum Design Metal Temperature".

   True ☐ False ☐

2. Up to certain limits, the higher the flow rate, the lower the pressure drop shall be.

   True ☐ False ☐

3. Gauge pressure can be negative.

   True ☐ False ☐

4. Maximum operating pressure shall be lower than the design pressure.

   True ☐ False ☐

5. Maximum Allowable Working Pressure (MAWP) is the pressure permissible at the strongest point of the equipment operating position at a designated temperature.

   True ☐ False ☐

6. Velocity is distance travelled per unit time.

   True ☐ False ☐

Notes

2.3.20 Tubes and Application

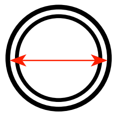
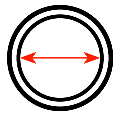
At the end of this topic, you will be able to:

1. define different types of tubes and manufacturing process
2. state different grades of tubes and their sizes
3. describe various applications of metallic tube in oil and gas industry.

Tube: Tube is a circular metallic structural member used in oil and gas industry, or is a cylindrical body of metal used, especially, for conveying liquid or gases.

Difference between Tube and Pipe

	Tubes	Pipes
Size	Tubes sizes are specified in mm millimeter or inches by outsize diameter (OD)	Pipes sizes specified in Nominal Pipe Size (NPS) or Nominal Bore (NB) or Diameter Nominal (DN)
Thickness	Wall thickness is expressed in millimeter (mm) or inches	Wall thickness is expressed in schedule number SCH-40, SCH-80, SCH-100

Diameter	OD–Outside diameter of tube is numerically equal to the corresponding size	The outside diameter of pipe up to size 12” is numerically larger than the corresponding pipe size
Uses	Used in all processes of piping and utility piping, structural members, etc.,	Used in Boiler, Heat exchanger, instrument connection, structural members, etc.
Images	Tube Cross Section Image  Tube Size is Always in OD	Pipe Cross Section Image  Pipe Size is always NB Nominal Bore up to 14” ϕ diameter

Tube Manufacturing Process:

There are three different methods of manufacturing. They include:

Seamless method, Welding method, Cold finishing method.

Seamless method

Steel tube products produced by seamless process are made in different diameters by hot extrusion.

Welding method

In this method, products are produced / longitudinally. Formed cylinders are joined and welded in the longitudinal seam welding process.

Cold Finished Tube

Both seamless and welded, tubes may be cold finished. The process may be used to increase or decrease the diameter, to produce a smoother surface.

Hot Finished Tube

Tubes made and finished by a hot working process. It is, generally, applied to seamless tubes.

Types of Steel Tubes and Grades

- carbon steel tubes
- alloy steel tubes
- stainless steel tubs
- copper tubes
- nickel and Nickel alloy tubes
- aluminium tubes
- titanium tubes

Fig. 2.3.120 Pipes and Tubes

Fig. 2.3.121 Carbon Steel Tubes & Pipes

Carbon Steel Tube

Carbon steel is an alloy made of iron and carbon. The carbon percentage can vary depending on the grade. It is mostly between 0.2% to 0.35% by Weight. Carbon is the main alloying element for carbon steel, and the properties are mainly defined by the amount of carbon it has.

Carbon – Steel Tube Grades

SA 209 – Grade T1 – Hot Finished

SA 210 - Grade A – 1 – Hot Finished – High temperature application for example, super heater tubes

SA 333 – Gr – 3 – Normalized – Low Temperature application

MATERIALS IBR – Carbon Steel Tube ASTM A 179, ASTM SA 210 - Grade A

IBR – Alloy Steel Tubes – ASTM / ASME / SA 213 Gr - T1, T5, T9, T11, T12, T21, T91.

Carbon Steel Tube Application

Some common oil and Gas industry application of metal tubes are:

- Boiler and pressure vessel manufacturing
- Automobile manufacturing
- Non-Corrosive Materials Transportation.

Fig. 2.3.122 Alloy Steel Tubes

Alloy Steel Tubes

Alloy steel tubes comply to ASTM Grade A 335, the specification that covers seamless ferritic alloy steel tubes suitable for high temperature applications. Alloy steel tubes that contain Chromium (cr), Moly (mo), Cobalt (Co), Titanium (Ti), Niobium (Nb), etc., are examples.

Alloy Steel Tubes Grades

Alloy Steel Tubes Grades – ASTM A 335 Gr T5, T9

ASTM A 335 Gr – T22, T91.

Fig. 2.3.123 Stainless Steel Tubes & Fitting

Alloy Steel Tubes Applications

Alloy steel tubes uses include: Oil and Gas industry, chemical Industry, Boiler Water Supply Systems, Power Plants, Paper and Pulp industry, etc.

Stainless Steel Tube

Stainless steel tube is made with alloys of Chromium and Nickel, Molybdenum (mo). Stainless steel has a broad range of properties like, higher Corrosion and temperature resistance, more attractive appearance. Stainless steel tubes comply to ASTM A 312, a specification that covers SS Tubes for corrosive services and high temperature applications.

Applications

Stainless steel is mainly used industries like Oil and Gas, Chemical, Aerospace, Automobile, Construction, Instrumentation, Heat Exchanger's, etc.

Copper tubes

Copper tube is supplied in accordance with ASTM Standard is a minimum of 99.9 per cent pure copper. The copper which is used to these specification is deoxidized with phosphorus.

Copper Tube Grades

IS 191 – Indian Standard for Copper Specification

Copper Tube Alloy C – 12200 – Deoxidized Copper

Copper Alloy – C 19400 – Good Electrical and thermal conductivity application

ASTM B – 280 – Copper tube for Air Conditioning

ASME B 16.15 – Copper alloy threaded fittings

Copper tube application

Main application of copper is for

- heating, cooling and their systems
- plumbing, Air conditioning and Refrigeration System

Fig. 2.3.124 Copper Tubes

- cold and hot water system
- non-flammable medical Gas piping system
- solar energy system.

Nickel and Nickel Alloy Tubing

Tubes are made of corrosion resistant Nickel alloy, adding chromium (cr), Molybdenum, Copper and other elements. It gives them an even higher resistance to oxidation and corrosion which makes it possible to use them in wider applications.

Nickel and Nickel Alloys Tube Grade

UNS 8825 – High strength and high corrosion resistance

UNS 6625 – Gr 1 High temperature and corrosion resistance service

UNS 6625 – Gr 2 Nickel alloy tubes and pipes

ASTM B 163 Nickel Gr 200 Seamless tube

ASTM B 163 - Gr 201 - Seamless tube

Fig. 2.3.125 Nickel Alloy Tubes

Nickel Alloy Tubing Applications

- Good Resistance to aqueous corrosion
- Chemical Industries
- Oil and Gas Industries
- Marine Industries
- Aerospace application
- Heat Exchangers
- Instrumentation tubing
- Sub-sea Oil and Gas Control instruments, etc.

Titanium tubes

Titanium is a chemical element with symbol - Ti. It is a seamless tube with a silver colour, low density with high strength, good corrosion resistance material.

Titanium Tubes Grade

Pure Titanium Grade 1, 2, 3, 4, 7, 11

Titanium Alloys – 6 Al – 4V ELI - Grade 5, 23

Fig. 2.3.126 Titanium Tubes

Titanium tube application

Titanium tubes various applications include

- Oil and Gas – High pressure and high temperature applications
- Aerospace – Titanium is used for the airframe and engine components
- Power generation plants for condenser tubing
- Chemical processing industries.

2.3.21 Tube Cutting and Bending

At the end of this exercise, you will be able to:

1. prepare a layout for tube bending
2. mark and cut tubes to the required length using pipe/tube cutter
3. bend the tube to the desired angle using tube/pipe bending machine
4. check the bend tube for the correctness of angle.

Requirements	
Tool/Instruments	**Materials / Components**
Measuring Tape – 1 No. Try Square – 1 No. Spirit Cutter – 1 No. Tube/pipe cutter – 1 No. Welding Machine Grinding Machine	1” ϕ – Copper tube/CS-tube – 2 meters Marker Pen – 1 No. Dune sand – as required

Practical

- Check the outside diameter of the tube by using measuring tape
- Measure the required length of pipe and mark it with marker
- Place the tube in the pipe vice and tighten it
- Fix the pipe/tube cutter on the copper tube (on the marked line) and tighten the jackscrew of the cutting wheel
- Rotate one or two turns to ensure that the cutting wheel is pointing exactly on the marked line at 90° to the tupe
- Rotate the tube cutter around the tube and increase the pressure to the cutter by repeating the cycle until the tube is cut through
- Remove burrs using deburring tools and check that the pipe ends are square
- Mark centre line of the tube and fix the tube in the bending machine
- Bend the tube by pulling the bending arm towards your
- Check the angle of bend and radius using the standard template

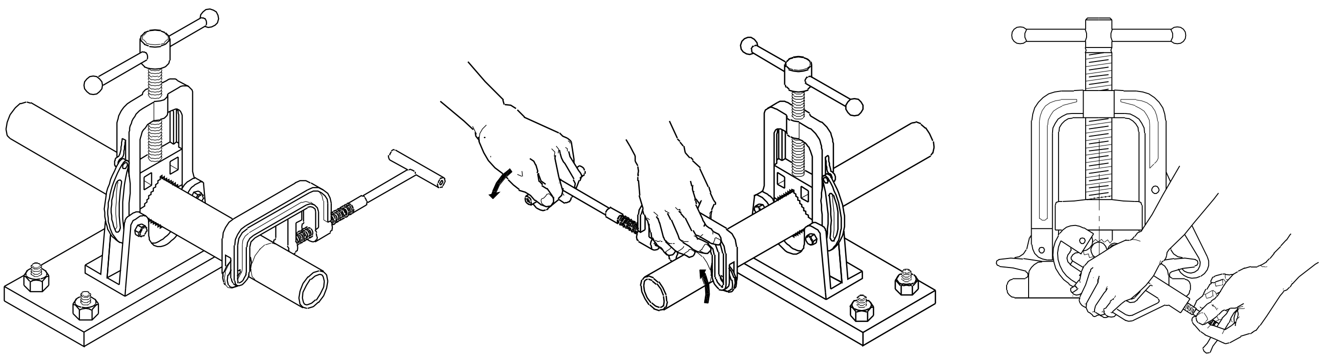
Tips

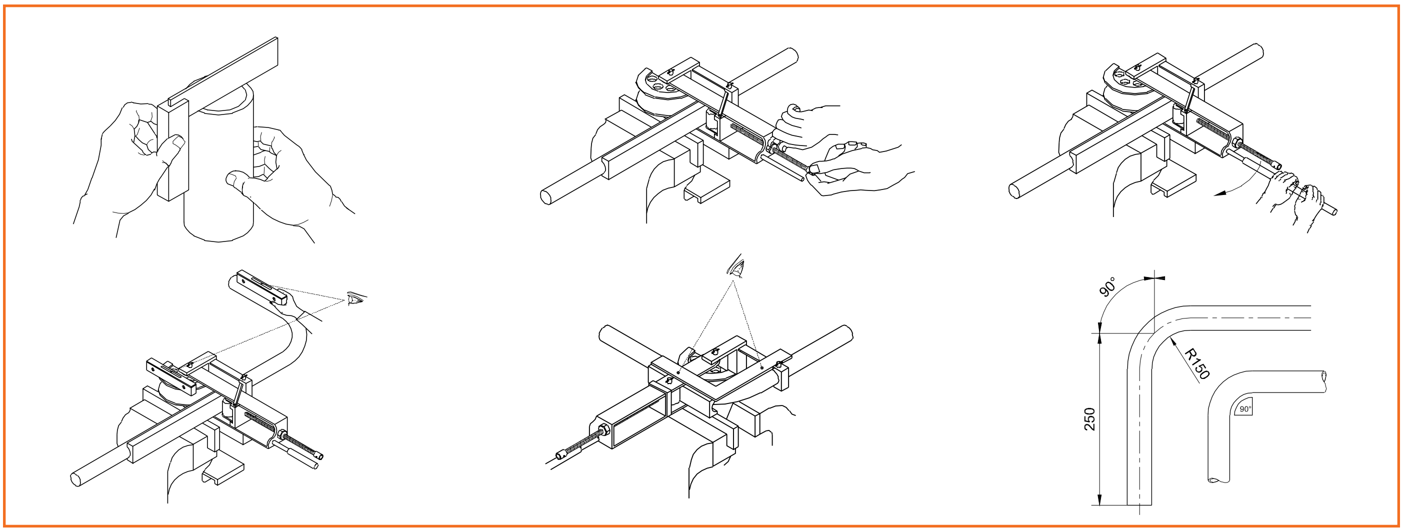
Use appropriate ‘PPE’ (Personal protective equipment)

Bend shall be smooth and free from particles.

Apply gradual/uniform bending force.

Various Stages of Tube Bending





Exercise

I. Answer the following questions.

1. Define tube.

2. What are the main differences between tube and pipe?

3. What are the three different methods for tube manufacturing?

4. State the name of the different types of tubes.

5. What are the applications of carbon steel tube?

6. Why are nickel alloy tubes better than stainless steel tubes as heat exchanger?

7. What are the applications of titanium tubes?

8. State a few grades of carbon and alloy steel tubes.

II. State whether the following statements are True or False.

1. Tubes are always measured by OD (outside diameter).

   True ☐ False ☐

2. Seamless tubes are always used in high pressure and temperature applications in the oil and gas industry.

   True ☐ False ☐

Notes

2.3.21 Branch Connection

At the end of this topic, you will be able to:

1. list the function of branch fittings
2. prepare a template for 'T' joint.

Pipe Fitting: A fitting is used in pipe systems to connect the straight pipe or tubing sections, adapt to different sizes or shapes and for other purposes such as regulating fluid flow.

Tee: A tee is the most common pipe fitting. A tee is used for connecting pipes of different diameters or for changing the direction of pipe runs. They are categorized as equal and unequal.

Tips

It is a short piece of pipe with a lateral outlet.

Butt welding tees should be used for branches equal in diameter to the run pipe.

Tee Joint: T-joint is a joint between two members located approximately at right angles to each other in the form of a T. With oil and gas piping, there is a need for cutting holes (run opening) at intersections (main member) and as a result, the branch connections have full penetration butt welds.

Branch connection welds: Branch connections that abut on the outside surface of the run pipe shall be contoured for groove welds that meet the welding procedure specification requirements.

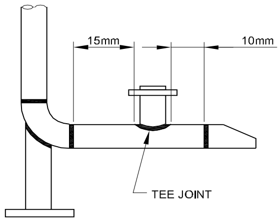


Fig. 2.3.127 Tee Joint

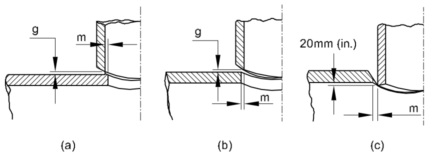


Fig. 2.3.128 Branch connection weld

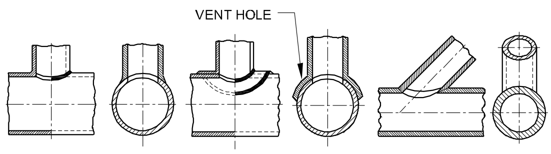


Fig. 2.3.129 Typical Welded Branch Connections

Cutting of branch pipe: Branch pipes in mild steel may be cut on a special oxy-fuel gas profile cutting machines. Where such equipment is not available, the branch can be produced by marking the outline using a template figure as shown and scriber or pointed chalk followed by centre punching.

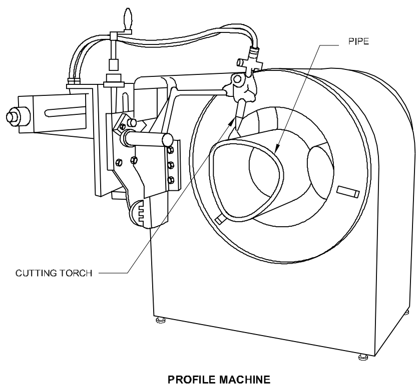


Fig. 2.3.130 Profile Cutting Machine

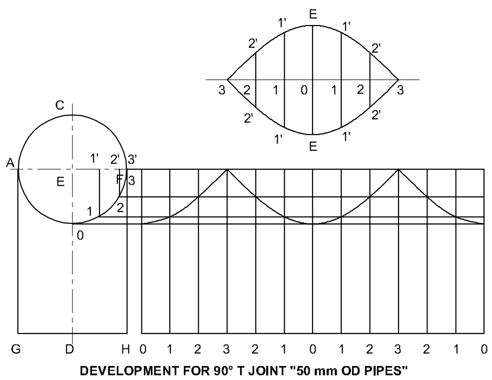


Fig. 2.3.131 Development of the Branch Pipe

The branch can then be produced by cutting to the marked outline, using manually operated oxy-fuel gas cutting equipment.

After cutting to the contour of the branch, align the branch pipe on the top of the main pipe, marking the outline and cut the hole (run opening).

Remove any burrs on the inside of the pipe by reaming or filing or grinding.

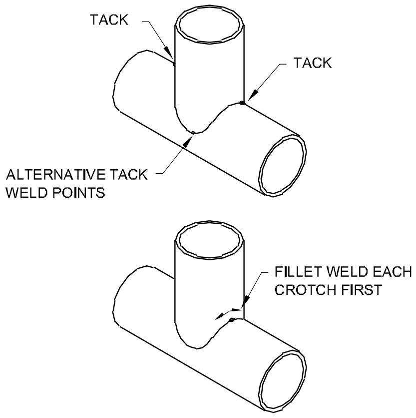


Fig. 2.3.132 Fitup of "T" Joint

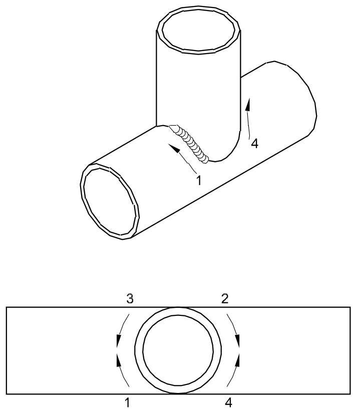


Fig. 2.3.133 Welding Sequence

The joint must be very carefully prepared by beveling the edges as per WPS, so that a good fit-up is obtained.

Set and align the branch pipe with the main pipe at an angle of 90° and tack weld the joint.

Use sequence welding technique on 'T' joints. This prevents weld metal contraction from pulling the pipe out of line.

Tips

Do not cut or weld in rooms containing inflammable materials, gases, vapours or liquids or flammable paint.

II. Outlets

Outlet fittings (also called branch connection fittings or Outlet fittings) are fittings which provide an outlet from a larger pipe to a smaller one (or one of the same size). The main pipe onto which the branch connection is welded is usually called the run or header size.

Tips

Good House Keeping Reduces Fire Risk.

There are several types of outlets available. The mostly used outlet fittings are weldolets, sockolets, nipolets and nipoflange.

Weldolet

Weldolet (weld - o - let) is basically self reinforced fittings. Weldolet is used for butt weld branch connection where standard tee is not available due to size restrictions and the piping is of critical / high pressure service.

Every fitting is produced with a base shaped to fit the header pipe or vessel. This provides an accurate alignment aid and base weld definition for the correct installation of the fitting. The outlet end in the case of the Buttweld, outlet has an accurately machined branch weld bevel, ready for fabrication. The flanged Buttweld outlet and Flanged Nipple outlet have accurately machined flanged outlets. Bolt holes straddle the fitting centre line in accordance with normal engineering practice.

Welding of Weldolet

The cross section of the weldolet is fully welded out. The skirt weld profile is achieved by fully welding out this section. The flanged range of fittings should be welded out in a similar manner to the buttweld outlets. Failure to fully weld out these fittings in accordance with the details given above would give adverse effects to strength, stress intensification factors and area reinforcement.

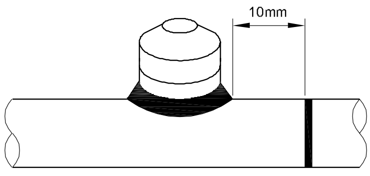


Fig. 2.3.134 Weldolet

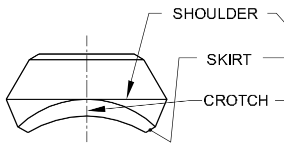


Fig. 2.3.135 Butt Weld Outlet

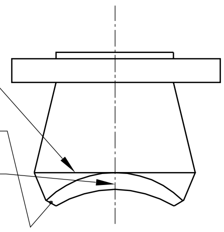


Fig. 2.3.136 Flanged Butt Weld / Nipple Outlet

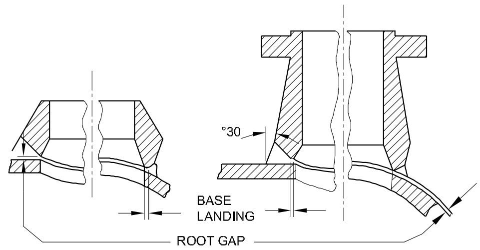


Fig. 2.3.137 Welding of Weldolet

Exercise

I. Answer the following questions.

1. What is Weldolet and where is it used?

----

2. What is Tee and where is it used?

----

3. How is branch pipe contoured?

----

4. Name any 3 types of outlets.

----

5. What is the importance of weldolet fittings welding?

II. State whether the following statements are True or False.

1. The cross section of the weldolet is fully welded.

   True ☐ False ☐

2. Good housekeeping increases fire risk.

   True ☐ False ☐

3. A tee is used for connecting pipes of same diameter only.

   True ☐ False ☐

Notes

2.3.22 Brazing, Soldering and Flash Butt Welds

At the end of this topic, you will be able to :

1. solder a sheet metal joint
2. braze a pipe fitting joint
3. describe electrical resistance butt welding and flash butt welding methods.

1. Brazing

Brazing is a group of joining processes that produce coalescence of materials by heating them to the brazing temperature in the presence of filler metal having a liquids above 450°C and below the solids of the base metal. The filler metal is distributed between the closely fitted surfaces of the joint by capillary action.

The temperature at which filler metal start to melt on heating is the solidus temperature, the liquidus temperature is the higher temperature at which the filler metal is completely melted. The liquidus temperature is the minimum temperature at which brazing will take place.

Applications

The brazing process is used in joining copper and other metals. Corrosion resistance is one of the main requirements of the kinds of piping and fittings commonly assembled by brazing. Accurate assemblies can be made by brazing. Temporary or emergency piping can be assembled rapidly by brazing.

Fig. 2.3.138 Brazing Fitting

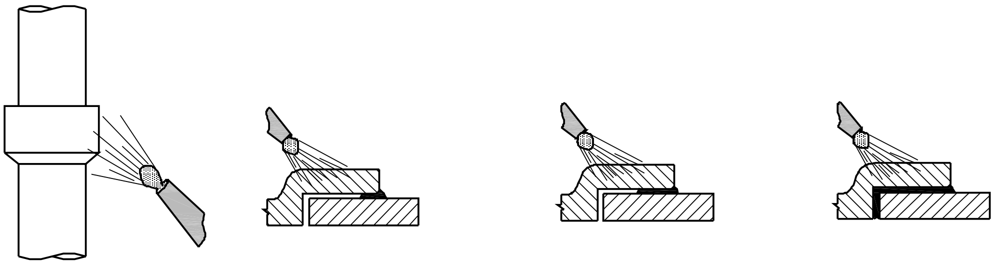


Fig. 2.3.139 Torch Brazing

Perform a brazing method

Brazing processes are customarily designated according to the sources or methods of heating. Industrial methods are the following:

- torch brazing
- furnace brazing
- induction brazing
- Dip brazing
- Infrared brazing
- resistance brazing

Whatever be the process used, the filler metal has a melting point above 450°C, but is below that of the base metal, and it spreads within the joint by capillary action.

Torch Brazing

Manual torch brazing is probably the most widely used brazing method. The following procedure should be followed for brazing carbon steel (mild steel) pipe fitting.

(a) Lap joint is commonly used since it provides for sufficient faying surfaces to attract the filler material.

(b) Select carbon steel pipe with diameter of 1 1/2 inches and carbon steel fitting to match the pipe diameter.

(c) Choose and apply a flux in accordance with the brazing procedure specification.

(d) Assemble the joint by inserting the pipe into the socket of the fitting, hard against the stop.

(e) Brush additional flux at the joint around the chamfer of the fitting. A small twist of the pipe and fitting helps to spread the flux over the two surfaces. The joint is now ready for brazing.

(f) Use an oxyacetylene torch for brazing and adjust the flame to neutral or slightly excess acetylene.

(g) Heat the pipe. continuously after the flux starts to bubble and until the flux becomes quiet and transparent like water.

(h) The flame must be kept moving to avoid burning the pipe or fitting.

(i) Apply the brazing rod at a point where the pipe enters the socket of the fitting.

(j) When the joint is filled, a continuous fillet of brazing alloy will be completely visible around the joint.

(k) Clean the brazed joints.

Advantages of a brazed joint

A brazed joint is a strong joint. A properly made brazed joint will, in many cases, be as strong as the metals / filler metals joined. The joint is made at relatively low temperatures (540° - 1150°C). Brazing is the case with which it joins dissimilar metals and gives good appearance. Brazing skills can usually be acquired faster than welding skills.

2. Soldering

Soldering is a group of joining processes that produce coalesence of materials by heating them to the soldering temperature and by using a filler metal having a liquidus not exceeding 450°C and below the solidus of the base metals. The filler metal is distributed between the closely fitted faying surfaces of the joint by capillary action. Most of the factors involved with brazing apply to soldering.

Applications

Copper tubes are available in a wide variety of diameters and wall thicknesses, with clean, efficient fittings to serve every purpose. Joints are made effectively by soldering and brazing. Copper tubing and pipe are widely used in ship building, oil refineries, chemical plants, oil lines and refrigeration systems.

Tips

Soldering differs from brazing in that lower temperatures are involved.

- In comparison with welded or brazed joints, a soldered joint has considerably less strength and is used primarily for liquid or air tightness.

Performing a Soldering method

1. Quality soldered joints can be made by following the basic principles of cleanliness, fluxing, joint detail and matching the proper flux and filler metal alloy.
2. Solder is the filler metal used in soldering. The solder has a composition that is different from that of the base metal.
3. The torch for soldering uses a fuel gas air system. Different torches are used for different fuel gases, oxygen or air combinations. The basic principle is to provide uniform heating of the parts being joined.

Fig. 2.3.140 Torch Soldering

4. Proper fluxing and proper fitup of the parts is essential to allow capillary action to pull the molten filler metal into the joint.
5. The normal joint is the lap joint and heat is applied to the joint.
6. After the metal surfaces have been wetted and the space between them has been filled with solder, the joint is cooled to room temperature. After the solder joint is cooled, post cleaning is necessary.

Advantages of a soldered joint

Soldering is an attractive metal joining process. The low temperature used for joining requires little energy input and allows precise control of the process. Modern automation produces large numbers of joints in electrical and electronic circuits. The occasional defective soldered joint can be easily repaired. High joint reliability can be obtained with carefully controlled procedures.

3. Electrical Resistance Butt Welding

A number of welding processes are based on the principle that a current passing through a resistance generates heat. The maximum amount of heat is generated at the point of maximum resistance, which is at the surface between the parts being joined.

The resistance welding processes differ from arc welding in that pressure is used, while filler metal or fluxes are not used.

Resistance welding processes can be classified, based on the type of welds (lap or butt) produced. Spot, seam and projection welding produce lap joints while flash and upset welding produce butt joints. Flash butt welding is a resistance welding process in which fusion is produced by the high localised heat obtained from the electrical resistance between two touching surfaces.

Applications

The most common application of flash welding is in making butt welds. It is used to join thin walled tubes, large pipelines, rounds, squares and annular blanks (flanges, wheel rims, etc.)

Tips

American Petroleum Institute (API) Standard 1104, Welding of pipelines and related facilities covers automatic welding without filler metal additions, shall be done using the flash butt-welding process.

Flash Butt Welding Method

The parts clamped in the jaws are moved towards each other at a constant or accelerated rate until they come into contact. Because the initial contact area is small, an intense current is generated between the parts. The term flash welding derives its name from the flash produced during the process.

Flash butt welds are made on a machine with one stationary and one opposing movable platen, which are provided with clamps. These clamps securely hold the two work pieces to be welded while simultaneously serving to conduct the welding current through these work-pieces.

Basic steps

1. Position and lamp the parts
2. Apply flashing voltage and start platen motion
3. Flash
4. Upset and terminate current.

Flash welds produce a fin around the periphery of the weld, which is normally removed by grinding.

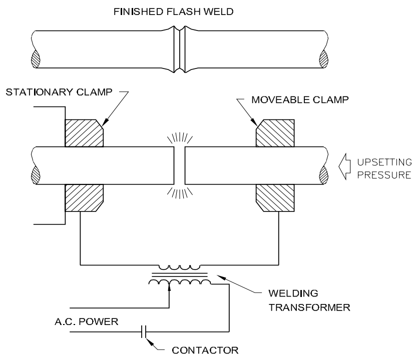


Fig. 2.3.141 Flash Butt Welding

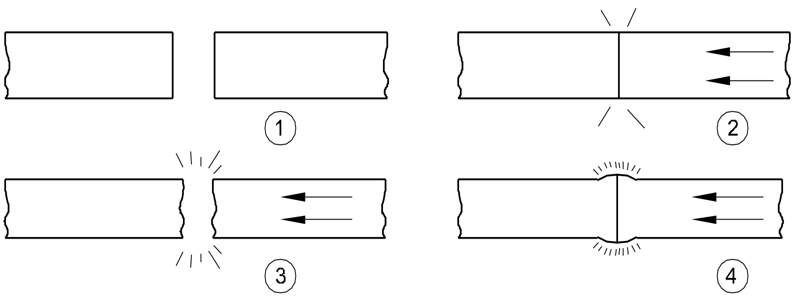


Fig. 2.3.142 Basic Steps of flash Butt Welding

Tips

Safety

The operator should wear face and eye protection and a barrier or shield should be used to block flying sparks. Hands must be kept clear of moving machinery and contact with electrically charged surfaces must be avoided.

Exercise

I. Answer the following questions.

1. Explain the fundamentals of flash butt welding and the steps to be followed.

----

2. Is filler metal required for making a resistance weld?

----

3. What makes flash butt welding different from other resistance welding processes?

----

4. Is it possible to obtain a brazed joint that is stronger than the filler metal?

----

5. What is the difference between soldering and brazing?

----

6. Why is flux required for soldering?

II. State whether the following statements are True or False.

1. In comparison with welded or brazed joints, a soldered joint has considerably less strength.

   True ☐ False ☐

2. Brazing skills can usually be acquired slower than welding skills.

   True ☐ False ☐

Notes

2.3.23 Solders and Fluxes

At the end of this topic, you will be able to :

1. define a solder
2. state the types of solders
3. state the functions of soldering fluxes
4. state different types of fluxes and their applications.

Solder

Solder is the filler metal used in soldering. Solders have a melting point below 425°C. An objective of the soldering process is to optimize solder wetting and spreading to promote a minimum amount of porosity in the joint clearance between the two faying surfaces.

A simple rule of thumb is, if the heating is uniform, then the solder is drawn to the closest fitting surfaces. If the joint clearance is uniform, then the solder is drawn to the hottest surfaces.

Solder Selection

The solder is selected to provide good flow, penetration and wettability in the soldering operation and the desired joint properties in the final product.

Types of Solders

There are a wide range of commercially available solder filler metals designed to work with most industrial metals and alloys. Tin lead alloys are the most widely used solder filler metals.

1. TIN LEAD Solders

Solders are described by identifying the tin content first. 40 / 60, 35 / 65, 50 / 50

For example, – 40 / 60 - 40 percent tin and 60 percent lead

Extensive use of these solders is found in sheet metal work, non – pottable water, plumbing and piping (50 / 50).

2. TIN – Antimony Solder

95 per cent tin, 5 per cent antimony solder is used in many plumbing, refrigeration and air conditioning applications because it has good creep properties.

3. TIN – Silver, TIN – Copper – Silver, TIN – Lead – Silver Solders

96 per cent tin, 4 per cent silver solder is often used to join stainless steel for food handling equipment. The tin - silver and tin - copper - silver solders are the standard alloys used with copper pipe and tubes in potable water systems.

The 62 per cent tin, 36 per cent lead, 2 per cent silver solder is used in electronic applications. High lead solders for automobile radiators and are recommended for cryogenic applications.

4. TIN - Zinc Solders

Alloys containing 70 to 80 per cent tin with the balance zinc are recommended for soldering aluminium.

5. Cadmium – Silver Solder

95 per cent cadmium 5 per cent silver solder is used in copper butt joints.

6. Zinc Based Solder

The 95 percent zinc 5 percent aluminium is specifically for use on aluminium.

Solder product form

Solders are commercially available in variable forms as wire solid is 0.25 to 6.35 mm diameters on spools, foil, sheet or ribbon, bars, ingots – rectangular or circular in shape.

Fluxes

A flux is a chemical cleaning agent flowing agent, or purifying agent. As cleaning agents, fluxes facilitate soldering, brazing and welding by removing oxidation from the metals to be joined.

All metals gets oxidised when exposed to air. This oxide layer must be removed before soldering because it affects proper formation of the joint. For this, a chemical compound called flux is applied to the joint.

Flux Selection

The selection of a flux is primarily driven by the base material and specifically by the type and thickness of surface oxide that is to be removed. Functions of the Fluxes include:

- support of wetting
- reduction of surface oxides on the base metal faying surfaces and molten solder surface
- prevention of further oxidation of the base metal surfaces during the soldering operation and
- the ability to reduce the surface tension of the liquid solder.

Types of Fluxes

Commercial soldering fluxes are normally designated by one of the following types:

(a) rosin based (least active) (b) organic (moderately active) (c) inorganic (most active)

(a) Rosin Fluxes:

The principal ingredient is white - water rosin (a derivative of pine tree sap). It is suitable for use in the electrical industries.

(b) Organic Fluxes: They are composed of such compounds as lactic acid or one of the citric acids. They are used in structural and electrical industries.

(c) Inorganic Fluxes: It contains zinc chloride, ammonium chloride, hydrochloric acid, sulphuric acid or nitric acid. It is used widely in automotive radiator industry. These fluxes can be formulated to provide stability over a wide range of soldering temperatures.

Flux Forms

The standard flux forms are as liquid solutions, pastes and dry salts. For most wire forms of the Sn - Ag and Sn - Ag - Cu solders, the wire has a core of the suitable flux. The 'flux cored wire' allows ease of application with a wire feeder and eliminates the need for a separate fluxing operation.

Tips

Safety

Improper use of solders containing cadmium may lead to health hazards. Therefore, care should be taken in their application, particularly, with respect to fume inhalation.

Workers using solders and fluxes should always wash exposed skin areas before consuming food.

Exercise

I. Answer the following questions.

1. What is the name of the joining method in which the sheet metal joint is obtained by melting a low melting alloy filler metal into the joint?

----

2. What are the two metals contained in a solder?

----

3. Name the flux used for automotive radiator industry.

----

4. Name any three types of solders.

----

5. What is the melting point of solder?

----

6. What are the functions of fluxes?

----

7. Mention the types of fluxes.

----

8. What are the safety precautions to be followed during the soldering process?

II. State whether the following statements are True or False.

1. Solders have melting point above 425°C.

   True ☐ False ☐

Notes

2.3.24 Brazing Filler Metals and Fluxes

At the end of this topic, you will be able to:

1. braze an M.S. square butt joint using oxy acetylene flame, brazing filler rod and flux
2. describe the brazing process.

Introduction

Brazing is one of the thermal joining processes extensively used to join numerous ferrous and non–ferrous metals that can withstand a wide range of service conditions.

Brazing

In brazing, the metals joined together (called base metals) are heated to a suitable temperature at which the brazing filler metal melts. The base metals do not melt and remain intact. The molten filler metal flows into the joint usually by capillary action and alloys with the base metal to create a strong metallurgical bond. Mechanical properties of properly made brazed joints are equivalent to those of welded joints.

2.3.25 Practice inBrazing

At the end of this exercise, you will be able to:

1. braze an M.S. Square butt joint

Requirements	
Tool/Instruments	**Materials / Components**
Wire brush – 1No.	M.S. Tube 1" dia X 3mm thickness – 1No.
Paint brush – 1No.	BAg filler metal – 1No.
Cotton rag – 1No.	Dune sand – as required
Spark lighter – 1No.	
Equipment/ Machines	
OXY-acetylene setup	

Practical

Brazing Skill Sequence

The brazing process requires the following:

filler metal, flux, heat source, techniques.

(a) Joint

Set the M.S. Tube 1" diameter X 3mm thickness as a square butt joint without root gap.

(b) Filler metal

Selection of a filler metal primarily depends on the following criteria:

- type of base metals to be joined
- service temperature
- stress conditions
- corrosive conditions.

  Silver based AWS filler metal bag is selected. (ϕ 1.6 mm).

(c) Flux

Fluxes are always required when using Ag - based filler metals. The function of a flux is:

(a) to minimize oxidation of base metals during initial heating

(b) to completely remove oxide scales from base metal surfaces prior to melting of the filler metal to promote wetting.

Flux residues should also be easy to remove after brazing to prevent corrosion of base metals.

FB 3 - A - AWS Flux classification is selected. (Paste form).

When using Ag - based filler metals, the flux should completely melt and be active at about 700°C just prior to melting of the filler metal.

(d) Heat source

Apply heat to the parts to be joined, preferably with an oxy fuel torch. Manual torch brazing involves broad heating of the assembly by a flame.

Torch brazing is widely used because of its relatively low cost and portability. The same equipment can be used with oxyfuel gas welding. The flame is generated by the combustion of a combination of oxygen and a fuel gas.

The fuel gas is acetylene. The most common flame conditions used are reducing and neutral. Oxidising flames are not recommended for brazing. Neutral flame is selected.

Brazing Techniques

1. Cleaning:

Sound brazed joints require clean, oxide free surfaces. The surfaces to be joined should be thoroughly cleaned of grease, oil, dirt and oxides to ensure uniform flow of filler metal. Once the parts are cleaned, they should be fluxed as soon as possible.

Fig. 2.3.143 Brazing Joint

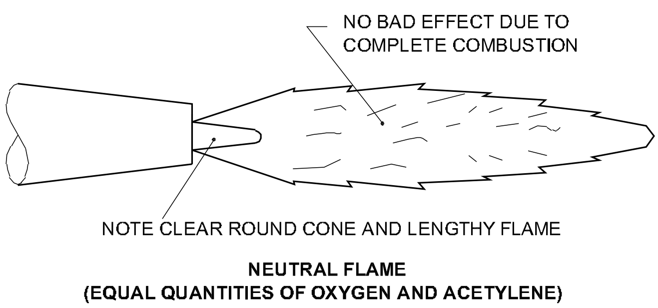


Fig. 2.3.144 Heat Source

2. Fluxing the parts:

Fluxes commonly come in liquid and paste forms. They must be applied evenly over the surfaces to be joined. Fluxes should be applied to the parts before heating. This helps to protec the parts from further oxidation during heating. Fluxes in paste forms are easiest to apply by using a brush. Flux reacts with oxygen, and when it becomes saturated it loses its effectiveness.

3. Assembly:

Parts to be brazed should be assembled immediately after fluxing, before the flux has time to dry and flake off. The clearance between the parts should not be too tight nor it should be too loose. An optimum clearance between the parts is about 0.4 mm.

4. Brazing:

In most manually brazed joints, the filler metal is fed from the face side of the joint. It is helpful to brush some flux on the brazing rod and to play the flame on the rod briefly to warm it up. Set the neutral flame or slightly reducing flame. Heat the plates first, beginning about 25 mm from the edge of the fitting. The active temperature is 450° to 800°C.

It is very important that the flame shall be kept in motion and not remain on any one point long enough to damage the plate.

Apply the brazing rod at the joint when the flux is completely clear. Because the temperature of the joint is hot enough to melt the brazing alloy, keep the flame away from the rod as it is fed into the joint.

Stop feeding as soon as the joint is filled. The key for successful brazing is do not disturb the joint in any way while the brazing filler metal is still motion. Allow it to solidify completely before quenching or moving. Careful adherence to this principle will prevent a lot of braze - quality issues in the brazing operation.

5. Cleaning the brazed joint:

After the brazed joint has cooled, remove the flux residue using warm water (about 50°C) and a clean cloth, brush or swab since flux residues are chemically corrosive. Chemical cleaning is also employed using a mild acid solution to ensure. Proper brazed joint.

Safety :

- At brazing temperature some elements vaporize, producing toxic gases.
- Fluxes contain chemical compounds which are harmful if they are inhaled or contact the eyes or skin.
- It is essential that adequate ventilation should be provided.

Exercise

I. Answer the following questions.

1. What is brazing?

----

2. Which gas flame is used for brazing of M.S. sheets?

----

3. State the temperature upto which the job is heated while doing brazing.

----

4. Name the type of filler rod and flux used for brazing operation.

----

5. Which welding technique is used for brazing of M.S. sheet joints?

----

6. Write down the brazing skill sequences.

II. State whether the following statements are True or False.

1. Mechanical properties of properly made brazed joints are equivalent to those of welded joints.

   True ☐ False ☐

2. Fluxes are not required when using Ag-based filler metals.

   True ☐ False ☐

Notes

2.3.26 Soldering and Brazing Operations

At the end of this topic, you will be able to:

1. explain the basic steps to be followed in brazing and soldering processes
2. carryout high quality soldered or brazed joint.

Joining Process

Brazing and soldering are the most common methods of joining copper tube, and fittings. The choice between brazing and soldering generally depends on the operating conditions of the system and the requirements of the governing construction codes.

The basic theory and technique of soldering and brazing are the same for all diameters of copper tubes. Regardless of the process, soldering or brazing, the same basic steps should be followed, with the only differences being the fluxes, filler metals and amount of heat used. The following are the basic steps for making a high-quality brazed or soldered joint:

1. measuring and Cutting
2. reaming
3. cleaning
4. fluxing
5. assembly and Support
6. heating
7. applying the filler metal
8. cooling, Cleaning
9. testing.

1. Measuring and Cutting

Measure the tube length accurately as inaccuracy can compromise joint quality.

Cut the tube to the measured length. The tube can be cut with a disc type tube cutting tool a hacksaw, an abrasive wheel.

Care must be taken to ensure the tube is not deformed while being cut.

The cut must be square so the tube will seat properly in the fitting cup.

2. Reaming

Remove any burrs on the outside of the tube ends created by the cutting operation to ensure proper assembly of the tube into the fitting cup.

Ream all cut tube ends fully inside the tube to remove the small burr. Tools used to ream tube ends include the reaming blade on the tube cutting device, half-round or round files, a pocket knife and a suitable deburring tool.

3. Cleaning

Clean, oxide free surfaces are essential to ensure sound joints of uniform quality. Failure to remove them can interfere with capillary action and may affect the strength of the joint and cause failure.

Lightly clean the tube ends using sand cloth or nylon abrasive pads for a distance slightly more than the depth of the fitting cup. Clean the fitting cups by using abrasive cloth, abrasive pads or a properly sized fitting brush.

Chemical cleaning may be used if tube ends and fittings are thoroughly rinsed after cleaning.

Do not touch the cleaned surface with bare hands.

4. Fluxing

Apply a thin, even coating of flux with a brush to both tube and fitting as soon as possible after cleaning.

The paste and liquid flux should adhere to clean metal surfaces.

When joining copper or stainless steel or when the heating cycle is long, a concentrated flux is required.

5. Assembly and Support

The parts to be joined should be assembled immediately after fluxing, before the flux has time to dry and flake off. Assemblies designed to be self-locating and self-supporting are the most economical.

Insert tube end into fitting cup, making sure the tube is seated against the base of the fitting cup. A slight twisting motion ensures even coverage by the flux.

Excessive joint clearance can lead to filler metal cracking under conditions of stress or vibration.

6. Heating

Preheating of the assembly should include the entire tube circumference to bring the entire assembly up to a suitable preheat condition.

Heat is generally applied using an oxyfuel torch with a neutral flame.

7. Applying the filler metal

Apply the filler metal at a point where the tube enters the fitting. When the proper temperature is reached, the filler metal will flow readily into the space between the tube and fitting drawn in by the natural force of capillary action.

8. Cooling and Cleaning

Allow the completed joint to cool naturally.

Clean off any remaining flux residue with a wet rag. A thorough water rinse after this is necessary.

9. Testing

Test all completed assemblies for joint integrity.

Every brazed or soldered joint should be visually examined. It is a convenient preliminary test when other test methods are to be used. The tests may be non destructive or destructive. Inspection of joints should always be required to protect the ultimate user, but it is often specified by regulatory codes or by the company / client.

Tips

Safety

Brazing / Soldering fluxes contains Fluorides.

Fumes and gases can be dangerous to your health.

Fig. 2.3.145 Cutting Tube

Fig. 2.3.146 Reaming the Tube Ends

Fig. 2.3.147 Deburing of Tube Ends

Fig. 2.3.148 Cleaning of Tube Ends

Fig. 2.3.149 Cleaning of Fitting

Fig. 2.3.150 Fluxing of Tubes

Fig. 2.3.151 Heating of Torch

Fig. 2.3.152 Clean off Flux Residue

2.3.27 Soldering

At the end of this exercise, you will be able to:

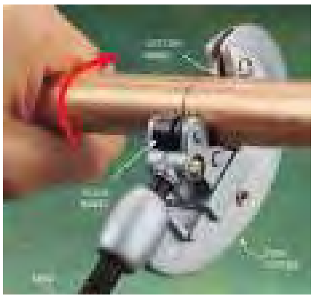
1. solder a sheet metal joint
2. practice the soldering process.

Practical

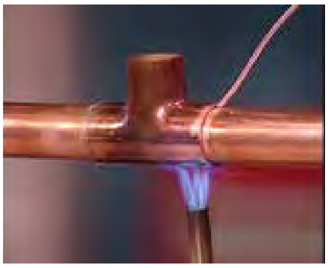
Requirements	
Tool/Instruments Copper tube cutter Reamer, Deburring Emery Sheet Cotton Rag **Equipment/ Machines** OXY - acetylene setup	**Materials / Components** Copper tube ϕ 1” Tin-Lead Solder Organic flux

Performing Soldering

1. Quality soldered joints can be made by following the basic principles of cleanliness, fluxing, joint detail and matching the proper flux and filler metal alloy.
2. Solder is the filler metal used in soldering. The solder has a composition somewhat different from that of the base metal.
3. The torch for soldering uses a fuel gas air system. Different torches are used for the different fuel gas and oxygen or air combinations. The basic principle is to provide uniform heating of the parts being joined.
4. Proper fluxing and proper fitup of the parts is essential to allow capillary action to pull the molten filler metal into the joint.
5. The normal joint is the lap joint and heat is applied to the joint.
6. After the metal surfaces have been wetted and the space between them has been filled with solder, the joint is cooled to the room temperature. After the solder joint is cooled, cleaning is necessary.








Exercise

I. Answer the following questions.

1. What are the most common methods of joining copper tube and fittings?

----

2. Write the basic steps for making a high quality brazed or soldered joint.

----

3. Explain the reaming operation.

----

4. Explain the fluxing operation.

----

5. What are the probable safety hazards during brazing and soldering?

----

6. What are the tests performed on completed joints?

II. State whether the following statements are True or False.

1. Mechanical properties of properly made brazed joints are equivalent to those of welded joints.

   True ☐ False ☐

2. The basic theory and technique of soldering and brazing are the same for all diameters of copper tube.

   True ☐ False ☐

Notes

2.3.28 Mechanical Joint in Piping

At the end of this topic, you will be able to:

1. recognise the flared joint, roll groove, press, push connect joint
2. make mechanical joints.

Flared Joint

A mechanical joint between two pieces of copper or plastic tubing is made by flaring one end of a tube to receive a special fitting which fits in the flare. may be taken apart and reassembled without difficulty. It is especially, useful in areas where fire hazard will not permit the open flame required in soldering or brazing a joint.

Steps to create a joint

2.3.29 Flared Joint

At the end of this exercise, you will be able to:

1. create a flared joint
2. recognise the flared joint.

Practical

Requirements	
Tool/Instruments	**Materials / Components**
Tube Cutter Cotton rag Reaming tool	Copper tube $\phi\ ^{3}/_{4}$” abrasive cloth
Equipment/ Machines	
Flared tool Flared set-up	

Copper tube used for liquified petroleum gas, propane gas or natural gas may be joined using flared brass fittings of single 45° flare type. A flare joint should be made with an appropriate tool such as those supplied by a number of tubing / piping tool manufacturers.

1. It is usually necessary to anneal the end of the tube to be flared, prior to flaring.
2. The copper tube must be cut square using an appropriate tubing cutter.
3. After cutting, the tube must be reamed to the full inside diameter leaving no inside burr.
4. Cleaning can be with the use of an abrasive cloth.
5. Place a flare nut over the end of the tube with the threads closest to the end being flared. Insert the tube between the flaring bars of the flaring tool in the appropriate opening.
6. Position the yoke with the flaring cone over the tube end and clamp the yoke in place. Turn the handle of the yoke clockwise. This lowers the flaring cone and forces the lip of the tube against the base of the flaring bar to create an angled flare that will make securely with a corresponding flare - type fitting.
7. The final flared tube end should have a smooth, even, round flare of sufficient length to fully engage the mating surface of the flare nut without protruding into the threads .

Fig. 2.3.153 Flared Joint

8. No material (pipe joint compound) should be applied to the mating surfaces of the flare fitting and the flared tube end before attaching the flare nut to the fitting body.

Roll Groove Joint: This method of joining pipes has been used reliably on steel and iron pipe in process piping and related applications. This method of mechanical joining is also available in a system of copper tube in sizes 2 through 8 inches. The system offers a practical alternative to soldering and brazing large diameter copper tube.

And most importantly it requires no heat or open flame, soldering or brazing. Copper roll groove joining takes advantage of copper's excellent malleability and its increased strength when cold worked.

Steps to create a joint

1. Examine the roll groove tube to ensure there are no dents, deep scratches, dirt, oils, grease or other surface imperfections.
2. Measure the tube length accurately.
3. Cut the tube end square, perpendicular to the run of the tube.
4. Remove burrs from the I.D. and the O.D. of the tube end by reaming the I.D. and chamfering the O.D. using appropriate tools.
5. Roll groove the tubing to the proper dimensions as required.
6. Examine the fittings, gaskets and clamps to ensure that proper gasket is inserted into the clamp and the fitting end is not damaged.
7. Lubricate the gasket as per manufacturer's recommendations.
8. Inspect the clamping surfaces to ensure taht they are clean and free from debris.
9. Assemble the joint according to the manufacturer's recommendations.
10. Tighten the clamping nuts to the proper torque.
11. Inspect the tightened clamp to ensure it is properly assembled.

Press Connect Joint

Press - connect joints for lower pressure plumbing, process piping and many non-medical grade compressed gases utilize a single standard hexagonal press pressing pattern.

Steps to create a joint:

1. Full depth of insertion into the fitting shall be clearly marked prior to inserting the tube into the fitting.
2. Crimping jaw choice and jaw placement prior to crimping are the same as described previously.

Fig. 2.3.154 Different types of mechanical joints

Fig. 2.3.155 Copper Tube press fit joint

3. Once the pressing process has been completed, the jaws can be removed from the fitting and visual examination of the final pressed fitting shall be performed. It is imperative that the tube has remained fully inserted after the pressing process.
4. The completed double 360° crimp shall be inspected for the appropriate crimp mark as required by the fitting manufacturer.
5. The crimp locations shall be checked with the go - no - go gauge, provided in the pressing kit, to ensure that the press process has been completed correctly.

Push Connect Joints

Like the press connect joining method, the push connect joining of copper and copper alloy tube is fast, economical and also requires no heat or open flame. However, unlike most other joining methods, no additional tools, special fuel gases or electrical power are required for installation.

Push connect joining utilizes an integral elastomeric gasket or seal (such as EPDM) and stainless steel grab ring to produce a strong, leak free joint. There are two common types of push connect fittings. Both create strong, permanent joints, however, one allows for easy removal after installation to allow for equipment service, while the second type cannot be easily removed once the fitting is installed.

Steps to create a push connect Joint

1. Measure the tube accurately to ensure it will socket to the back of the fitting cup.
2. Cut the tube square, perpendicular to the run of tube, using an appropriate tubing cutter.
3. Remove burrs from the I.D. and O.D. of the cut tube end by reaming the I.D and chamfering the O.D. using appropriate tools.
4. Chamfering the cut tube end is required to reduce the possibility of gasket damage when inserting the tube. Cleaning of the chamfered tube end with emery paper will ensure that no sharp edges or kicks are present, as they might damage the sealing gasket upon insertion of the tube into the fitting.
5. Examine the fitting to be used to ensure the sealing gasket and gripper ring are properly positioned and not damaged.
6. Mark the depth of insertion on the tube prior to inserting it into the fitting.
7. Lubrication of the tube end may or may not be required. Follow the manufacturer's recommendations.
8. Align the tube so that it is straight and in line with the fitting .
9. Using a firm pushing and twisting motion, insert the tube into the fitting and push the tube and fitting together until the tube is seated at the back of the fitting cup as evidenced by the pre-marked tube insertion depth line.

2.4.2 SMAW – 1F Position – M.S. Plate

At the end of this exercise, you will be able to:

1. set the Tee joint in flat position for welding
2. deposit root run in 'T' joint of proper size
3. deposit final run in the 'T' joint of proper leg size.

Practical

Requirements	
Tool / Instruments Chisel, File – as required Wire brush, Try square Chipping hammer **Equipment / Machine** Welding machine with accessories – 1 No.	**Material / Components** M.S plate 10 X 50 X 150 mm – 2 Nos. Welding Electrode E 6013. Ø 3.15 mm – 2 Nos.

Set the pieces in alignment at an angle 92° between plates. This is done to compensate the effect of shrinkage forces when weld deposit cools down.

Tack weld the pieces at both ends of the Tee joint by using a 3.15 mm diameter electrode and 110/120 amps welding current.

Ensure the alignment of the tee joint after tacking.

Weld the tee joint after tacking.

Weld the tee fillet joint 1F

Use a channel to place the joint in a flat position.

The electrode angle of 45° will help to fuse both plates equally and the 80° angle will help to get a good root penetration.

Proceed along the welding line with uniform travel speed and short arc to get uniform fusion and root penetration.

The slag has to be removed thoroughly from the root run so that the slag inclusion defect can be avoided in the next run.

Use a slightly side-to-side weaving motion. The width of weave should give a leg size of 10mm.

Maintain the same electrode angle as in the root bead.

If the leg size is less than 10mm, then deposit a third run using the same technique used for the second run.

Clean the final covering bead thoroughly.

Stop the electrode weaving for a moment at the toes of the weld to avoid undercut. Fill the crater at the end of the bead.

Inspection of fillet welds

Inspect the fillet for defects, correct shape and size of fillet and equal leg length on either side of the weld.

2.4.2 SMAW - 1G Position - M.S. Plate

At the end of this exercise, you will be able to:

1. prepare the bevel by gas cutting and /or grinding
2. deposit root run in single-V-butt joint
3. deposit filling and covering runs with proper fusing and reinforcement.

Practical

Requirements	
Tool / Instruments Welding helmet Chisel, File Wire brush, Try square Chipping hammer **Equipment / Machine** Welding machine AG7 / AG4 machine	**Material / Components** M.S plate 10 X 50X 150 mm – 2 Nos. E 6013 / E 7018, Ø 2.5, Ø3.15 mm

Preparation of the pieces

Cut a 300 bevel on each piece using oxy acetylene cutting. Grind the bevel edges to remove oxide deposits on the bevel. Prepare uniform root faces 1.5 mm by filling on both the bevelled edges.

Setting the single Vee butt joint and tacking

Keep the bevel edges upside down with a root gap of 2mm.

Tack weld on both ends.

Ensure safety apparels are worn.

Place the joint in flat position after tacking.

Deposition of root bead

Deposit root bead suing a 3.15 diameter. M.S. electrode and 110 amps welding current.

Proceed with a uniform normal speed holding a short acc.

Keep the electrode angle (as shown in) at of 800 to the line of weld.

Give a whipping motion to the electrode to maintain the size of the keyhole for correct penetration.

Deposition of covering and intermediate beads

Deposit the 1st covering bead using a 4.00mm diameter electrode and 160 amps welding current.

Ensure the electrode angle is the same as it was for the root bead.

Clean the bead thoroughly and grind the humps in beads (if present).

Rectify possible defects, if any.

Deposition of final bead

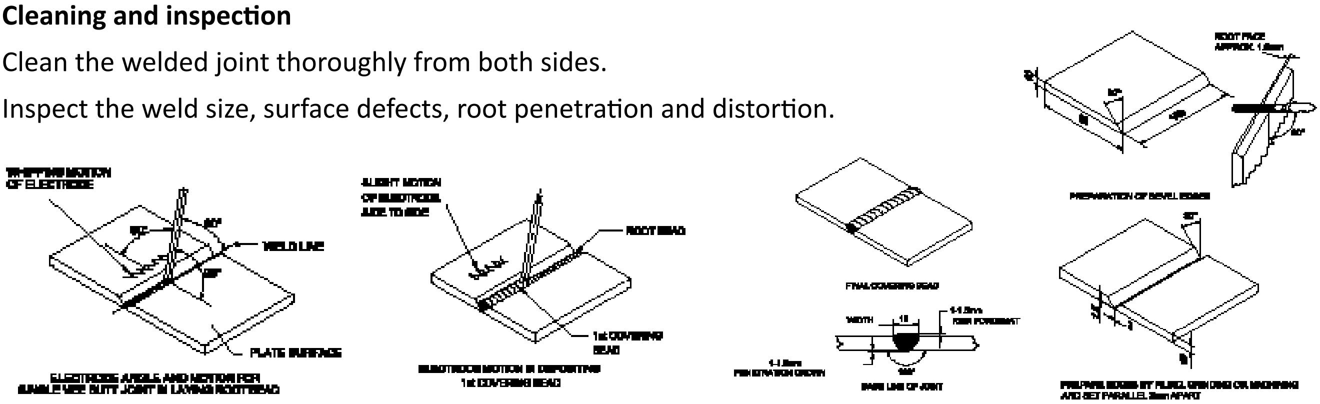
Deposit the final covering bead using a 5.00mm 220 amps welding current, and imparting a wider side-to-side weaving motion to the electrodes. Pause (stop) the electrode weaving at the toes of the weld so that undercut defect will get eliminated.

Follow the other steps as done for the 1st bead.

Cleaning and inspection

Clean the welded joint thoroughly from both sides.

Inspect the weld size, surface defects, root penetration and distortion.



Exercise

I. Answer the following questions.

1. What are the two types of push connect fittings?

----

2. What is the purpose of chamfering the tube end in the push connect joint?

----

3. What is the use of go - no - go gauge in the press connect joint?

----

4. Explain the steps to be followed in the roll groove joint.

----

5. What is the meaning of flared joint?

II. State whether the following statements are True or False.

1. Push connect joint requires no heat or open flame.

   True ☐ False ☐

Notes

2.4 Pipeline Laying

Unit Objectives

At the end of this unit, you will able to:

1. determine pipeline diameter and design parameters
2. explain properties of the transported medium
3. define pipeline laying process
4. describe pipeline testing and commissioning.

2.4.1 Pipeline Diameters and Design Parameters

At the end of this topic, you shall be able to:

1. gain knowledge of pipeline diameter and wall thickness
2. express pipeline design, testing and operating pressure
3. define pipeline design and operating temperature.

Pipeline diameter

Nominal pipe size is used to designate pipe diameter and thickness. Pipe size is specified with two non-dimensional numbers, a nominal pipe size (NPS) for inside diameter based on inches, and a schedule (Sch) for wall thickness. For example, 2" inch diameter pipe, schedule 40)

Pipe Schdule Chart

Nominal O.D.		O.D.	Nominal W.T.					
NPS	BN	D	SCH10	SCH20	SCH30	SCH40S	STD	SCH40
1	25	33.4	--	--	--	3.38	3.38	3.38
1 1/4	32	42.2	--	--	--	3.56	3.56	3.56
1 1/2	40	48.3	--	--	--	3.68	3.68	3.68
2	50	60.3	--	--	--	3.91	3.91	3.91
2 1/2	65	73	--	--	--	5.16	5.16	5.16
3	80	88.9	--	--	--	5.49	5.49	5.49
4	100	114.3	--	--	--	6.02	6.02	6.02
5	125	141	--	--	--	6.55	6.55	6.55
6	150	168.3	--	--	--	7.11	7.11	7.11
8	200	219.1	--	6.35	7.04	8.18	8.18	8.18
10	250	273.1	--	6.35	7.8	9.27	9.27	9.27
12	300	323.9	--	6.35	8.38	9.53	9.53	10.31
14	350	355.6	6.35	7.92	9.53	--	9.53	11.13
16	400	406.4	6.35	7.92	9.53	--	9.53	12.7
18	450	457.2	6.35	7.92	11.13	--	9.53	14.27
20	500	508	6.35	9.53	12.7	--	9.53	---
24	600	609.6	6.35	9.53	14.27	--	9.53	---

Pipeline material selection

The selection of pipeline material should be based on design life cycle and supported by maintenance, inspection and operation parameters.

Selecting pipe wall thickness and diameter

Once the inner diameter (ID) of the pipeline segments has been determined, the pipe wall thickness must be calculated. There are many factors that affect the pipe wall thickness requirement, which include:

- the maximum working pressures
- maximum working temperatures
- chemical properties of the transported fluid / medium
- the velocity of the fluid / flow rate
- pipe material and grade
- safety factors
- internal and external corrosion
- abrasion
- over pressurization
- geo–technical forces

Pipe diameter = $\sqrt{\frac{4 \text{ x flow rate}}{\pi \text{ x velocity}}}$

Pipeline design pressure

The internal pipeline pressure is used in the determination of the pipeline wall thickness requirements.

Pipeline operating pressure

It is the maximum pressure at which a pipeline is allowed to be operated under steady state process conditions, in accordance with BIS /IS 15663-Part 1, 2, 3, 4 and ASME B 31.4/B31.8.

Surge pressure

It is pressure due to mass flow velocity changes, caused by operational activities.

Test pressure

It is the pressure at which the pipeline will be or has been tested for strength.

Flow rate

It is the volume of fluid which passes per unit time. The flow rate is the speed at which fluid in a pipeline moves, or the speed at which it moves from a reservoir into a well/storage/process facility. The normal range of flow velocities is 1 to 2 m/s in liquid lines, and 5 to 10 m/s in gas lines.

Design temperature

The design temperature is the metal temperature expected in normal operation. In general, the pipeline design temperature varies from -30°C to 120°C.

Hydraulic design

In order to determine the possible range of operational parameters of the pipeline, a hydraulic analysis should be performed, based on given parameters:

- pipe size
- fluid properties
- fluid flow rate

- pressure
- temperature

The hydraulic analysis should provide the pressure and temperature profiles along the pipeline for steady state and transient conditions. Full account shall be taken of possible changes in flow rates and operational modes, over the complete operational life of the pipeline. For continuous operations above 4 m/s for liquids lines and 20 m/s for gas line should be avoided. Lower units may apply to fluids containing solid particles.

Properties of transported medium

Properties of transported process fluids piping in oil and gas industry included:

mass density (mass density)	specific volume
viscosity	specific weight
temperature	specific gravity
pressure	flash point.

Mass density: Mass density is the mass per unit volume of a fluid. In other words, it is the rating between mass (M) and volume (V) of a fluid. Density is denoted by the symbol 'P'. Unit is kg/m^3.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

Corrosion: The occurrence and rate of internal corrosion is governed by a variety of process conditions which include:

- Corrosivity of the fluid, in particular, due to the presence of water combined with hydrogen sulphide, carbon dioxide or oxygen. Temperature and pressure can have a great impact on the corrosion rates.
- Velocity of the fluid containing water and CO_2 or H_2S, which determines the flow regime in the pipeline. In pipeline transporting fluids containing water, low velocities lead to settlement of water, which will lead to the bottom of pipes internal corrosion. Too high velocities can increase the overall corrosion rate due to destruction of any protective scale or inhibitor films.
- Considering the possibilities of hydrocarbon reservoirs going sour service during the field's life time, pipeline materials should be designed for sour service as specified in BIS /IS and NACE MR0175.
- Carbon steel line pipe material may be used in "low corrosive conditions (typically where corrosion rates would not exceed 0.3 mm/ years without inhibition).
- Materials able to resist CO_2 and oxygen corrosion include duplex stainless steel and carbon steels with internal austenitic stainless cladding.

Viscosity: Viscosity is the property of fluid which defines the interaction between the moving particles of the fluid. It is the measure of resistance to the flow of fluids. In a liquid, the viscosity decreases with increase in temperature. In a gas, viscosity increases with increase in temperature.

Temperature: It is the property that determines the degree of hotness or coldness or the level of heat intensity of a fluid. Temperature is measured by using temperature scales. There are three commonly used temperature scales. They are: Celsius (or centigrade) scale, fahrenheit scale, kelvin scale.

Pressure: Pressure of a fluid is the force per unit area of the fluid. Pressure is denoted by the letter 'P'. its units are N/m^2, kg/cm^2, bar / PSI.

Specific volume: Specific volume is the volume of a fluid (V) occupied per unit mass (m). Specific volume is denoted by the symbol 'V'. Unit is m^3/kg.

Specific weight: Specific weight is the weight possessed by unit volume of a fluid. It is denoted by 'W'. Its unit is N/m.

Specific gravity

Specific gravity is the ratio of specific weight density of the given fluid to the specific weights of standard fluid. It is denoted by the letter 's. It has no unit.

$$\text{Specific gravity, } S = \frac{\text{Specific weight of given fluid}}{\text{Specific weight of standard fluid}}$$

Exercise

I. Answer the following questions.

1) Define ID and OD?

---

2) Which are the key elements used to consider for the selection of pipeline materials?

---

3) Which are the factors that affect the pipe wall thickness?

---

4) Define pipeline flow rate.

---

5) List the properties of fluids.

---

6) Define pressure.

II. State whether the following statements are True or False.

1) Pipe size is always specified with two non–dimensional numbers.

   True ☐ False ☐

2) Pipeline design and operating pressure are designated in accordance with BIS/IS 15663-Part 1 to 4.

   True ☐ False ☐

3) The pipeline design temperature varies from -30° to 120°C.

   True ☐ False ☐

Notes

2.4.2 Pipeline Construction Process

At the end of this topic, you will be able to:

1. recognise pipeline, route, survey, clear and grading
2. define right of way preparation and trenching
3. explain pipe stringing and bending.

Pipeline construction parameters as listed below:

1) Pipeline route survey
2) Clear and grading
3) Right of way (Row) preparation
4) Trenching
5) Stringing
6) Pipe bending
7) Pipeline welding and testing
8) Weld joint coating
9) Pre padding and lowering in
10) Tie in and post padding
11) Back filling and pressure testing
12) Rein statement and signage installation

Fig. 2.4.1 Pipeline Route Survey,

Pipeline Route Survey

- During pipeline routing finalization the following shall be considered.
- Population and buildings densities for the establishment of location of inhabited buildings, location of rivers, rock and mountain, roads and density of traffic.
- Records of existing special features, which will need reinstatement after construction is completed.
- Soil investigation for foundation design.
- Soil resistivity for cathodic protection design.
- Environmental data (climatic floods, earth, earthquakes, current at river crossing, landslides).
- Existing buried pipeline facilities and cables.
- Existing facilities and CP systems, which may influence pipeline design construction.
- Overhead high voltage power line crossing.

Clearing

Clearing means, but is not necessarily limited to, the cutting and leveling, disposal of trees, crops and bushes.

Grading

It means cutting and leveling of rock, sand, soil tree stumps and roots along the pipeline routes.

Right of way (Row) preparation

Right of way is used to construct, operate, protect, inspect and maintain pipeline system. This row preparation will commence after the survey and setting out. A crew personnel and equipment comprising mainly large heavy tracked bulldozer will form the right of way access on to the land. The operations will include the removal of all soil, sand, rubble, hedging for disposal of site, and re-grading of existing ground contours to assist access. The working strip should be cleared over its entire width and length of pipeline route.

Trenching

The pipeline trench should be excavated to provide a minimum depth of cover as specified in the table, unless specified in the scope of work, drawing and specification.

Location class (as defined in ASME B31.8 and 31.4)	In normal ground	In rock, rock cutting area
Location – Class 1	0.80	0.60
Location – Class 2	0.90	0.60
Location – Class 3 and 4	0.90	0.80
Road, river and livestock passageways	1.50	1.50

The minimum depth coverage should be measured from the top of the pipe to the top of the undisturbed surface of the soil. Fill materials in the working strip should not be considered to add to the depth of cover.

The minimum depth of cover at crossing of rivers ditches, tarmac and graded roads, rail tracks, livestock crossing should be measured from the bottom of river.

Trench bottom and sides should be kept free from all rocks, 5 tones sticks, skids and other sharp objects.

Where the pipeline crosses other pipelines, water lines, cables or other underground services, company / contractor should excavate and grade the trench to a depth in such a manner that the top of the pipeline will be at a minimum of 500 mm below the bottom of the underground structure crossed.

Pipe stringing

Stringing the line pipe is performed along the trench side as required for the work. No pipe should be strung

2.4.2. Pipeline Route Grading

2.4.3. Right of Way formation

before the trench is excavated to full depth and trench should be inspected and accepted by company inspector / pipeline engineer.

Stringing shall not be placed directly on the ground, but on wooden skid with proper protective padding. The skids and protective padding material edges should be free from sharp corners.

Pipe fitter / pipeline incharge should be responsible for proper stringing and locating of the pipe by size, wall thickness, specification and manufacturer's name.

The length of the pipe stringing shall be planned with due consideration of thermal expansion and other expected or accidental movement of the pipe string. Special attention should be paid to strings with one or more bends, and the length of individual pipe strings should not exceed 1 km. If pipe string length is more, it will be difficult to lower into the trench.

Pipe bending

Once the pipe has been strung along the casement, engineers and pipeline crew will follow to determine the location of all bends required in order that the pipeline can follow the contours of the land and the required line and level as detailed on the drawings.

There are two types of bends normally used in pipeline: Hot bend, Cold bend.

Hot pre-formed or forged bends is manufactured off site in a factory and the bend radius is 5 times the pipe diameter or larger.

Cold bends should be made by a smooth stretch bending machine. The pads, dies and rolls of the bending equipment should have soft surfaces to avoid damage to the pipe coating.

2.4.4. Pipeline Trenching

2.4.5. Pipe Stringing

The cold bending crew consists of a four man team together with a bending machine and a side boom tractor / mobile crane. The bending machine is towed along the pipeline route by the side boom /crane and includes "bend formers" consisting 20-150 ton hydraulic rams. It bends the pipe to the required radius and angle.

All bends should be tested in the presence of the company inspector / pipeline engineer with a gauging plate of 97.5% of the nominal internal diameter of the pipe prior to installation. The radius of the cold bends should be not less than:

- 25D for pipe OD of less than 200 mm
- 30D for pipe OD of 200 to 400 mm
- 40D for pipe OD of over 400 mm

Tips

The radius of hot bends shall not be less than:

- Pipeline DN 100 and below, 10 D
- Pipeline DN 150 to 250, 5 D
- Pipeline DN 300 and above, 3D

2.4.6 Pipe Cold Bend

2.4.7 Pipe Hot Bend

Pipe fitup and welding

Pipe bevel

The bevel of the pipe ends in line with API 5L specification, factory made bevel angle should be 30° and included bevel angle should be 60° as per approved drawing and welding procedure specification. Site bevelling shall also comply with these requirements, and should be carried out using floating head cutter. Manual oxygen cutting is not permitted.

Pipe fitup

The pipe ends should be cleaned thoroughly and any coating, rust or other surface residues should be removed. Power tools, wire brushes, grinders should be used. The cleaning should be extended for at least 50 mm along the internal and external pipe surfaces from the edge of the weld bevel.

Line up clamps for pipe fitup

There are two types of line clamps normally used in pipe fitup: external clamps, internal clamps.

External line up clamps are essential for pipe up at special working conditions during pipeline construction.

External line up clamps is suitable for joining of 2” to 12” variety of carbon alloy steel, and stainless steel pipelines.

Pneumatic internal line up clamps assure a quick accurate alignment of two joints of pipe during the fitup and welding operation. All internal clamps are self propelled. Internal line up clamps are suitable for joining of 12” to 80” variety of carbon and stainless steel pipeline. If the use of internal clamps is impracticable, external line up clamps should be used.

2.4.8 Pipe Beveling

2.4.9 Pipe Fitup

Pipeline welding

The welding of pipeline will commence after the welder qualification and pipe fitup are accepted. The welding crew will weld the pipeline in continuous lengths between features such as roads, river crossing, rail track crossing. There are three methods of welding which are: manual, semi-automatic and automatic welding.

Manual welding involves the welding of the pipes by qualified and certified welder’s only.

Semi automatic welding is essentially an improvised version of manual welding, where the stick electrode is replaced with a continuous automatically fed welding wire. For example, GMAW, FCAW, GTAW processes.

2.4.10 Pipe Fitup with External Clamp

2.4.11 Pipe Fitup with Internal Clamp

Automatic welding is a welding process performed the equipment that requires little or no observation of the weld and no manual adjustment of equipment controls. For example. GMAW, FCAW, SAW processes.

Tips

The maximum permissible misalignment between the surfaces of pipes of the same nominal diameter and thickness shall be 1.6 mm.

Tapering shall be required to align pipes of the same diameter but of different thickness. The taper shall have a manimum slope of 1:4.


2.4.12 Tack Welding


2.4.13 Production Welding


2.1.14 Semi Automatic Welding


2.4.15 Automatic Welding

2.4.2 Pipe Bending – 90° Angle

At the end of this exersice, you will be able to:

1. prepare a layout for pipe bending
2. mark and cut pipes to required length using hacksaw
3. bend the pipe to the desired angle using pipe bending machine
4. check the bend pipe for the correctness of angle.

Practical

Requirements			
Tool / Instruments		**Material / Components**	
Measuring tape	– 1 No.	2" ϕ – CS – pipe –	– 2 meters.
Steel note	– 1 No.	Marker Pen,	– 1 No.
Try square	– 1 No.	Dune sand	– as required.
Spirit level	– 1 No.		
Bevel protractor	– 1 No.		
Hack saw frame	– 1 No		
Equipment / Machine			
Manual pipe bending machine	– 1 No.		
Pipe cutter / Hacksaw set	– 1 No.		
Personal protective equipment	– 1 No.		

Check the inside diameter of the pipe by using steel rule / tape

Mark and cut the pipe to the required length using hacksaw

File the pipe end and check its squareness.

Mark off the beginning and end of the bend from the centre line.

Select the standard bend former, to suit the size of the pipe.

File the dune sand into the pipe, if required.

Fix the pipe into pipe, the bending machine / bend former.

Set roller on the bending arm by adjusting the lock nut.

Bend the pipe by Bulling the bending arm towards your side.

Check the bend for squareness using a try square / protractor.

Check level of former and first leg (90° bend) with spirit level.

Check the angle of bend and radius using standard template / protractor.

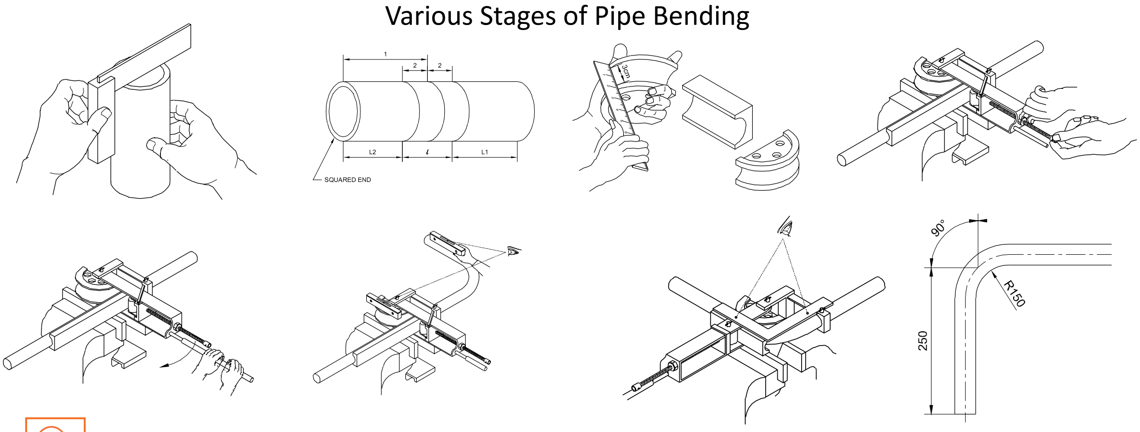
Protect the bend with suitable end cover / cap.

Tips

Bend former shall be smooth and free from foreing particles.

Apply gradual / uniform bending force.

Various Stages of Pipe Bending



Tips

Safety:

Use appropriate ‘PPE’ (Personal protective equipment).

2.4.2 Pipe Alignment using of External and Internal clamp

At the end of this exersice, you will be able to:

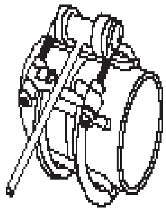
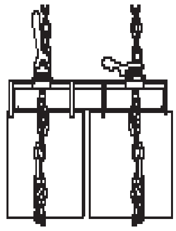
1. select and use external pipe clamp for pipe joint alignment
2. select and use internal pipe clamp for pipe line joint alignment.

Requirements			
Tool / Instruments		**Material / Components**	
Measuring tape	– 1 No.	6” or 4” SCH 40 CS pipe – 500mm– long	– 2Pcs.
Try square	– 1 No.	Grinding Disc – 4” ϕ	– 2Pcs.
Ball peen Hammer	– 1 No.	Face Sheild	– 1 No.
Flat File	– 1 No.	Welding electrode 3.15 ϕ	– 1 No.
Spirit level	– 1 No.	Welding Hand sheild	– 1 No.
Spacer wire	– 1 No		
Equipment / Machine			
Personal protective equipment	– 1 No.		
Grinding Machine	– 1 No.		
200 Amps - Capacity welding Machine with comple accessories	– 1 No.		

Use appropriate ‘PPE’.
Select the size and type of pipe clamps.
Hold the pipe with crane / side boom / using chain block.
Check the pipe beveled edges prior to fitup.
Pipe fitter should check the pipe ends inside and outside for damages and contamination.
Pipe to pipe beveled ends should be set up and correctly spaced according to drawing and specification.

Insert external / internal alignment clamp to reduce misalignment.
For pipes of same nominal wall thickness offset misalignment shall not exceed 1.6mm.



Practical

Requirements	
Tool / Instruments Measuring tape – 1 No. Marking scriber /marker – 1 No. Try square – 1 No. Spirit level – 1 No. Clamps (external) – 1 No. Bevel gauge – 1 No External clamps – 1 No **Equipment / Machine** Orbital cutting /beveling machines – 1 No. Gas cutting and heating equipment – 1 No. Grinding machine – 1 No. Welding equipment – 1 No. Crane /side boom – 1 No. Set of personal protective equipment – 1 Set	**Material / Components** 6", 8"-3 mts Pipe - 2 Nos. Marker Pen, Paper, Pencil Approved Procedure and Drawing Welding Electrode Grinding Disc

Tips

1. Instructor may explain various pipeline construction methods and techniques.
2. Instructor may demonstrate pipeline fitup and alignment.

Read and interpret the drawing that follows and carry out as following.

1) Perform measuring and marking on the pipe.

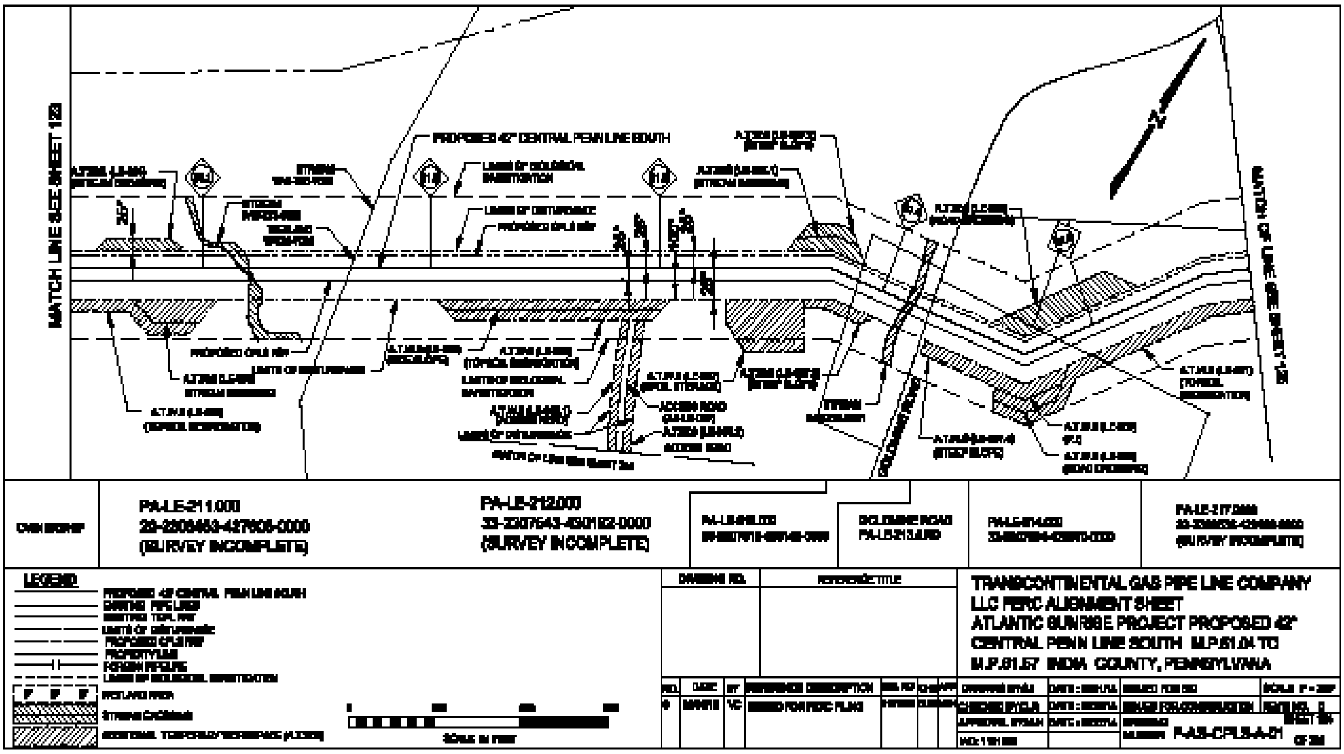
2) Carryout gas cutting and grinding as required.

3) Perform pipe edge beveling as specified in the drawing and WPS.

4) Check the bevel angle and align the pipes together.

5) Start fitup and alignment with external clamp.

6) Perform tack welding as a qualified welder.



Exercise

I. Answer the following questions.

1) Explain different stages of pipeline construction activities.

----

2) What is the purpose of pipeline route survey?

----

3) Define right of way (Row).

----

4) Define pipeline trenching and stringing.

----

5) List the pipeline alignment clamps.

----

6) How many methods are used in pipeline welding.

----

7) How many types of bends are used in pipe line laying.

II. State whether the following statements are True or False.

1. Pipeline route survey should be carried out before the pipeline laying activities start.

   True ☐ False ☐

2. The main purpose Right of way (Row) is used to construct and operate oil gas pipeline system.

   True ☐ False ☐

3. When pipe stringing, the line pipe should not be placed directly on the ground.

   True ☐ False ☐

4. The length of the pipeline strings should not exceed more than 1 km (kilometer).

   True ☐ False ☐

5. The radius of hot bends should not be less than 5D of pipeline norminal diameter.

   True ☐ False ☐

6. The bevel of the pipe ends should be as per API 5L and approved project drawing, specification.

   True ☐ False ☐

7. Tack welding of pipe joints should be performed only by a qualified welder.

   True ☐ False ☐

Notes

2.4.3 Inspection and Testing of Pipeline Installations

At the end of this topic, you will be able to:

1. gain knowledge of weld joint coating, trench inspection, pipeline installation
2. explain pre and post paddling
3. define back filling and pressure testing
4. define reinstatement and signage installation.

Inspection and testing of weld joints

All the welded joints should be completely cleaned free from any slag, spatter and residues using suitable clean power (tool) brushes before inspection and testing.

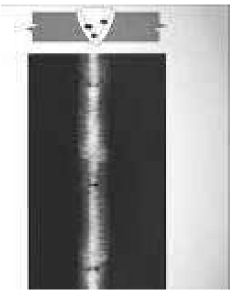
Visual inspection

Visual inspection should be carried out by a approved qualified inspector before conducting (NDT) Non – destructive testing (NDT) methods.

Radiographic testing

Radiation source: X-ray or Gamma -Ray sources may be used, as they shall produce indications of imperfections that can be accurately interpreted and evaluated by qualified and experienced inspection personnel. Industrial radiography is a method of non – destructive testing (NDT) where many types of pipe welds can be examined to verify the internal structure and integrity of the weld joints.

2.4.16 Visual Inspection of Welds



2.4.17 Radio Graphic Weld Image

Tips

Experienced and qualified radiography specialists shall undertake the activities under controlled conditions. Before the operation is started, the section of pipeline may be cordoned of using a warning tape.

Ultrasonic testing (AUT and MUT)

Ultrasonic testing (UT) is a family of non–destructive testing techniques based on the propagation of ultrasonic waves in the object (or) welds tested. Welds completed by semi-automatic welding process are examined using automatic ultrasonic testing (AUT) technique. This consists of an assembly that traverses the circumference of each completed weld in order to detect any defects. The tie-in welds should be examined using manual ultrasonic testing (MIJT) techniques.

Magnetic Particle Testing (MPT)

Magnetic Particle Testing (MPT) is a non–destructive testing technique used to detect defects or discontinuities at or near the surface in ferromagnetic metals such as carbon steel and some of is alloys.

Liquid Penetrant Testing (LPT)

Liquid Penetrant Testing (LPT) or penetnant testing is widely applied NDT technique and is a low cost inspection method used to check surface breaking defects in all materials. All trenches should be prepadded before lowering in of pipe string.

2.4.18 Manual Ultrasonic Testing

2.4.19 Automatic Ultrasonic Testing

2.4.20 Magnetic Particle Testing

2.4.21 Liquid Penetrant Testing

Prepadding (Bedding)

Prepadding is pipeline protection method to provid soft soil to surround and protect a pipeline before and after it is laid into a trench. The bottom of the pipeline trench should be padded with fine and clean soft sand materials throughout its length, whether in normal ground or rock to provide a minimum compacted padding and thickness of 150 mm at any point around the pipe. The purpose of padding materials is to protect the pipeline and provide a protective coating.

2.4.22 Sand Bedding

Weld joint coating

Pipe weld coating is a protective layer that is applied to the metal surface of two pipes that have been joined along their circumference during pipeline construction. These coatings are designed to prevent corrosion and are often produced in the form of an epoxy or polyurethane or heat shrink sleeve application. Prior to coating , the field joint area should be blast cleaned. Surface preparation, including blast cleaning should be carried out.

Testing and inspection of field joint coating

Field joint coating should be visually inspected.

Holiday testing

Holiday testing is a non–destructive test method applied on protective coating to detect unacceptable and invisible discontinuities such as pinholes and voids. The test involves checking an electric circuit to see if current flows to complete the circuit. This testing is used to find coating defects that are not readily visible.

2.4.23 Weld Joint Coating (Shrink Sleeve)

2.4.24 Holiday Testing

Installation of permanent cathodic protection system

As the pipe is being installed into the trench, cathodic protection lugs are welded to the pipe. These lugs which can be 50 mm square plate are welded on the pipeline.

2.4.25 Cathodic Protection

Pipeline lowering in

The pipeline string will be positioned approximately 5 metres from the trench centre line. It will be installed into the open unobstructed trench using a number of side booms, pipe layer / mobile crane.

Before commencing the lowering in operation, the coating should be checked for holiday. Wide non abrasive slings or belts should be used in all lowering operations. Care should be taken when removing the sings from around the coated pipe.

Pipeline tie-ins

Tie–ins are the welds generally undertaken in the trench that connect pipelines together. Once the river crossing /road crossing section and the main pipeline either side are installed. Tie-in crews consist of pipe fitter, pipe welder trench excavators to prepare trench, side booms to lift and set up the pipe for welding.

All tie-in weld joints are 100% visually inspected and applicable NDT methods are to be used, RT and UT testing methods can be used to examine and verify the internal structure and integrity of the weld joints.


2.4.26 Pipeline Lowering

Pipeline post padding

The top of the pipeline trench and pipe surface should be padded with fine and clean soft sand materials. Sand padding should be placed around and above the pipe, fill the trench to a depth of 300 mm above the crown of the pipe. No pipe should be left overnight in the trench without sand padding around and above the pipe.

Back filling

On completion of the post padding activities on the mainline a final, back filling is the process of putting soil into the trench. Back filling is used to protect underground pipeline. The materials used for initial back fill should be from the screening plant or other material not greater than 20 mm in diameter. The fill material should be placed in such a manner to avoid disturbing the sand padding and excessive penetration of rock into the sand layer.

2.4.27 Pipeline Post Padding

2.4.28 Pipeline Trench Back Filling

Hydro testing

Hydro testing also known as hydrostatic test is a way of checking the integrity of oil and gas pipelines. This test also helps in understanding the pressure loss inside the pipeline system, and can be used to declare fit for its use. The minimum requirement for hydrostatic testing operations include: Pigging and cleaning, Gauging, Water filling, Hydrostatic testing.

Pipeline pigging and cleaning

Pigging refers to technique of cleaning or inspection of pipeline inside through recovering trapped products in the pipeline without stopping the operation. All oil and gas pipelines should be suitable to pass pigs. Pigging should be used for the pre-commissioning and cleaning and corrosion control (removal of wax, debris and stagnant liquids, batch inhibition).

Gauging (Guage Pigging)

The pipeline inspection gauge is used in conjunction with pigs. They are used to prove pipe roundness and indicate obstruction or the internal damage of a pipeline.

In pipeline gauging plates, the most common material used is aluminum and the most common size for a gauging plate is 90 to 95% of the ID (Inner diameter).

Water filling

2.4.29 Pipeline Pigging and Cleaning

2.4.30 Pipeline Gauging

Pipeline shall be cleaned with appropriate pigs. The use of the pigs ensures that all air is removed from the pipe. Once the line is filled, it will be left to stand to allow the water temperature to equalize to the surrounding ground conditions. Once the temperature is stable, the test will commence with an initial rise in pressure.

Hydrotesting

All the temporary equipment used for the hydrostatic testing operation will be fully tested and certified for the test pressure. Copies of the certificate should be available on site for inspection prior to start of the hydrotesting.

Once the air content confirmed, the test pressurization continues to the pressure at a steady rate of typically no faster than 1 bar per minute. Once the test pressure is reached it should be held for the required time. Which is likely to be 4 hours /24 hours. During this hold period, the pressure and temperature will be monitored and recorded.

On completion of the hold period and successful acceptance of the test, the water is removed from the pipeline by swabbing pigs propelled by dry, oil free compressed air. The water will be sent to an approved disposal site.

Reinstatement

The pipeline working strip /Right of way (Row) is reinstated to the grade level using the top soil that has been stored to one side of the running track. Area of soft sand in the continuous 6 m wide vehicle access strip should be restored. The intention during the reinstatement works is to return the whole of the construction occupied areas to its former condition. This operation consists of a number of activities which includes:

2.4.31 Water Filling

2.4.32 Hydrotesting

- removal of all temporary access equipment
- final formation of ditch banks
- clean up /patch up of any damage to high ways
- replacement of top soil and final leveling
- the remaining excavated materials should be neatly crowned over the trench (the windrow), except river area.
- all creeks, water courses, wells, drains, streams, river ditches and irrigation channels should be reinstated by the contractor to their former condition.
- all private roads, bridges and other private structures used for access should be restored.
- all debris left over after removal of camp facilities should be removed to designated scrap drumps. The site should be levelled and cleared in accordance with the regulation for pipeline construction company.

Signage installation

The contracting company should supply and pipeline route as close as possible to the windrow.

Purpose

Ensuring the safety of the public and security of oil and gas supply that Row (right of way) and pipeline clearly have marked and defined is important.

The different types of pipeline markers are: chainage markers, block valve station markers, road crossing markers, river crossing markers, pipeline crossing marker, cable crossing markers, stop sign (Row).

2.4.33 Marker Post Installation (Pipeline)

Chainage markers

Chainage markers should be installed along the pipeline at each one (1) kilometer chainage station.

Block valve station signage (Signage)

Block valve station signage should be installed along the pipeline at each block valve station.

Road crossing signage

Road crossing signage should be installed at both sides of each paved or graded road crossing. Location should be 5 metres from the borders of the road.

River crossing signage

River crossing signage should be installed at both sides of each river crossing.

Pipeline crossing signage

Pipeline crossing signage should be installed at each crossing with an existing underground or above ground pipeline.

Cable crossing signage

Cable crossing signage should be installed at each crossing with an existing underground cable.

Row stop signage

At each crossing, permanent stop signs should be installed on the R.o.w access strip, at both sides of the roads for the attention of drivers of pipeline maintenance vehicles on the Row.

Exercise

I. Answer the following questions.

1) What are the common inspection and testing methods of weld joints?

----

2) What is the minimum compacted prepadding material thickness into a pipeline trench?

----

3) What is the purpose of weld joint coating ?

----

4) Which NDT (Non–Destructive Testing) method is used to detect coating invisible defects?

----

5) What is the size for initial back fill material used from the screening plant?

----

6) Name the different stages of hydrotesting operations followed in pipeline integrity checking.

----

7) What is the purpose of pipeline gauging?

----

8) What is the limitation in hydrotest pressuring rate?

----

9) What is the purpose of reinstatement?

----

10) List the names of the different types of pipeline markers.

II. State whether the following statements are True or False.

1. Prior to inspection, the welded joints should be cleaned free from slag and spatters.

   True ☐ False ☐

2. In radiography testing method, x-ray and gamma-rays sources are used to produce radiation.

   True ☐ False ☐

3. The welds completed by semi/automatic welding process should be examined using automatic ultrasonic testing methods.

   True ☐ False ☐

4. Magnetic particle testing technique is used to detect discontinuities near Surface only.

   True ☐ False ☐

5. The main purpose of prepadding materials is to protect the pipeline and provide pipeline protective coating.

   True ☐ False ☐

5. The purpose of holiday testing applied on protective coating to detect invisible discontinuities such as pin holes.

   True ☐ False ☐

5. The most commonly used gauging plate material is aluminum and the most common size is 90 to 95% of ID of the pipe .

   True ☐ False ☐

Notes

2.5 Physical Requirement

Unit Objectives

At the end of this unit, you will able to:

1. state the importance of safety precautions to be followed at the site
2. explain safety precautions and measures taken during fitting
3. identify safety signage
4. define the importance of working in a clean and safe environment.

2.5.1 Safety Standard in Pipe Fitting Activity in Oil and Gas Industry

At the end of this topic, you will be able to

1. describe safety precautions associated with oil and gas pipelines
2. state the importance of personal protective equipment.

Safety and its importance

The following are the important elements which are necessary for implementation of safety culture in oil and gas construction site/plant:

Safety consciousness is to be ingrained amongst the workforce as well as among the top management of the oil and gas producing plant.

Recognition of best practices in safety and exchange of the safety related ideas both with in the team members is important.

The management should develop and environment to build safety an essential part of the professionalism of every employee with eveyone accepting responsibility.

Good safety practices

Good safety practices includes the following:

- assigning and publishing the responsibility and duties of the employees associated with the management of the safety in the workshop / worksite.
- conducting regular shop /site review meetings, safety monthly review meeting at the chief executive level,
- conducting training as well as refresher safety training programs for the employees
- conducting emergency safety drills.

Work environment requirements

The workplace environment should be designed and regulated as far as possible to ensure safety free of health risk. Some basic environment standard requirements are:

- space
- seating
- ventilation
- heating
- lighting
- noise control.

Pipe fitter physical requirements

Pipe fitters frequently use their hands to handle, control or feel objects, tools or controls

Stand for long periods of time

Bend or twist their body

Walk or run for long periods of time

Climb ladders, scaffolds

Kneel, stop, crouch or crawl

It is important for pipe fitter's to be able to

- see the details of objects that are less than a few feet away.
- hold the arm and hand in one position or hold one the hand steady while moving the other arm.
- use one or two hands to grasp, move or assemble the pipe.
- move two or more limbs together (for example, two arms, two legs or one leg and one arm) while remaining in place.
- make quick, precise adjustments to machine controls.
- use fingers to grasp, move or assemble very small objects.
- bend, stretch, twist, or reach out.
- use stomach and lower back muscles to support the body for long periods without getting tired.
- keep or regain the body balance or stay upright when in an unstable position.
- speak clearly so listeners can understand.
- understand the speech of another person.
- use muscles to lift, push, pull or carry heavy objects.

Pipe fitters to be able to:

- determine the distance between objects
- coordinate movement of several parts of the body, such as arms and legs, while body is moving
- see the details of objects that are more than a few feet away
- see the differences between color, shades and brightness
- react quickly using hands, fingers or feet
- hear sounds and interpret the difference between them
- use muscles for extended periods without getting tired
- adjust body movements or equipment controls to keep pace with speed changes of moving objects
- move arms and legs quickly
- see objects in light bright.

Interpersonal relationships

The following are the important elements for pipe fitter's interpersonal relationships:

- have a medium level of social contact as they often work alone. Talk to supervisors.
- communicate by telephone and in person on a daily basis.
- pipe fitters are greatly responsible for their own health and safety and that of others.
- pipe fitters should work as part of a group or team.

Manual handling hazards, risk and control measures

Manual handling is an activity that takes place in most workplaces. Often manual handling is a routine part of day -to-day work activities.

Tips

Pipe fitters may lift maximum weight of 25 kg, but as per OSHA (Occupational Safety and Health Administration) not more than 22 kg.

Risks

Manual handling is a common cause of musculoskeletal injury such as injury to the back ligaments, muscles and work related upper limb disorders.

Safe lifting technique

Employees should be trained in basic safe lifting techniques. This technique minimizes the risk of musculoskeletal disorders.

Manual handling

The following are the important elements which are necessary for implementation of safe manual handling:

- Check the load
- Where possible, gloves should be worn to protect against cuts, scratches or wounds.
- Do not attempt to lift any load that is too heavy too large alone.
- Check for poor lighting conditions. It may be dark in the area where you need to deposit the load.
- Bend the knees, back muscles shuld be related.
- Get a secure grip of the load.
- Lift keeping the back straight, arms close to the body, chin and head up with the leg muscles taking the strain.
- Step off in the direction the advanced foot is pointing with load held close to the body.
- Do not carry a load, which obscures your vision.
- When lifting to a height from the floor do it in two stages, if possible.
- Using a trolley, if you can.

Climb up and down ladders

Prior to using a ladder the following factors are to be verified:

- Using a ladder properly is not very difficult. there are only a few simple rules that need to be followed to ensure that the ladders provide a stable work platform.
- Prior to using a ladder, inspect the ladder for any damaged or missing rungs, cleats, steps or other defects. When using portable ladders make sure that the ladder is provided with a slip resistant feet.
- Ladders with structural defects must be tagged “do not use” and removed from service unitl repaired.
- Keep the area around the top and bottom of ladders clear.
- When ascending or descending a ladder, do not carry any object or load.
- Maintain 3 point contact at all times.

Scaffolding

There are number of ways in which the scaffold can be use safety:

Fig. 2.5.1 Scaffold

- Use appropriate scaffold construction methods.
- Erect, move or alter scaffold properly.
- Protect from falling objects or tools.
- Ensure stable access.
- Erect and inspect with the help of competent persons.
- Inspect scaffold /scaff tags before each shift and after alterations.
- Determine fall protection requirements.
- Never work on a scaffold unless you are authorized to do so.
- Never climb a scaffolding with a red tag on it.
- The scaffold should be stable and, if necessary should be secured to the building/structure in enough places to prevent collapse.
- The scaffold should be checked for clearance from nearby power lines prior to its erection.
- Mobile scaffold wheel locks should be secure before people work from the scaffold.

Working at heights

While working at heights collective protection should be used because this will protect all workers who may fall from height. It will be necessary to provide fall arrest equipment.

Fall arrest equipment come in two type

1. collective protection system (safety nets and air bags)
2. personal protective system (Fall arrest harness/belt).

Fig. 2.5.2 Safety Belt

Tips

Those involved in work at height are trained and competent.

Collective protection system

Ideally, collective protection should be used to protect all workers irrespective of whether they are using their PPE correctly example safety nets.

Personal protective system

Personal fall arrest equipment usually consists of a full body harness connected to one or two lanyards. The lanyard is connected to an anchor point during use.

Exercise

I. Answer the following questions.

1) Explain safety and its importance?

----

2) Define good safety practices for pipe fitup?

----

3) What are all the physical requirements for pipe fitters

----

4) What is the maximum manual safe handling load limit as per OSHA standard?

----

5) What are the importance elements are necessary for safe manual handling?

----

6) Define some important factors that are to be followed while using ladders.

----

7) Which are the two fall arrest equipment used while working at heights?

II. State whether the following statements are True or False.

1. Pipe fitters should exchange safety related ideas within the team members.

   True ☐ False ☐

2. Conducting safety training programs is a way to prevent incidents /accidents.

   True ☐ False ☐

3. Pipe fitters are responsible for the health and safety of workers assiting them.

   True ☐ False ☐

4. Pipe fitter may lift loads up to maximum as per OSHA standard which is not more then 22 kg/50 ibs.

   True ☐ False ☐

Notes

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=uetc3jQGfSk

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=O9UgBE-FITI

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=eqwBR-jaEQ4

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=8oO2p91rXeI

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=Xo60anxN8nw&t=156s

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=503fYa8r718

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=BeHxGJYNyy0&t=29s

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=KBVdjeUtMYE

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=NEGohTCkkYY

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=vD0kbdIS6kE

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=PxVP5Fun3Gg

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=d_l3SdqlQ68

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=b0EfJaYUfF8

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=4_uZ3Acfjus

Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

N·S·D·C
National
Skill Development
Corporation
Transforming the skill landscape

HYDROCARBON SECTOR
SKILL COUNCIL

1. Fitting, Welding Basics and Jointing Process of Materials (CGS)

HYC/N6105

Key Learning Outcomes

At the end of this module, you will be able to:

1. Wear proper PPE and exhibit proper safe working principles and practices duly implementing all HSE requirements
2. Read and interpret drawings and approved work procedures
3. Receive materials, ensure material release for construction and check for any material damage
4. Carryout measuring, marking, cutting and transfer / maintain material ensuring identification and traceability
5. Identify and make readily available appropriate consumables, tools and equipment for piping edge preparation and fitup work activities
6. Prepare joints for edges of pipes to drawing requirements and perform pipe fitup activities as per approved procedures requirements
7. Perform / ensure functional checks of valves and other instruments / accessories and install them as per approved for construction drawings
8. Install gaskets, bolts / studs, nuts, washers, clamps, etc., and perform proper bolt tightening / torqueing in sequence
9. Perform pipe stringing, cutting, Grinding, Thrending, Bending, fitting activities at pipeline installation site
10. Ensure proper trench preparation and pipe bedding and then pipeline lowering
11. Prepare for hydrotest / pneumatic test and perform the test with appropriate work permit duly complying with all safety precautionary requirements
12. Perform depressurizing, dewatering and cleaning piping / pipeline systems
13. Describe Electrofusion principles
14. PE/HDPE/MDPE Pipeline Installations as per qualified and approved procedures and techniques.

1.1 Introduction

Unit Objectives

At the end of this unit, you will be able to:

1. read and interpret all types of piping and pipeline drawings
2. make simple drawings and prepare bill of materials
3. describe various pipes and pipe fitting materials
4. perform pipe fitting works of all type of materials such as carbon steel, stainless steels, duplex stainless steels, PE, HDPE, PVC, UPVC, etc.
5. perform pipe fitting works related to process plant, power plant, petroleum refineries and in all sorts of oil and gas distribution piping and pipeline.

1.1.1 Introduction to the training program

Introduction to QP and NOS

This training program is based on Qualification Pack (abbreviated as 'QP') named "Pipe-Fitter City Gas distribution sector". The code for the QP is "HYC/Q6102". HYC stands for "HydroCarbon". This QP consists of a set of National Occupational Standards (NOS). NOS specifies the standard competency a pipe fitter must achieve when carrying out a function in the workplace. Under this QP, there are four NOS. They deal with the city gas distribution pipes and pipelines related functions to be performed in the worksite duly complying with all safety requirements.

NOS Code	Major Functions / Task
HYC/N 6105	Fitting, Welding, Basics and Joining Process of Materials
HYC/N 6106	Perform Electrofusion Welding
HYC/N 6103	Work effectively in a team
HYC/N 6104	Follow health, safety and security procedures

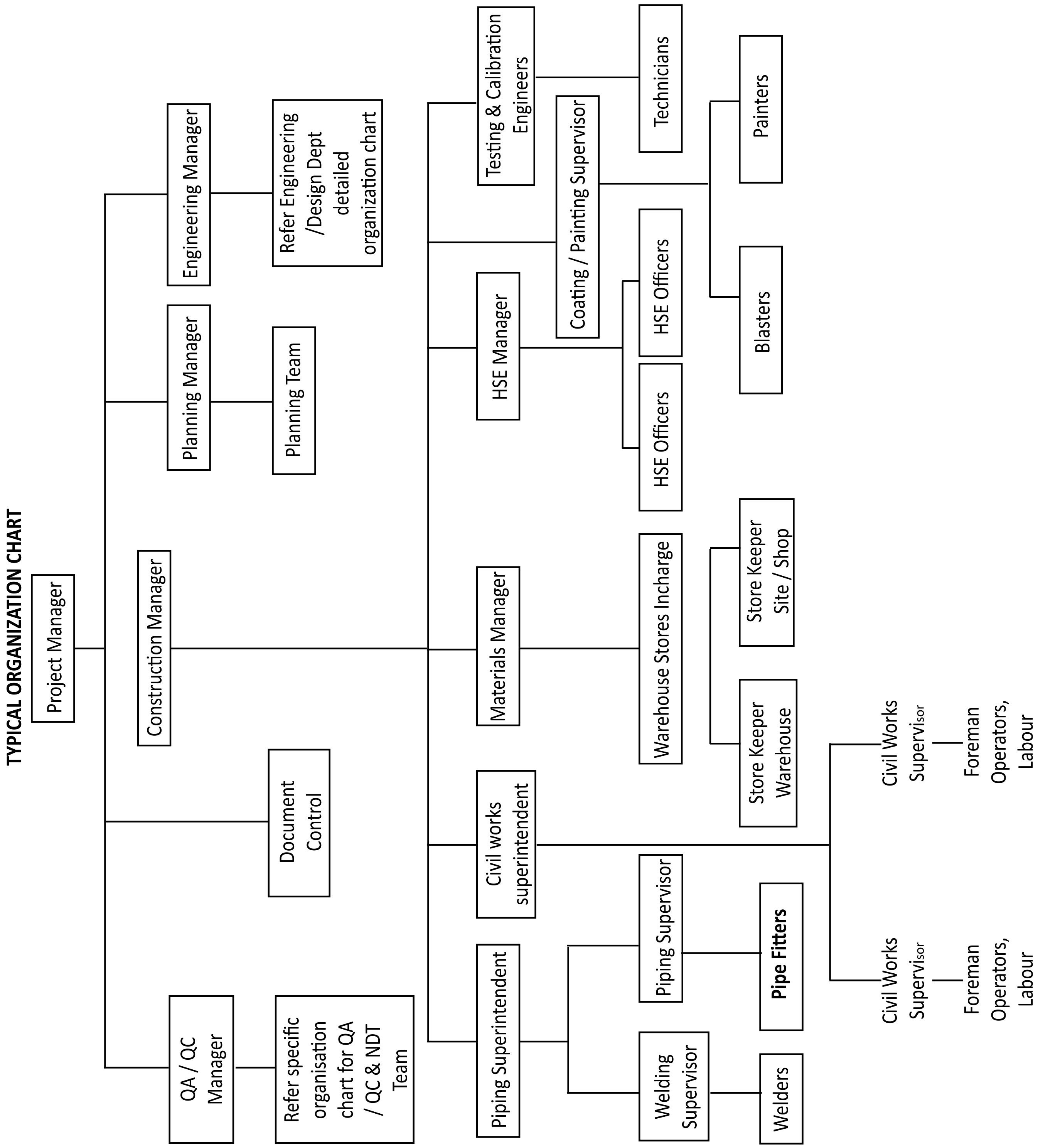
Benefits of this Fitter Training

After successful completion of training and passing the assessment, the candidate will be issued a certificate. The certificate will help the candidate to get employment in fabrication, and construction industries in oil and gas distribution piping and pipeline sector. Natural Gas industries need a great number pipe fitters all over the world. Pipe fitter is not only trained on simple pipe fitup, but are trained in the basics of engineering drawings, pipe materials, pipe fitting materials, all type of joints related to Natural gas distribution piping / pipeline. The city gas distribution pipe fitters can be directly employed to perform pipe fitting activities without site / on the job training at the worksite. Oil and Gas industry pipe fitters are one of the highest paid of all the trades, with more job openings in the near future. Job growth for the pipe fitting industry is expected to expand is the forthcoming years in India as well as abroad. Satellite cities development in all over India needs more infrastructure for oil and gas transportation and distribution . Hence a lot of opportunities are getting lined up for pipe fitters trained to oil and gas related facilities, construction (including transportation and distribution) requirements.

1. Organization and its process

City gas distribution pipe fitter shall have enough information / knowledge about the organization and its process to thoroughly understand the organization and its context. He / She shall go through the company policies on personnel management, duty reporting procedures and comply with the same duly maintaining with discipline. Pipe fitter must be aware and comply the respective legislation, standards, policies, and procedures followed in the company, mainly those relevant to his employment and performance conditions. He / She shall receive employment terms and entitlements from the employer along with job description, roles and responsibilities.

The pipe fitter shall receive adequate induction in problem escalation procedure and escalation matrix for reporting work and employment related issues. Pipe fitter shall have access to company standard operating procedures so as to refer and meet with respective procedure's requirements while working. He shall be aware of documentation and related procedures applicable in the context of employment and work.Pipe fitter must have adequate information about his reporting structure within the organization and relevant people and their responsibilities within the workarea with whom he has to liaise for day-to-day work activities.



2. Health, Safety and Environment (HSE) System Requirements

Pipe fitter shall strictly adhere with relevant health and safety requirements applicable in the workplace.Safety should be the top priority in any facility to keep productivity at its best and to avoid injury or health concerns. Pipe fitter shall be aware about importance of working in clean and safe environment. One of the most effective ways to improve the safety of worksite is to make sure that it is cleaned properly maintained. Cleaner work environment reduces injuries on the job. Poorly cleaned / poorly maintained / faulty / broken equipment or slippery surfaces could lead to a potential fall /injury / accident. The cleaner the working facility is, the better the quality of products and services.

3. Importance and Purpose of Documentation

Documentation is a record of information which can be referred to or used, whenever required. Documents act as the store of collective organizational knowledge regarding the processes and can be accessed by anyone, whenever needed. Documented information shall be maintained to support the operation and its processes. Documented information in the form of records shall be maintained / retained to provide evidence of conformity to requirements. The purpose of documentation include

- to provide permanent reference for understanding, implementation and maintenance of a system
- to preserve the knowledge gained from experience and share
- to remove process ambiguity and maintain consistency and uniformity
- organisational knowledg is recorded, retained, transferred and embedded into process, products and services
- to stipulate and specify requirements for carrying out processes in a specified manner and control of operational processes.
- to provide evidence that processes are being carried out as planned
- to provide evidence that activities have been done as per the planned arrangement
- contain formulated information about who is supposed to do what and when
- details of best practises and methods along with step by step instructions to each task needs to be performed
- to provide evidence of results achieved and contain statement of fact
- to provide evidence of fitness for purpose of the monitoring and measuring activities
- to show conformity of products and services that meet their requirements. Pipe fitter must know and follow the review and approval process of the requisition of materials/equipment by assigned employees. Pipe fitter shall be aware of required records to be prepared and maintained. Knowledge in preparing reports and recording repairs and successful completion of repair are important. Pipe fitter shall be trained in implementation of inspection and test plans, that includes inspection and test stages along with customer inspection and meeting quality standards requirements.

Pipe fitter roles, responsibilities and tasks include:

a. reporting to foreman / supervisor and following their instructions for everyday pipe fitting work activities.

b. duly discussing with supervisor / foreman, prioritising work schedule and process implications for own work and schedule of others.

c. attending site daily Tool Box Talks and Safety Meetings without fail.

d. reading and understanding organization procedures for necessary approval, work permit (PTW- Permit To Work) and for receiving materials.

e. reading and interpret piping drawings, specifications and work procedures.

f. following all safe work practices and handling all piping works related equipment carefully.

g. selecting pipe sizes, types and related materials and planning the fitup work sequence.

h. ensuring that pipes and pipe fittings have been inspected on receipt and released for fabrication / installation.

i. measuring, marking and cutting pipes duly maintaining identification and traceability.

j. using appropriate tools, instruments and equipment for pipe edge preparation, cutting, fitup and tack welding / deburring tools.

k. Piping ends and edge preparation for welding / jointing as required by the drawing / specification.

l. for cutting and edge preparation, employing appropriate methods such as gas cutting, hacksaw cutting, grinding, machining, threading, etc.

m. checking all pipes and fitting inside for cleanliness / any objects.

n. aligning / joining pipes using various methods such as tack welding, brackets and wedging, clamping (internal and External).

o. performing piping / pipeline stringing & alignment.

p. assembleing and securing pipes, tubes, fittings and related equipment according to specifications / drawings using techniques such as welding, bolting, threading joints.

q. performing dimensional check and ensuring the correct size, length, orientation, position / location.

r. checing piping / pipeline alignment, straightness, level and all other dimensional checks.

s. assembling valves and other instruments / accessories by taking into account the flow directions.

t. marking the hole locations and cut / bore/ drill holes in structures / supports.

u. installing pipe supports as per drawing / specifications.

v. performing bolting in sequence with required torque by the approved / permitted torque method. Some cases minimum torque will be specified. In some cases, torque may be limited to certain limit / range to avoid gasket / joint face damages.

w. preparation for hydotesting / pneumatic testing and reinstutement after test completion.

x. performing PE pipe scraping, fitting and joining by heat fusion / electrofusion.

- Natural Gas, which is colourless and odourless is converted to Compressed Natural Gas (CNG) and Piped Natural Gas (PNG) which is distributed to the endusers through City Gas Distibution (CGD) network. Owing to availability of huge reserves of naural gas in India, its environmental friendliness and easy transportability, city gas distribution is forecast to witness robust growth in the country over the next decade. City gas distribution is gaining importance as Government of India wants to expand natural gas distribution network accord India and distribute gas throughout India through piping and pipeline. It is one of the government of India missions with replace the LPG gas cylinder supply to domestic and business industries by natural gas supply through piping. One of the largest infrastructure development in India is smart cities mission. Government of India has planned to develop more than 100 smart cities within a span of about five years. All these smart cities have been planned with Natural Gas Distribution through piping. There is going to be very high demand for “City Gas Distribution-Pipe Fitters all over India.

Exercise

I. Answer the following questions.

1. List any four objectives of this training program.

----

2. What is the need for city gas distribution pipe fitter training?

----

3. Write any five purposes of pipe fitter training.

----

4. What are the benefits of pipe fitter training?

----

5. Briefly describe organizational context and its processes with respect to piping / pipeline works.

----

6. Write about the importance working in a clean and safe environment.

----

7. What is the importance and purpose of documentation in the context of employment and work?

----

8. Describe pipe fitter Roles, responsibilities and tasks.

II. State whether the following statements are True or False.

1. Purpose of city gas distribution pipe fitter training includse "Make familiar to various pipe and pipe fitting materials".

   True ☐ False ☐

2. Pipe fitters need not perform piping / pipeline stringing activities.

   True ☐ False ☐

3. Safety standards are not relevant to pipe fitting activities.

   True ☐ False ☐

4. Welded pipe systems demand least degree of excellence in materials and quality of work.

   True ☐ False ☐

5. After completion of training, student will be issued trade certificate.

   True ☐ False ☐

6. City Gas distribution Pipe Fitter Certificates issued to the student will not be useful for fabrication industries.

   True ☐ False ☐

7. Pipe fitter must be aware of and comply with the respective legislation, standards, policies, and procedures followed in the company.

   True ☐ False ☐

8. Fitup work should be the top priority than safety.

   True ☐ False ☐

9. Ensuring clean and safe environment is not pipe fitters responsibility.

   True ☐ False ☐

Notes

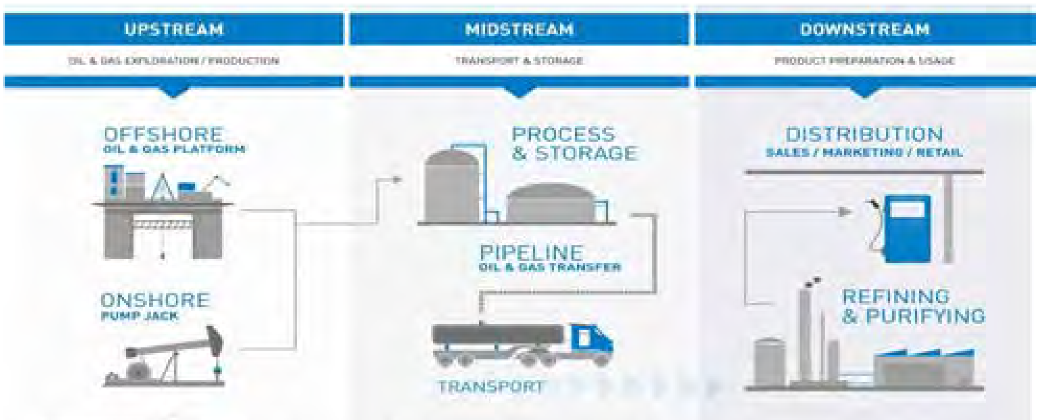
1.1.2 Introduction To Piping & Pipeline

At the end of this topic, you will be able to:

1. define piping and pipeline construction methods in city gas distribution industry
2. describe codes and standards
3. define terms and definitions.

Piping and pipeline: City Gas Distribution piping / pipeline fitter shall have knowledge on various piping and pipeline systems and their standards / specifications to have proper understanding about what they are doing and the purpose. Pipe fitters show know that the oil and gas industry is usually divided into three major sectors midstream, and downstream.

- **Upstream:** The upstream sector also known as "Exploration and Production E&P" includes finding underground or underwater crude oil and natural gas fields, locating exploratory wells, and subsequently drilling and operating the wells that recover and bring / lift the crude oil or raw natural gas to the surface and get it ready for transportation.
- **Midstream:** The midstream sector involves transportation (by pipeline, rail, barge, oil tanker or truck) and storage of crude or refined petroleum products. Pipelines and other transport systems can be used to move crude oil from production sites to refineries and deliver the various refined products to downstream distributors. Natural gas pipeline networks aggregate gas from natural gas purification plants and deliver it to downstream customers such as local utilities.
- **Downstream:** The downstream sector also known as "Refining and marketing R & M" is further processing of crude oil and natural gas into useful final product or raw material. Downstream process includes refining of petroleum crude oil and the processing and purifying of raw natural gas, as well as distribution of products derived from crude oil and natural gas. The downstream sector reaches consumers through products such as gasoline or petrol, kerosene, jet fuel, diesel oil, heating oil, fuel oils, lubricants, waxes, asphalt, natural gas, and liquefied petroleum gas (LPG) as well as hundreds of petrochemicals.



Piping

Piping is the term normally used to describe plant or process piping or station piping in oil and gas industries. Process plant is a place where a series of activities are performed with various piping systems in are ordered manner to convert raw material into useful products or transfer fluid from one equipment to another within the plant boundary. Piping is a complex network of pipe and fittings including pipe, pumps, equipment, valves, fittings, flanges, bolts, gaskets, regulators, pressure vessels, pulsation dampeners, relief valves / devices, appurtenances attached to pipe, compressor units, metering facilities, pressure regulating stations, pressure limiting stations pressure relief stations, and fabricated assemblies and pressure containing parts within the defined boundaries of the plant. It also includes hangers and supports and other equipment necessary to prevent overstressing the pressure containing parts. Process plant piping is mostly above the ground with very few underground services such as sewage and drainage piping.

Onplot piping: Onplot is a location inside the designated plant boundaries and, generally, piping inside the on –plot boundaries comes under process piping.

Petroleum refinery is an industrial plant for processing or handling of petroleum and products derived directly from petroleum / oil and gas wells. Such a plant may be an individual gasoline recovery plant, a treating plant, a gas gathering and compression plant, gas processing plant (including liquefaction), or an integrated refinery having various process units and attendant facilities.

- Large series and networks of pipes are within the well defined boundaries of the plant/plot with all fittings and equipment's like pump, valves, instruments, equipment, unions and other miscellaneous items with an intention to transfer fluid from one facility to another within those boundaries as required.

ASME / ANSI B31.3 Code prescribes requirements for materials and components, design, fabrication, assembly, erection, examination, inspection, and testing of process / plant piping. This Code applies to piping for all fluids, including

(a) raw, intermediate, and finished chemicals

(b) petroleum products

(c) gas, steam, air, and water

(d) fluidized solids

(e) refrigerants

(f) cryogenic fluids.

The pipeline is series of straight pipes, welded together over a long distance for conveying oil or gas, over long distances. A system of pipes and other components are used for the transportation of fluids, between (but excluding) plants. A pipeline extends from pig trap to pig trap (including the pig traps) or, if no pig trap is fitted, to the first isolation valve within the plant boundaries. Pipelines used in the oil and gas industry vary according to many factors, such as the product to be transported, the delivery stage and whether it is part of the upstream, midstream or downstream sector. Natural gas is transported through the transmission pipeline system which is composed of large diameter steel pipe.

Pipelines are mostly large is diameter and transport bulk liquid or gas from one place to an other sometimes along 1000 kilometre long distances. Pipeline system comprise all parts of physical facilities through which liquid or oil / gas moves in transportation. Included within this definition are transmission and gathering lines, which transport liquid / oil / gas from production facilities to onshore locations and storage area.

Other Pipeline Components are Pig launcher / Pig receivers, Barred Tees, Isolation Joints, Pig signallers, Corrosion monitoring fittings, Shrink sleeves / External coatings / Cathodic protection for buried lines. The pipelines are laid underground, above the ground and underwater such as a subsea pipelines.

Piping & Pipeline Comparison

In the pipeline, use of pipe fittings is limited. Mostly long radius bends with very few other types of fittings are used at a pumping station and valve station. Whereas, in the case of piping, a very wide range of pipe fittings are used that serve different purposes within the piping system for change the direction, size, branching, blinding, etc. Similarly, in pipeline few equipment are used within the pipeline system such as pumps, booster, valves and instruments that support the function of the system to transport fluid safely over a long distance. Whereas, varieties of equipment such as a pump, valves, filter vessel, column, heat exchanger, instruments are used within the piping system that supports the function of the plant to produce the finished product.

Table 1 Piping and pipeline comparison

Sl. No.	Pipe / Piping System	Pipeline / Pipeline system
1.	Series and networks of pipes and fittings within the defined boundaries of the plant	Many straight pipes are welded together for conveying / transporting oil or gas, over long distances.
2.	These are plasnt or process piping, generally not exceeding 400 meter in length..	Mostly transporting bulk liquid or gas from one place to another. Sometimes 1000 kilometer long distances.
3.	Wide range of many pipe fittings are used.	Pipe fittings are comparatively very less in pipeline system.
4.	Mostly above the ground with very few underground services.	Pipelines are laid underground, above ground and underwater such as subsea pipeline.
5.	Piping system includes very small size piping to large diameters from ½" to 36" in diameter.	Comparatively and mostly larger size pipes are installed.
6.	Comprise many equipment within the piping system.	Few equipment are used within the pipeline system.
7.	Piping system design code include ASME B31.1, ASME B31.3	Pipeline system design code includes ASME B31.4, ASME B31.8
8.	In general on plot	In general Off plot.

IV. Types of Pipeline in Oil & Gas Industry

Gathering lines: Pipelines forming network and are connected from the wells to processing facilities. Gathering pipelines are used to deliver the oil or gas product from the source to processing plants or storage tanks. These are commonly fed by 'flow lines', each connected to individual wells in the ground. Additionally, subsea are pipes used for collecting product from deep water production platforms. Typical products carried by gathering pipelines include natural gas, crude oil (or combinations of these two products), natural gas liquids such as ethane, butane and propane. Compared to other pipelines, length of gathering pipelines are relatively short approximately 200 metres long. They are, typically, much smaller than transmission pipelines, usually under 20" diameter.

Transmission Pipelines: Transmission pipelines are used to transport crude oil, natural gas and refined products for long distances across states, countries and continents. They are used to move the product from the production regions to distribution centres or refineries. Transmission pipelines may have compressor stations (for gas lines) and pump stations (for crude oil and liquid products.

Flow lines: Flow line is a pipeline transporting untreated hydrocarbons and other reservoir fluids. Pipelines from the well are set the nearest processing facility / gathering station which is also called flow lines. Their purpose include moving the raw product from the well to the gathering lines. They carry a mixture of oil, gas, water and sand and are normally no more than 12" diameter in size.

Loading lines / Export lines: Loading / exporting pipeline is a pipeline between an onshore facility and an offshore loading facility. In other words, this is the pipeline from the processing facility to the loading or export point.

Trunk lines / Inter field lines: This is also a main transmission pipeline to which spurlines and offtake lines may be connected. Pipelines between two processing facilities or from pig trap to pig trap or from block valve station to block valve station are also called trunk line.

Spur lines / Transfer lines: It is the branch line exiting into trunk line or export line. That is, Spurline is a pipeline transporting fluid into a larger pipeline.

Injection lines: Injection lines are pipelines, injecting water / steam / polymer / gas into the wells to improve the lift by injected fluid pressure.

Off plot piping: Off plot is a location outside the designated plant boundaries and generally comes under the category of pipelines.

Disposal lines: Pipeline which disposes normally produced water into disposal wells (shallow / deep).

Subsea pipelines: Pipelines connecting the offshore production platforms to onshore processing facilities. Pipelines under deep seawater of Floating Platform Facilities are also called subsea pipelines.

Distribution pipelines: are a system made up of 'mains' and 'service' lines, used by distribution companies. Together they deliver natural gas to the neighbourhoods of homes and cities.

Mains pipelines: Distribution pipelines classed as 'mains' are the step between high-pressure transmission lines and low-pressure service lines. Materials used for these pipes include steel, polyethylene, cast iron, plastic and copper.

Feeder pipelines: Feeder pipelines are used to move the product from processing facilities and storage tanks to the long-distance transmission pipelines.

Distribution or Service pipelines - Distribution Service pipelines connect to a meter and deliver natural gas to individual customers. Materials used for service pipes include plastic, polyethylene, steel or copper. Pressure of the gas in these pipes is low at around 60 psi.

V. Piping and pipeline codes / standards

1. ASME B31.1 Power Piping

Piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, heating and cooling plants.

2. ASME B31.3 Process Piping

Piping typically found in petroleum refineries, chemical, pharmaceutical, textile, cryogenic plants and related processing plants and terminals.

3. ASME B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids

B31.4 prescribes requirements for the design, materials, construction, assembly, inspection, and testing of pipeline transporting liquids between production facilities, between plants and terminals and within terminals, pumping, regulating, and metering stations, tank farms, natural gas processing plants, refineries, ammonia plants, terminals (marine, rail, and truck), and other delivery and receiving points.

4. ASME B31.5 Refrigeration Piping

Piping for refrigerants and secondary coolants.

5. ASME B31.8 Gas Transportation and Distribution Piping Systems

Piping transporting products which are predominately gas between sources and terminals including compressor, regulating and metering stations, gas gathering pipelines. This Code covers the design, fabrication, installation, inspection, and testing of pipeline facilities used for the transportation of gas.

6. ASME B31.9 Building Services Piping

Piping typically found in industrial, institutional, commercial and public buildings and in multi-unit residences which does not require the range of sizes, pressures and temperatures covered in B 31.1

7. **ASME B31.11 Slurry Transportation Piping Systems**

   Piping transporting aqueous slurries between plants and terminals within terminals, pumping and regulating stations.

9. **Pipeline related ISO standards include :**

- ISO 3183 – Petroleum and Natural gas industries – Steel Pipe
- ISO 14692 – Petroleum and Natural gas industries – Glass Reinforced plastic piping
- ISO – 15590 – 1, 2 and 3 Pipeline fittings
- ISO 14313 – Petroleum and Natural gas industries – Pipeline valves
- BS / ISO 4427–1 2007 – Plastic piping systems – polythylene pipes and fittings for water supply systems.
- BS / ISO – 4437–2007 Buried polyethylene (PE) Pipes for the supply of gaseous fuel.
- IS - 14885 – Polyethylene (PE) Pipes for the supply of gaseous fuel.
- BIS / IS – 4984 – High Density PE Pipes for water supply

Abbreviations and Definitions

Many abbreviations are used in piping and pipeline works. The pipe fitter shall be familiar with those abbreviations and definitions as she may encounter these abbreviations in his routine work. Important abbreviations and corresponding definitions are listed herewith.

Abbreviations	Definitions
Abs	Absolute
AFC	Approved For Construction (Mostly specified in drawings & procedures)
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Standard for Testing Materials
Assy	Assembly
BIS	Bureau of Indian Standard
BLDG	Building
Btu	British thermal unit(s)
BOM	Bill Of Material
BOP	Bottom of pipe
BW	Butt Weld
CI	Cast Iron
CS	Carbon Steel
°C	Degrees Centigrade
°F	Degrees Fahrenheit
Dia / ϕ	Diameter
Drg	Drawing
DSS	Duplex Stainless Steel
EL	Elevation
EN	European Norms (Standards)
ERW	Electric Resistance Weld
FCAW	Flux Cored Arc Welding
FLG	Flange
FF	Flat Face (of Flange)
G	Gage or Gauge

GA	General Arrangement
GAIL	Gas Authority of India Limited
GALV	Galvanised
Gr	Grade
GTAW	Gas Tungsten Arc Welding
HDPE	High Density Polyethylene, MDPE - Medium Density Polyethylene
Hex	Hexagonal
HSE	Health Safety and Environment
IBR	Indian Boiler Regulation
ID	Inside Diameter
IFC	Issued For Construction
INS	Insulation
IS	Indian Standards
ISO	International Organization for Standardisation
Kw	Kilowatt(s)
LC	Lock Closed
LO	Lock Open
LR	Long Radius
Max	Maximum
MFG	Manufacturing
Min	Minimum
mm	Millimeter
MSS	Manufactures Standardization Society
MT / MPT	Magnetic Particle Testing
NDT	Non Destructive Testing
NPS	Nominal pipe size
OD	Outside Diameter
ONGC	Oil and Natural Gas Corporation
PCD	Pitch Circle Diameter (or) Pitch Centre diameter
P&ID	Piping & Instrumentation Diagram
PNGRB	Petroleum and Natural Gas Regulatory Board
PPE	Personnel Protective Equipment
PQR	Procedure Qualification Record
PRV	Pressure Relief Valve
Psi	Pounds per square inch
PSV	Pressure Safety Valve
PT	Penetrant Testing
PVC	Polyvinyl Chloride
RED	Reducer
RF	Raised Face
RT	Radiographic Testing
RTJ	Ring Type Joint
SMAW	Shielded Metal Arc Welding
SAW	Submerged Arc Welding
Sch	Schedule
SMLS	Seamless
Spec	Specification
SO	Slip On
SQ	Square

SR	Short Radius
SS	Stainless Steel
Std	Standard
STL	Steel
SWG	Swage
Temp	Temperature
T.O.C	Top Of Concrete
TOS	Top Of Steel
TYP	Typical
UT	Ultrasonic Testing
VT	Visual Testing
WN	Weld Neck
WT	Weight
XS	Extra strong
XXS	Double extra strong

Exercise

I. Answer the following questions.

1. Explain process piping.

----

2. What do you understand by the term "on plot" piping?

----

3. Explain oil and gas major sectors upstream, midstream and downstream.

----

4. Distinguish piping and pipeline system.

----

5. Describe trunk lines and spur lines.

----

6. Explain the purpose and significance of ASME B31.4 Pipeline Transportation Systems.

----

7. Write down the expanstion for the following abbreviations related to piping and pipelines.
   AFC, ASTM, BOM, ERW, NPS, PRV, SMLS, T.O.C, XXS

II. State whether the following statements are True or False.

1. Off plot is a location inside the designated plant boundaries and for generally piping inside the plant boundaries.
   True ☐ False ☐
2. Pipeline is series of straight pipes, welded together over a long distance, for conveying oil or gas.
   True ☐ False ☐
3. Exploration and production is a "midstream stream process" in oil and gas industry.
   True ☐ False ☐

4. Further processing of crude oil and natural gas into useful final product is a “downstream process.

   True ☐ False ☐

5. Pig launcher / Pig receivers and Pig signallers are pipeline components.

   True ☐ False ☐

6. Pipelines comprise many equipment and accessories within the pipeline system.

   True ☐ False ☐

7. Pipeline system design code includes ASME B31.4.

   True ☐ False ☐

8. Pipelines used to move the product from the production regions to distribution centres or refineries are called gathering lines.

   True ☐ False ☐

9. Transmission pipeline is a pipeline from the processing facility to the loading or export point.

   True ☐ False ☐

10. Loading / Export lines are used to deliver oil or gas products from the source to processing plants or storage tanks.

    True ☐ False ☐

11. Abbreviation ‘BOP’ stands for Bottom Of Piping.

    True ☐ False ☐

12. HDPE represents “High Density PVC Ethelene”.

    True ☐ False ☐

13. SWG is the abbreviation for “Sewage”.

    True ☐ False ☐

Notes

UNIT 1.2 Piping and Pipeline Layout Drawing

Unit Objectives

At the end of this unit, you will be able to:

1. read and interpret basics of engineering drawings and symbols
2. read, interpret piping isometric drawings, pipeline layout drawings, hangers and pipe support drawings and related engineering drawings
3. draw and illustrate pipeline system and bill of materials
4. describe various pipe supports.

1.2.1. Piping and Pipeline Drawings- Basics of Engineering

At the end of this topic, you will be able to:

1. describe basics of engineering drawings
2. read and interpret engineering drawings / projections
3. prepare simple drawings both in 1st angle and 3rd angle projections.

Introduction

Transmission of oil and gases subjects the pipe to intense stresses and strains and this demands the highest quality throughout the construction process from material sourcing, fitup, welding till installation. All pipework must be designed and fabricated in a way that ensures the safety of plant operators, the plant, the public and the environment and to the medium being transmitted.

Process piping is designed, constructed and installed in accordance with ASME B31.3 code. Power plant piping is designed, constructed and installed in according with ASME B 31.1.

In Oil and Gas Industries, a pipeline is designed in accordance with ASME B31.4 code for Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum, Anhydrous Ammonia, and Alcohol and ASME B31.8 that is the governing code for Gas Transmission and Distribution Piping Systems. Pipelines are laid above the ground, below the ground, river and in subsea.

Basics of Engineering Drawings

a. Drawings are prepared in grids with title blocks and coordinates.
b. Bill of materials, notes and instructions, if any, are incorporated into the applicable drawings.
c. Drawings may be prepared with or without scales.
d. Different types of drawings are prepared for piping and pipelines. They include GA – General Arrangement Drawings, Assembly drawings, plot plan, layout drawings, pipeline drawings, PID – Piping and Instrument Diagram, PEFS – Process Engineering Flow Scheme Isometric drawings, detailed drawings etc.
e. Drawings may be prepared in projectional view or isometric view.

Drawing line indications need to be:

- Visible continuous lines to depict edges directly visible from a particular angle and represent the features that can be seen in the current view.
- hidden / dotted or short dashed lines indicate the features that cannot be seen in the current view, representing edges that are not directly visible.

- centre line represents axis and symmetry of the object, path of motion, center of circle. Center line is drawn as long and short dashed lines, alternately.
- dimension, extension and leader lines indicate the sizes and location of the features.

1. Orthographic Projection

Piping drawings may be prepared in orthographic projection, isometric and block diagrams. Orthographic projection is a two dimensional drawing showing the true size / shape of the three dimensional object. It is a way of representing a three dimensional object on a drawing sheet. Image of a three dimensional object is projected and viewed / seen in directions that are right angle with each other. Orthographic drawings usually consist of the following:

Elevation / front view: This is a view of the object from the front side.

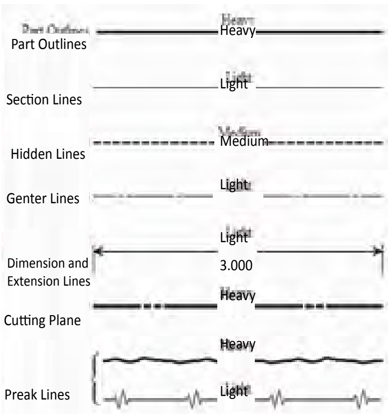
Top / plan view: This is the view of the object from the top.

Side view: This is the view of the object from the leftside or right side.

Sectional View: This is a cross – sectional view used to show the inside configurations / details.

Normally, in case of third angle projection, front view is drawn in lower left corner of the drawing; top view is drawn in the upper left corner and right side view on the lower right corner of the drawing. Same scale is used for drawing all the views. Orthographic Projection drawings may be prepared and presented in 1st angle or 3rd angle projection.

Orthographic projection symbols depicts whether the drawing is prepared in the first angle or third angle projection as given in the figure that following.



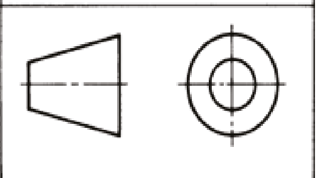
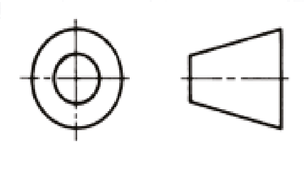
Projection	Symbol
First Angle	
Third Angle	

Fig. 1.2.1 Orthographic drawing projection symbols

a. First Angle Projection Method

First angle projection means viewing a body in the first quadrant. In India, at present, generally first angle projection drawings are used. Referring to 1.2.2 of the Tea cup, top view is drawn below front view and left side view is drawn in right side of the front / elevation view:

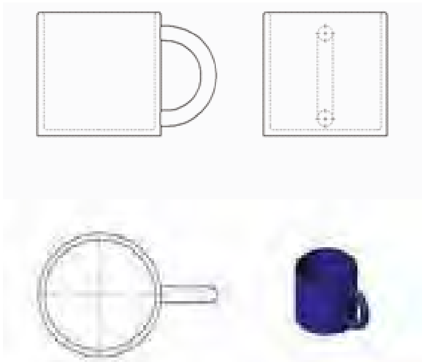


Fig. 1.2.2 First angle projection drawing of a Tea Cup

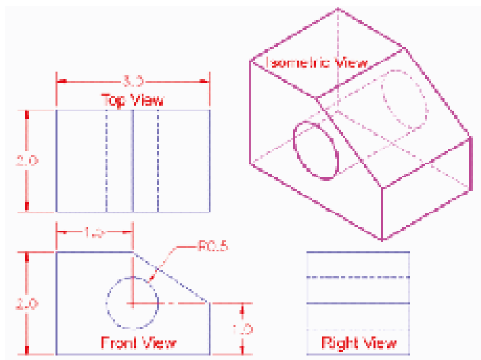


Fig. 1.2.3 Third angle projection drawing example

b. Third Angle Projection Method

Referring to Fig 1.2.3, the object is placed in the third quadrant. Vertical plane is a view from front of the object. Horizontal plane is a view from above the object. Top view is drawn above front view and right side view is drawn in the right side of the front / elevation view.

c. Piping system drawn in both 1st and 3rd angle projection

A simple piping system (consisting of run pipe, tube support welded to a flange, bolted to a stationary steel plate structure) drawn in both first and third angle projection methods has been illustrated in Fig.1.2.4.

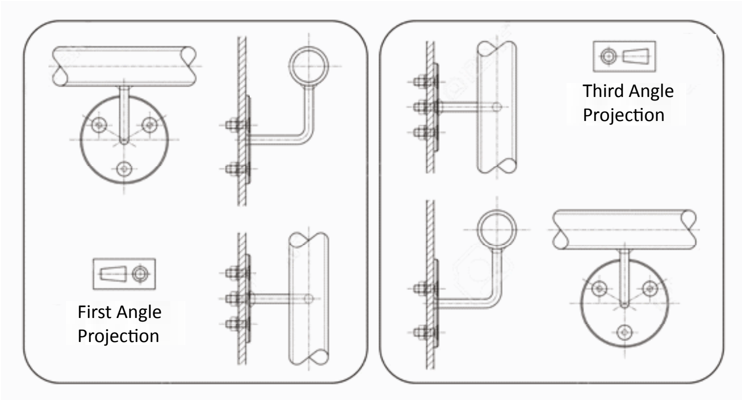


Fig. 1.2.4 – A simple piping system drawn in both 1st angle and 3rd angle projection.

Making Simple Drawings

1. Drawings shall include title block, revision block, notes list, bill of materials, views and sections, zone grids, scales, etc.

a. **Title Block:** Drawings shall include a title block. Contents of title block include project name, drawing title, drawing number, revision number, drawing scale, drawn by, reviewed / checked by, approved by, direction, first / third angle projection symbol, Issue status (such as AFC– Approved for Construction / IFC, Issued for Construction).

b. **Revision Block:** The revisions block is a tabulated list of the revisions (versions) of the drawing, documenting the revision history. Traditional location for the revisions block is the top / adjoining the title block.

c. **Zones / Grids:** Drawings contain letter and number labels along the margins such as A,B,C,D in sides and 1,2,3,4,5,6 along the top and bottom. Names of grids / locations are specified as A5, D2, or B1. This grid identification helps to reference particular areas of the drawing.

d. **Section Views:** Section views are projected views, showing crosssection of the source object along the specified cut plane. These views are commonly used to show internal features with more clarity than may be available using regular projections or hidden lines.

e. Revision locations are represented with clouded area and a triangle with the revision number.

f. Dimensioning in drawing shall be performed with unique practice. Examples of dimensioning has been shown in the Fig. 1.2.5 and 1.2.6.

h. Drawing to scale

1. When a drawing is to be preparded, all dimensions shall be proportional. Otherwise it will look like a cartoon.

2. If a house elevation drawing is to be propared, the drawing sheet shall not be to full height and length / width of the house. Hence, drawings are to be prepared to a reduced scale. All dimensions shall be converted to the convenient scale and drawn.

For example scale 1:20 means,

1mm in drawing represents the true size of 20mm

10mm in drawing represents the true size of 200mm

100mm in drawing represents the true size of 2000mm

For example scale 10:1 means,

10mm in the drawing represents the true size of 1mm

100mm in the drawing represents the true size of 10mm

g. Dimensioning Sample: It is a cylindrical solid object 2 inch (50.8 mm) long with major diameter (outside diameter) of 1 inch (25.4 mm) and a step having 0.65 inch (16.51 mm) diameter for 0.4 inch (10.16mm) depth.

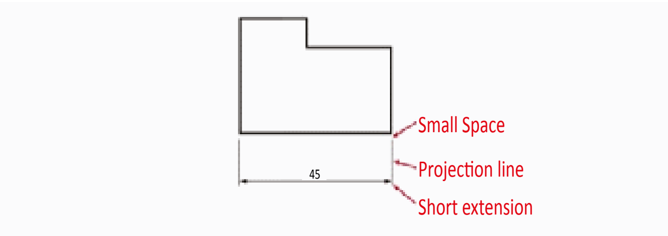


Fig. 1.2.5 Dimensioning system

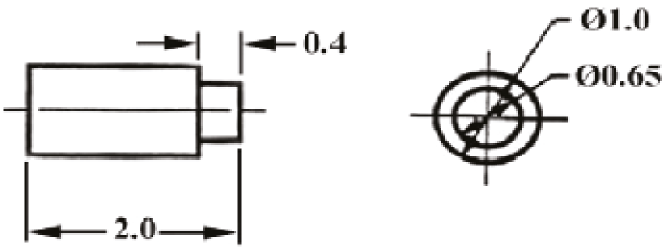


Fig. 1.2.6 Dimensioning(in inch unit) a cylindrical solid object having two different diameters

Spool drawings

A spool is an assembly of fittings, flanges and pipes that are to be prefabricated.

Piping Isometric views showing details and dimensions of all lines are produced from general arrangement drawings. These are called piping spool isometric drawings or simply spool drawings. A spool drawing will contain

- title block information
- the piping schedule
- the orientation symbol
- view of the pipe spool
- dimensions, elevation (height level) and location / position with respect to coordinates
- adjoining pipe spools
- the direction of flow of the conveyed fluid or gas.

Each pipe spool drawing may also list the materials required for fabrication of the spool.

Guidelines for making simple drawings

1. Choose the scale of the drawings considering the drawing size and object size. The scale shall be chosen in views that can be drawn in single sheets.
2. Draw the title block, revision block and grids.
3. Use appropriate pencils 2H, H, HB, etc., to draw the lines, outlines, section line, hidden line, centre line, etc.
4. Study the object and draw the elevation / front view.
5. Draw top / plane view.
6. Draw side / section view.
7. Assign dimensions and dimension lines with 'H' pencil and arrow with HB pencil.
8. Show the internal details such as holes, key ways, etc., in dotted line using "H" pencil.

1.2.2 1st and 3rd Angle Projection Drawing

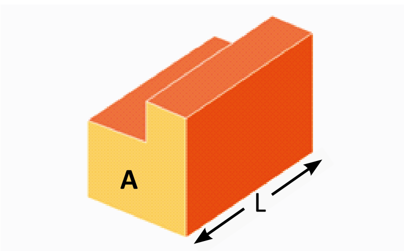
At the end of this exercise, you will be able to:

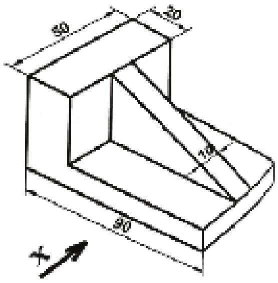
1. draw the 1st angle projection drawing for cylindrical pipe
2. draw the 3rd angle projection drawing of any given object
3. draw the orthographic projection drawing.

Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Geometry box	– 1 No.		
Steel rule	– 1 No.	Paper	–1No.
Set Sqaure	– 1 Set	Pencil	–1No.
		Drawing Sheet	–1No.
Equipment/Machines			
Personal Protective Equipment	– 1 Set		

1. Draw 1st angle projection drawing for a cylindrical pipe of sizes – 10 mm thickness, 220 mm outside diameter and one meter long (Scale 1:5).
2. Draw the 3rd angle projection drawing of the following object, looking at the side A (front view / elevation).
3. Draw the orthographic projection of the following object in 1st angle projection method and then in 3rd angle projection method, looking from X (Scale 2:1).





Exercise

I. Answer the following questions.

1. Draw the first angle projection symbol to be incorporated in the first angle projection drawings.

----

2. How is the axis / symmetry centre line represented in the orthographic projection drawing?

----

3. Distinguish Ist angle and 3rd angle projections.

----

4. What are the typical contents of a piping spool drawing?

----

5. What are the typical contents of the “Title block” of a drawing?

----

6. A drawing has been prepared to a scale of 1:100. If the length, width and height are measured in the drawing as 270mm, 180mm and 190mm respectively, what is the actual length, width and height of the object?

II. State whether the following statements are True or False.

1. Hidden / dotted or short dashed line in orthographic projectional drawing, indicates the features that cannot be seen in the current view.

   True ☐ False ☐

2. Orthographic projection drawings are drawn in a manner in which the length, width and depth are shown in a single view.

   True ☐ False ☐

3. In first angle projection drawing, top view is drawn below the front view and right side view is drawn in the left side of the front / elevation view.

   True ☐ False ☐

4. In revised drawings, revision locations are represented with clouded area and a triangle with the revision number

   True ☐ False ☐

Notes

1.2.3 Illustration of Pipeline System – Isometric Drawings

At the end of this topic, you will be able to:

1. describe various oil and gas pipe and pipeline drawings
2. read and interpret drawings for site / plant piping coordinates, elevation and plane North
3. describe significance of isometric drawings
4. read and interpret isometric drawings
5. prepare isometric drawings.

Major Types of Piping and Pipeline Drawings

Two major types of piping system drawings are

Orthographic – Plans and Elevations

Pictorial – Isometric Views

Orthographic drawings are views (front, side, top, etc.) of a piping system, and called "Piping Arrangements" while they represent piping system. (Select suitable scale.) An orthographic view shows only one side, and therefore multiple drawings (views) are necessary to show a complete piping arrangement.

Orthographic views are not really a best option, as a piping system is to be drawn in several planes (North to South, then down and then to the West, etc.). In an orthographic view, it is not a problem if the pipe runs in one plane. But when a pipe in two or three planes is to be drawn, an orthographic view can be unclear.

Isometric view of an object can be obtained by choosing the viewing direction such that the angles between the projections of the x, y, and z axes are the same, or 120°.

Illustration of Coordinates, Elevations and Plant North

Indicating the starting point of the piping installation site related to the North / South direction, is one of the first steps in setting up a coordination system. Coordinates are normally specified with reference to East or West and North or South directions. Fig 1.2.7 isometric drawing has east coordinate as 360.235 and South coordinate as

177.300 at one end of the spool and E 360.235 and S 180.300 at the other end of the spool. This indicates that both ends are at the same location/ position with respect to East – West direction and the distance between the spool ends are 3000 mm (180.300-177.300) with respect to North-South direction.

Elevations (height locations) are shown as EL + xxxxxx or E.xxxx. In fig 1.2.7, both end elevation (height with respect to datum) is EL =3.200 m which means that both ends are at the same height + 3.200m.

In principle, with a simple reliable compass the direction of the magnetic North can be determined.

In the Fig. 1.2.8 the true North is at 18°. As a draftsman would work with the true North coordinates, he will immediately find out that each line from West to East and from North to South at an angle of 18° must be drawn.

To avoid this, a Plant North will be determined. In the example is Fig. 1.2.8, the true North, 18° is reversed.

General rule is, that the angle between true North and Plant North cannot exceed 45°.

1 = Official reference point

2 = South West angle of new plant

X = East West distance from new plant to reference point

Y = North South distance from new plant to reference point

The highest point of finished grade refers to an official reference point on which all vertical measurements are related.

Isometric View Drawings

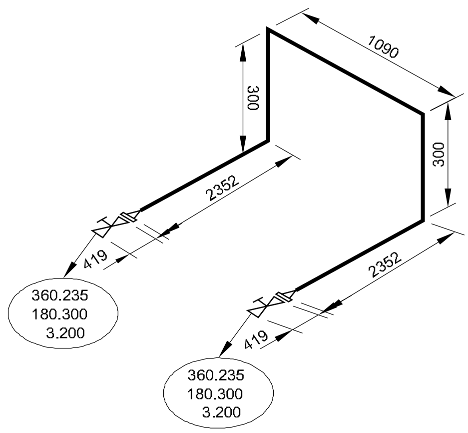


Fig. 1.2.7 Simple isometric drawing of a piping spool

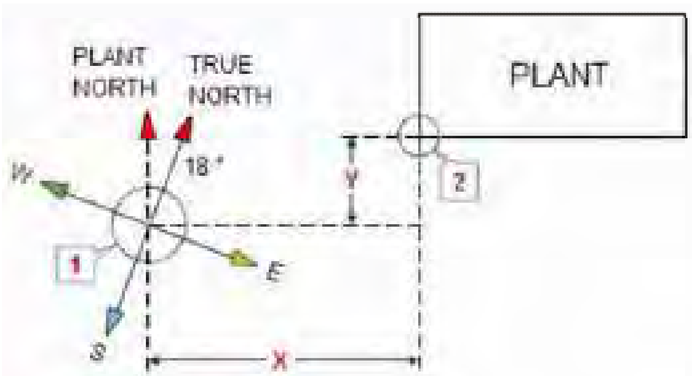


Fig. 1.2.8 Plant North Illustration

1. Introduction to Isometric Drawings

- Piping components are represented on the drawing by simple & stylised symbols which are widely accepted and self-explanatory.
- Isometrics are used in fabrication / shop drawings for pipe fabrication.
- Isometric spool drawings show the pipe spool in a pictorial view. Isometric drawing is a view of an object from a corner angle so that all the different views can be represented.
- Piping isometrics are drawn in a manner in which the length, width and depth are shown in a single view.
- Usually, piping isometrics are drawn with lines of equilateral triangles of 60°.
- Vertical lengths of pipes are calculated using elevations, while horizontal lengths are calculated using north-South and East-West coordinates.

2. Isometric Drawing Direction and Location

- Location and direction help to properly orient the isometric drawing.

- The orientation symbol or 'North arrow' appears on all piping drawings. The orientation symbol is of the utmost importance as it shows the direction of the piping run through the plant. It also shows the position of pipes relative to others and the relationship between pipes and other items of equipment.
- A north arrow gives direction and should always point to the upper-right corner of the drawing.
- South is opposite from North and points downside of the drawing and to the left. West is 90° from North however, in the isometric, it becomes the opposite 120° line. In this case, running up and to the left. East will be opposite to West and will run down and to the right. Pipelines running North/South or East/West will run parallel to the ground unless they are noted as otherwise.
- Coordinates and elevation should also be shown on the isometric drawing.
- Isometric drawings are drawn with hatches to indicate that a pipe runs (rotates) at a certain angle and in a certain direction.

3. Piping Isometric Reading and Interpretation

a. A piping in isometric view, is always drawn as a single line.

b. This single line is the centerline of the pipe and dimensions are measured from that line.

c. The Fig. 1.2.10 shows orthographic view of a butt welded pipe with three sizes (A, B, C).

- Size A is measured from the front to the center line of the elbow / pipe.
- B size is measured from center line to center line.
- C size is like A, measured from the front to the center line of the elbow / pipe.

4. Isometric view drawing preparation

The same object drawn in an orthographic projectional view as in fig 1.2.9 is drawn in isometric view as below.

The above drawing lines is drawn in a simple manner the showing the pipe with black dots. The black dots denote the butt welds. A, B and C are the dimensions of the front to the centre line, the centre line to the centre line and the centre line to the edge, respectively.

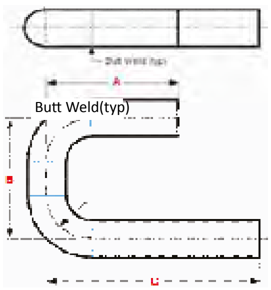


Fig. 1.2.9 Orthographic View (Double line presentation)

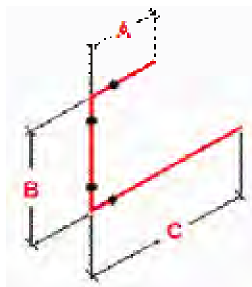


Fig. 1.2.10 Isometric view drawing sample

5. Interpreting Isometric views in more than one plane

i. Below are some examples of isometric drawings. (Fig. 1.2.11 & 1.2.12). The auxiliary lines in the shape of a cube, ensure better visualization of the piping / pipeline routing.

For pipeline which runs through three planes, has flanges at both ends. Routing starting point X (Fig. 1.2.11)

- pipe runs to the East
- pipe runs up
- pipe runs to the North
- pipe runs to the West
- pipe runs down.

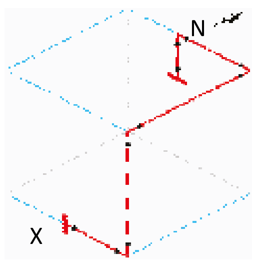


Fig. 1.2.11 Isometric view drawing representation in three planes

ii. Almost identical to the drawing above. A different perspective is shown, and the pipe that comes from above is longer. As this pipe runs behind the other pipe, it is indicated by a break in the line. Routing starting point X (Fig. 1.2.12)

- pipe runs to the South
- pipe runs up
- pipe runs to the West
- pipe runs to the North
- pipe runs down.

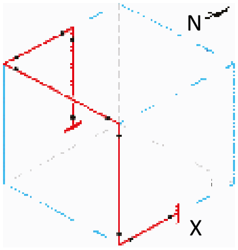


Fig. 1.2.12 Isometric view of different prospective

iii. Pipe that runs through three planes, from one plane to the opposite plane.

Routing starting point X (Fig. 1.2.13)

- pipe runs to the South
- pipe runs up
- pipe runs up and to the North-west
- pipe runs to the North.

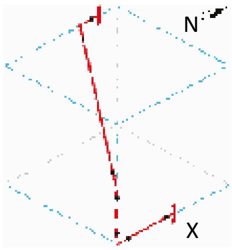


Fig. 1.2.13 Isometric view of a pipe from one plant to opposite plane

6. Hatches on Isometric Drawings

Hatches on isometric drawings are applied to indicate that a pipe runs at a certain angle and direction. Sometimes, with small changes in the hatch, the routing of a pipe is no longer the East, but suddenly becomes the North.

i. Pipe, where the hatch indicates that the middle leg runs to the east.

Routing starting point X (Fig. 1.2.15)

- pipe runs up
- pipe runs up and rolls to the East
- pipe runs up

ii. Pipe, where the hatch indicates that the middle leg runs to the North.

Routing starting point X (Fig. 1.2.16)

- pipe runs up
- pipe runs up and rolls to the North
- pipe runs up.

The above two drawings show that changing from only the hatch, a pipeline receives a different direction. Hatches are particularly important in isometric views.

iii. Pipe, where the hatches indicate that the middle leg runs up and to the North-West.

Routing starting point X (Fig. 1.2.17)

- pipe runs up
- pipe runs up and rolls to the North-West
- pipe runs to the North.

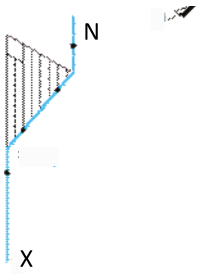


Fig. 1.2.14 Isometric view of piping with rolling and running to east

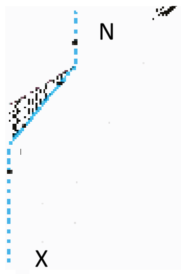


Fig. 1.2.15 Isometric view of piping with rolling and running to east

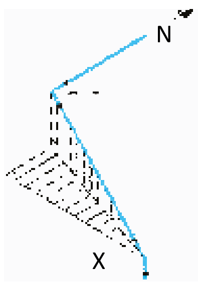
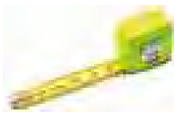
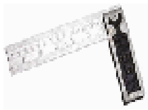
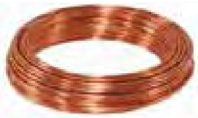


Fig. 1.2.16 Isometric view of piping with rolling north-west

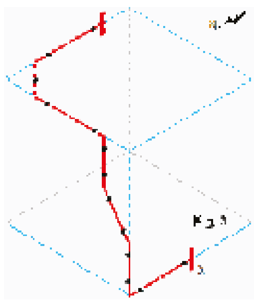
1.2.4 Pipe Spool Fabrication Simulation Practice

At the end of this exercise, you will be able to:

1. read and interpret isometric drawings with respect to pipe flow and rolling direction
2. fabricate pipe spools from raw materials as per the given isometric drawing.

Required	
Tools Instruments: Measuring tape Scale, Angle Bevel protractor, Try-square, Cutting plier.    	**Materials / Components:** MS / Copper solid wire 1.6 or 2 mm diameter – to the required length (500 to 900 mm approx). 

Work Instruction



1. Go through the drawings, read and interpret. North direction has been shown in the drawing as “N”. From this north direction, you can identify other directions.
2. Take a solid wire of the required length,which shall be flexible for bending by hand.
3. Routing starting point X and pipe runs to the South horizontally. Cutting plier can be used to twist / bend the wire.
4. Bend the wire to 90˚ up from one end, so as to show that the pipe runs up vertically.
5. After a certain distance, bend the wire to 45˚ inclination to vertical to show that the “pipe runs up and bows to the West”.
6. After a certain distance of inclined portion, bend the wire towards vertical up to show that the “pipe runs up” vertically.
7. Again a after certain proportional distance, bend the wire at 90 ˚ to show that the “pipe runs to the West” horizontally.
8. After a certain distance, bend the wire 90˚ to vertical up to show that the pipe “goes up” vertically.
9. Finally, bend to 90 ˚ along and towards North, horizontally. Check the angle using a bevel protractor.
10. Ensure that the bend wire end is parallel to the initial wire direction started at point ‘X’.

Figure 1. 2.12 shows a pipe spool that runs through three planes. There is a bow (rolling) in one plane 45 ˚ towards West .

Tips

- During practice, all lengths need to be proportionate and approximate. “Not to scale”.
- Bend angle is also approximate for practice. Try Square and angle protractor can be used if needed.
- **Safety:** Take care of sharp edges of solid wire while twisting as it may pierce / injure the hand. Use appropriate PPE.

1.2.5 Practising Isometric Drawing

At the end of this exercise, you will be able to:

1. draw the isometric drawing
2. make pipe spool model using solid wire.

Practical

Requirements **Tools/Instruments**		**Materials/Components**	
Steel rule	– 1 No.	Paper	–1No.
Set Sqaure	– 1 Set	Pencil	–1No.
Geometry Box	– 1 No.	Drawing Sheet	–1No.
		Steel solid line / Copper wire	–1No.
Equipment/Machines			
Personal Protective Equipment	– 1 Set		

1. Draw an isometric drawing for the piping system with 2” inch diameter piping when has flanges at both ends and has four 90° elbows of 2” inch diameter size duly getting welded with five pipe pieces. Routing shall starts at the entry point of the fluid at the lower point and flows towards cast. 250 mm long pipe runs to the East then 500 mm long pipe runs up 500 mm long pipe to the North. 260 mm long pipe runs to the West 150 mm pipe runs down.

Exercise

I. Answer the following questions.

a. Describe isometric drawings.

----

b. Explain drawing coordinates, elevation and plant north illustration.

C. Distinguish between isometric and orthographic drawings.

II. State whether the following statements are True or False.

1. Isometric drawing is a pictorial representation type of drawing.

   True ☐ False ☐

2. Hatches in isometric drawings indicate that a pipe runs at a certain angle.

   True ☐ False ☐

3. In isometric view, the pipe is always drawn as a double line.

   True ☐ False ☐

4. In piping isometric drawing length, width and depth are the same.

   True ☐ False ☐

Notes

1.2.6 Piping and Pipeline System – Plot Plan, GA Drawing, P & ID

At the end of this topic, you will be able to:

1. describe plot plan, general arrangement, piping arrangement drawings
2. explain the significance of single and double line representation
3. determine the contents of P & ID drawing.

Plot Plan

Plot Plan is generally drawn to a scale. Plot plan gives an overview (top view) of the entire plant. All roads, buildings, equipment, entrance, etc., will be shown on a plot plan. It also contains arrow indications to show the true North direction and Plant North. Plot plans may be overall plot plan called site plan in which only major items will be shown or detailed plot plan which may be drawn for each elevation level.

Detailed Plot Plan: Detailed Plot Plan gives an overview (top view) of a part of a process plant. Generally, it shows a part of a certain area, floor or unit.

General Arrangement (GA) / Equipment Arrangement Drawings

These drawings indicate the locations / general arrangement of main equipment in the plant. The main piping items, valves, and fittings are also indicated in the General Arrangement (GA) drawings. Most often the piping is indicated using a top view. Sometimes, a side view of the pipe rack is also presented on the GA drawing.

Equipment Arrangements are drawings which show the top and side view of a part of a process plant. The top view is similar to a detailed Plot Plan, except that only the equipment is shown. Equipment arrangements drawing shows the equipment in a particular area, and sometimes, a few details around a specific device.

Plot Plans and equipment arrangements are resources to help determine relative and specific positioning of equipment on a process plant, related to the plant North.

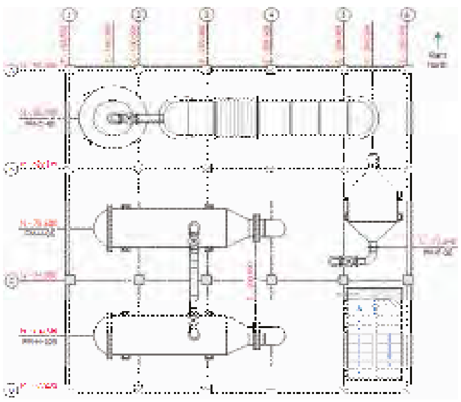


Fig. 1.2.17 Top view 4th floor detailed plot plan at EL.129200

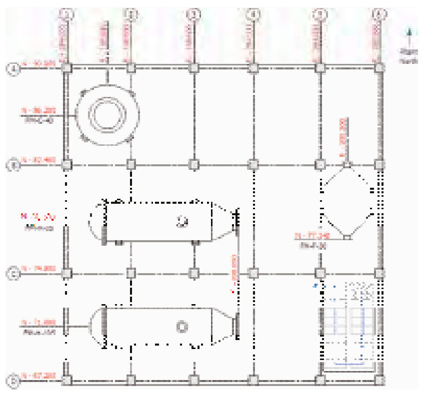


Fig. 1.2.18 -4th floor equipment arrangement at EL.121900

Piping Arrangement Drawings

Pipelines on a piping arrangement are shown as single lines and double lines. In single line representation only the center line of the pipeline is drawn using a solid line. In double line representation the actual size to scale is drawn with center line marked in chain dotted lines. When orthographic projection is used, pipelines may be drawn as either single line or double line drawings.

a. Double line presentation

Double line representation shows the two edges of the pipework and is usually used for pipes over Ø 350. Double line drawings show more graphic representation of the pipework; however, these are more difficult and more expensive to produce.

b. Single line presentation

Single line orthographic drawings represent the pipe by its centre line only, which is drawn as a continuous heavy line (usually the darkest line on the drawing). The size of the pipe is shown by drawing a representation of the pipe end to scale, either at the end of the line or some other convenient place.

- On single-line diagrams, all fittings except reducing fittings are drawn as single lines. Flanges are shown as thick lines drawn to the scale, outside the diameter of the flange.
- For flanged joints, a small gap between dimension lines will be shown to indicate a gasket.
- Valves are shown with identification number and a handwheel is drawn with the stem fully extended. If a valve is lever operated, then the movement of the handle's position is given.
- Dimensions for flanged valves are given to the flange faces, while non – flanged valves are dimensioned to the center lines of their stems.

Piping and Instrumentation Diagram

1. Piping and Instrumentation Diagram (P & ID) is a detailed diagram in the process industry which shows the piping, vessel / equipment, interconnection of process equipment and the instrumentation and control devices used to control the process. In the process industry, a standard set of symbols is used to prepare drawings of processes. They usually contain the following information:
    - process piping sizes and identification
    - pipe classes or piping line numbers
    - flow directions
    - interconnections references, vents, drains, reducers, swages
    - permanent start up, flush and bypass lines
    - mechanical equipment and process control instrumentation and designation (names, numbers, unique tag identifiers)
    - valves and their identifications (isolation, shut off, relief and safety valves)
    - control inputs and outputs (sensors and final elements, interlocks)
    - miscellaneous – vents, drains, flanges, special fittings, sampling lines, reducers, etc.
    - interfaces for piping class changes
    - identification of components and subsystems delivered by others, such as vendors, suppliers.

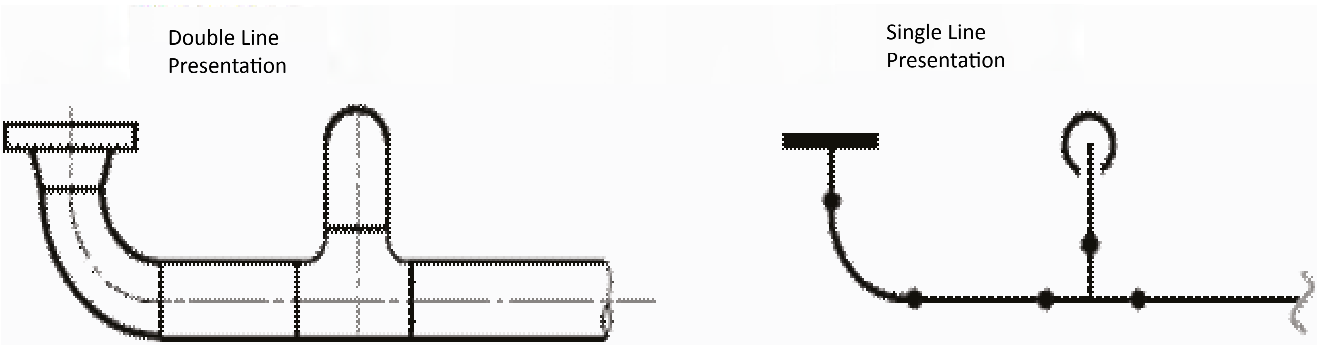


Fig. 1.2.19 Example of a single line and double line representation of a piping

2. P & ID provides a schematic representation of the piping, process control, and instrumentation which shows the functional relationships among the system components. The P & ID also provides important information needed by the constructor and manufacturer to develop the other construction input documents (the isometric drawings or orthographic physical layout drawings).

3. The P & ID provides direct input to the field for the physical design and installation of field-run piping. It accomplishes this by showing all the piping, equipment, principal instruments, instrument loops, and control interlocks.

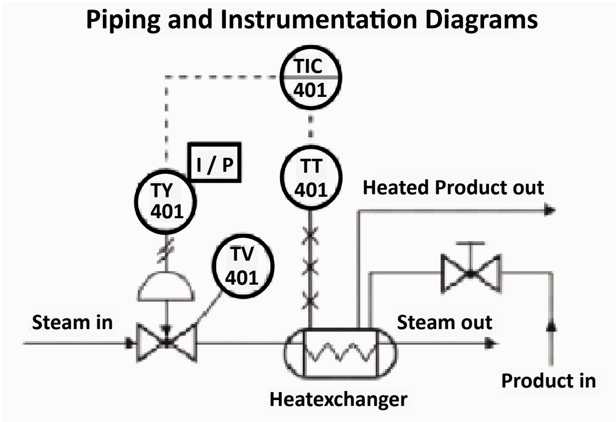


Fig. 1.2.20 Large image of a simple Piping & Instrument Diagram

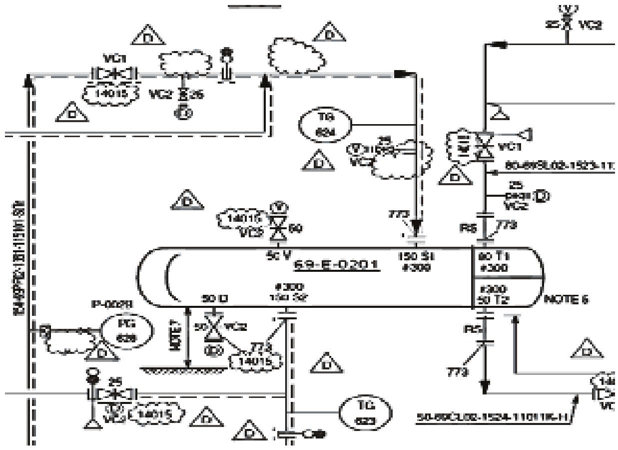


Fig. 1.2.21 Sample Piping & Instrument Diagram

Exercise

I. Answer the following questions.

1. Describe plot plan and general arrangement drawings.

2. List out any six contents of P & ID drawings.

3. Distinguish between single line and double line representation drawings.

II. State whether the following statements are True or False.

1. Pipelines may be drawn as either single line or double line drawings in the orthographic projection.

   True ☐ False ☐

2. P & ID will not show flow direction.

   True ☐ False ☐

3. P & ID provides a schematic representation of the piping, process control, and instrumentation

   True ☐ False ☐

4. On single line diagrams, reducing fittings are drawn as double lines.

   True ☐ False ☐

Notes

1.2.7 Reading Pipe Chart, and Preparing Bill of Materials

At the end of this topic, you will be able to:

1. describe pipe and tube
2. specify pipe size / diameter in different nomenclatures
3. read pipe chart / pipe thickness table
4. recognise dimensional tolerances
5. prepare bill of materials.

1. Pipe and Tube

International standards do not differentiate tube and pipe. Pipe is a pressure tight cylindrical hollow item, used in the piping system to transport liquid, gas and rarely solids. Tube is the common word used for hallow sections, like square tube, rectangular tube and round tube. Pipe is the word used for round tube only. However, the manufacturing industry provides the differentiation of pipe and tube based on diameter duly stating that tubes are always assigned with OD (all sizes) and pipes with inside diameter basis.

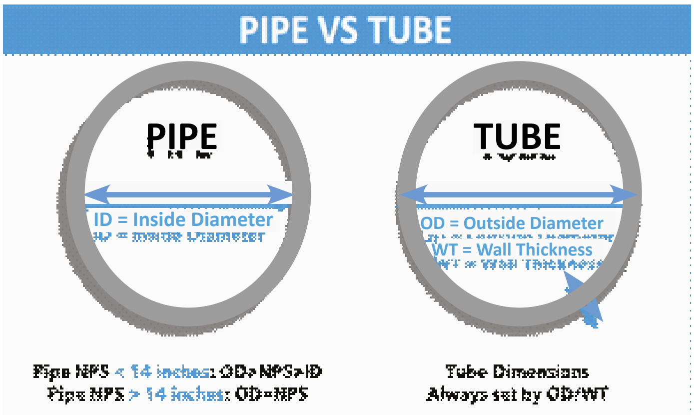


Fig. 1.2.22 Sample Piping & Instrument Diagram

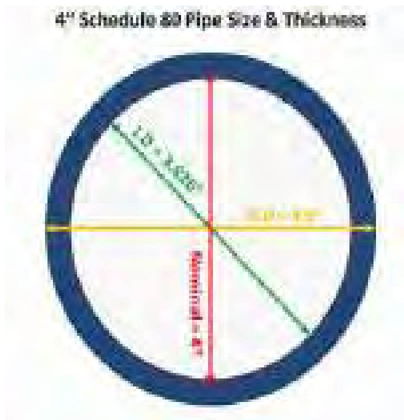


Fig. 1.2.23 – Pipe - OD & ID indication

2. Specifying pipe sizes – Pipe diameter

Pipe diameter sizes are specified with different abbreviations such as – NPS, NB, DN, etc.

a. **Nominal pipe size (NPS)** is the size of the pipe diameter based on inches. 6” pipe means 6” is the nominal size of that pipe.

For pipe sizes, NPS 14 and above outside diameter is same as NPS, meaning that NPS 14 (DN350) and above pipe OD is corresponding to the Nominal Size of a pipe.

NPS 1/8 (DN 6) to NPS 12 (DN 300) pipe is based on fixed outside diameter (OD). So, any increase in the wall thickness decreases the inside diameter (ID) of the pipe.

Table1 Specifying nominal pipe size

OD in Inch	OD in MM	Thickness in Inch	Thickness in mm	ID in inch	ID in mm
For NPS 2” Schedule 40 pipe					
2.375NPS	60.3	0.154	3.91	2.067	52.5
For NPS 4” Schedule 40 pipe					
14	350	0.438	11.13	13.124	333.3

Table 2 Specifying nominal pipe size

Nominal Pipe Size	Diameter Nominal	Nominal Pipe Size	Diameter Nominal
NDN (mm)nches)	DN (mm)	NPS (inches)	DN (mm)
1/8	6	20	500
1/4	8	22	550
3/8	10	24	600
1/2	15	26	650
3/4	20	28	700
1	25	30	750
1 ¼	32	32	800
1 ½	40	36	900
2	50		
2 ½	65		
3	80		
3 ½	90		
4	100		
5	125		
6	150		
8	200		
10	250		
12	300		
14	350		
16	400		
18	450		

From the table 2, it can be observed that for NPS 2, Pipe ID is near pipe NPS and for NPS 14 pipe OD is the same as NPS.

Pipe size‘inch’ dimension to ‘mm’ by multiplying it with 25.4 and rounding as follows.

i. outside diameter above 16 inches rounded to nearest 1 mm

ii. outside diameter 16 inches and below rounded to nearest 0.1 mm

iii. pipe wall thickness is rounded to nearest 0.01 mm

b. **Pipe Nominal Bore (NB):** NPS is frequently referred as an NB (Nominal Bore). As such, there is no difference between NB and NPS.

c. **DN (Diameter Nominal) Pipe Sizes:** DN or Diameter Nominal is International designation (SI or Matric Designator). 2” pipe is simply mentioned as DN 50. There is no change in other dimensions when the term DN is used.

d. Pipe diameter comparison is given in Table 2.

3. Specifying pipe sizes – Pipe Thickness:

Table 2.3 – Standard Pipe thickness designation

For Carbon Steel and Wrought iron Pipe as per ASME B36.10	5, 10, 20, 30, 40, 60, 80, 100, 120, 140, 160, STD, XS, XXS
For Stainless Steel Pipe as per ASME B36.19	
STD (Standard) and Schedule 40 has same thickness up to NPS 10 (DN 250)	
Above NPS 10 STD have a wall thickness of 3/8 in. (9.53 mm)	
XS has same thickness as Schedule 80 for up to NPS 8 (DN 200)	
Above NPS 8 XS have a wall thickness of ½ in. (12.5 mm)	

Table 2.4 pipe thickness chart (ASME B 36.10)

Nominal Pipe Size (NPS)		Outside Diameter		Nominal Wall Thickness																			
				Sch 40		Sch 60		XS		Sch 80		Sch 100		Sch 120		Sch 140		Sch 160		XXS	
A	B	MM	IN	A	B	MM	IN	A	B	MM	IN	A	B	MM	IN	A	B	MM	IN	MM	IN
8	1/4	13.7	0.540	2.24	0.088	-	-	3.02	0.119	3.02	0.119	-	-	-	-	-	-	-	-	-	-
10	3/8	17.1	0.675	2.31	0.091	-	-	3.20	0.126	3.20	0.129	-	-	-	-	-	-	-	-	-	-
15	1/2	21.3	0.640	2.77	0.109	-	-	3.73	0.147	3.73	0.147	-	-	-	-	-	-	4.78	0.188	7.47	0.294
20	3/4	26.7	1.05	2.87	0.113	-	-	3.91	0.154	3.91	0.154	-	-	-	-	-	-	5.56	0.219	7.82	0.308
25	1	33.4	1.32	3.38	0.133	-	-	4.55	0.179	4.55	0.179	-	-	-	-	-	-	6.35	0.250	9.09	0.358
32	$1^{3/2}$	42.2	1.66	3.56	0.140	-	-	4.65	0.191	4.85	0.191	-	-	-	-	-	-	6.35	0.250	9.70	0.382
40	$1^{3/2}$	48.3	1.9	3.68	0.145	-	-	5.08	0.200	5.05	0.200	-	-	-	-	-	-	7.14	0.281	10.15	0.400
50	2	60.3	2.38	3.91	0.154	-	-	5.54	0.218	5.54	0.218	-	-	-	-	-	-	8.74	0.344	11.07	0.436
65	$2^{1/2}$	73.0	2.68	5.16	0.203	-	-	7.01	0.276	7.01	0.276	-	-	-	-	-	-	9.53	0.375	14.02	0.552
80	3	88.9	3.5	5.49	0.216	-	-	7.62	0.300	7.62	0.300	-	-	-	-	-	-	11.13	0.438	15.24	0.600
90	$3^{1/2}$	101.6	4	5.74	0.226	-	-	8.08	0.318	8.08	0.318	-	-	-	-	-	-	-	-	-	-
100	4	114.3	4.5	6.02	0.237	-	-	8.56	0.337	8.56	0.337	-	-	11.13	0.438	-	-	13.49	0.531	17.12	0.674
125	5	141.3	5.56	6.55	0.258	-	-	9.53	0.375	9.53	0.375	-	-	12.70	0.500	-	-	15.88	0.625	19.05	0.756
150	6	165.3	6.62	7.11	0.250	-	-	10.97	0.432	10.97	0.432	-	-	14.27	0.562	-	-	18.26	0.719	21.95	0.664

a. Pipe schedule is one way of mentioning pipe wall thickness. Schedule 40 means a pipe thickness designator. If the schedule number increases, the thickness also increases. Schedule 80 pipe is thicker than schedule 40 pipe. For stainless steel piping, ASME has introduced different schedule numbers for stainless steel pipe and fittings. "S" suffix is introduced for SS pipe. For example, 10S.

b. Three more symbols are used for piping thickness 'STD, 'XS' and 'XXS'.

- STD is identical to SCH 40 for NPS 1/8 to NPS 10, inclusive.
- XS is identical to SCH 80 for NPS 1/8 to NPS 8, inclusive.
- XXS wall is thicker than SCH 160 from NPS 1/8" to NPS 6" inclusive, and
- SCH 160 is thicker than XXS wall for NPS 8" and larger.

c. Standard Pipe Schedule are as per ASME B36.10 and B36.19 as summarised in table 3 and 4.

4. Pipeline diameter and thickness tolerances

Unless specific tolerances are stipulated and specified in the drawings or project specific specifications, respective manufacturing standards shall be followed for diameter and thickness tolerances for all pipes and fittings. As an example, pipeline standard -API 5L diameter and thickness tolerance tables

5. Calculation of Pipe Inside Diameter (ID) is done with the help of Outside Diameter (OD) and thickness of the pipe by using formula given below.

Pipe ID = [Pipe O.D. – (2×Pipe wall thickness)

For example, 2.1: If Pipe OD is 610 mm and wall thickness is 16 mm, find out pipe ID

Pipe ID = 610-2 x16 = 578 mm.

Bill of Materials preparation for piping / pipeline fabrication

- Bill of Materials is a list of raw materials, sub-assemblies, intermediate assemblies, sub-components, parts, and the quantities needed for piping / pipeline manufacturing, construction and installation. It is the basis for preparation of Material Take Off list (Part No).
- Bill of Materials:
- is essential for piping materials planning
- helps to accurately plan material requirements
- helps for material sourcing,
- makes easier material forecasting and expediting easier
- makes the estimation of material requirements, material and products cost easy
- helps to plan in advance about which materials that are available in stock and the materials that are to be purchased
- helps to prepare Master Production Schedule / tasks / targets in sequence considering materials availability in stock / purchase duration.

Bill of Material Preparation

i. Bill of materials shall include – Part / Item number, List of items, description, size, unit of measure, material specification / standard, quantity etc. It shall list all piping / pipeline components shown in piping / pipeline drawings. While preparing bill of materials, there shall be adequate length of pipe for field joints allowance, cutting and edge preparation etc. Additional / extra bolts, nuts, gaskets and other fasteners shall be listed considering the testing requirements, spare parts and replacement after testing.

ii. Part Number shall be assigned to each part or assembly to quickly reference and identify parts.

iii. Unique name / material item description shall be given to each part or assembly to help distinguishing between similar parts and identify specific parts more easily.

iv. Quantity / number of parts or items shall be specified for each assembly or sub – assembly. Extra / additional quantities for testing requirements, spare parts requirements and replacement after testing shall be specified.

v. Unique, consistent and standard unit of measure such as feet, inches, millimetre or meter shall be specified.

vi. Necessary notes shall be incorporated for more clarity / explanation.

1.2.8 Pipe Spool Fabrication-Bill of Material (BOM) Preparation

At the end of this exercise, you will be able to:

1. Prepare Bill and Materials for the given pipe spool fabrication.

Practical

Required Tools / Instruments	Required Materials / Components:
Scale for drawing lines to form table.	Isometric drawing, paper and pen

Work Instruction

1. Prepare a table with columns for part number, material description and size, material standard with specification, size with unit of measurement and quantity.
2. Add 100 mm extra length for each pipe spool free end, either for cutting allowance or for field adjustment.
3. Check for number of same size pipes and group same size pipes together.
4. Add same size pipe length together and calculate total running length for each pipe size.
5. Specifythe length in "size and unit" column. If the pipe length is more than 6 meter, it is usual practice to calculate the number of pipes considering each pipe length as 6 meter long.
6. Count the number of flanges of same material, same size and same rating together and add the quantity in the BOM. Repeat this exercise for each group (size, rating, material) of flange.
7. Similarly, count the quantities of fittings elbows, weld o lets etc for each group and fill the BOM.
8. Calculate the quantity of fasteners (stud bolts and nuts) of each diameter /size , grade, material etc.
9. Add 10 % spare for each fasteners group to keep in the store as "spare item" and use later during any repair / replacement at the time of operation / maintenance.
10. Similarly, calculate the gaskets required and specify in the BOM.
11. First, list all pipes in the BOM on pipe size descending order. Then list all fittings, flanges, bolts and nuts, valves, gaskets duly leaving a blank row between each material type.

BILL OF MATERIAL / MATERIAL TAKE OFF				
Part No	**Item / Material Description and size & unit**	**Material Std / Spec**	**Qty**	**Remarks**
1	2"Ø sch 80 Pipe -3.5 meter long	ASTM A 106 Gr B	1	
2	¾ " Ø sch 80 pipe- 300 mm long	ASMT A 106 Gr B	1	
3	2"Ø-300# WNRF BW RTJ flange sch 80	ASTM A 105 / B16.5	1	
4	¾" Ø -3000# WNRF flange sch 80	ASTM A 105 / B16.5	2	
5	2" Ø-45˚ LR BW Elbow Sch 80	ASTM A 234 WPB	2	
6	¾" Ø-90˚ LR BW Elbow Sch 80	ASTM A 234 WPB	1	
7	2"x ¾"Ø Branch outlet – Sch 80	ASTM A 105	2	
8	2"Ø –300# RTJ – Metallic gasket R23	ASTM B16.20	2	
9	¾"Ø – 3000# Spiral wound gasket	ASTM B16.20	6	
10	¾" Ø – 300# ball valve	ASTM B 16.33	1	
11	5/8" Ø -110 mm long stud bolt – B7	ASTM A 193	8	
12	5/8" Ø- nut- 2H	ASTM 194	16	
13	5/8" Ø- 65 mm long stud bolt- B7	ASTM 193	20	
14	5/8" Ø- nut -2H	ASTM 194	40	

Tips

Safety: The installation and putting in to operation are only to be executed by qualified, competent and experienced personnel, who are acquainted with installation and mounting as well as the applicable standards.

1.2.9 Prepare Bill of Material (BOM)

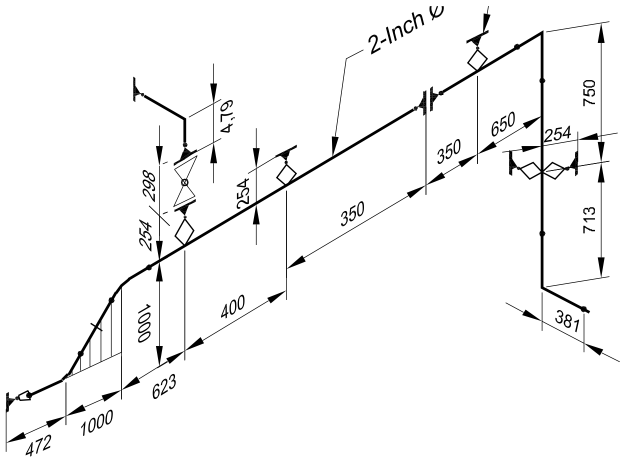
At the end of this exercise, you will be able to:

1. prepare bill of material for piping isometric drawing
2. prepare bill of material for the pipe support drawing.

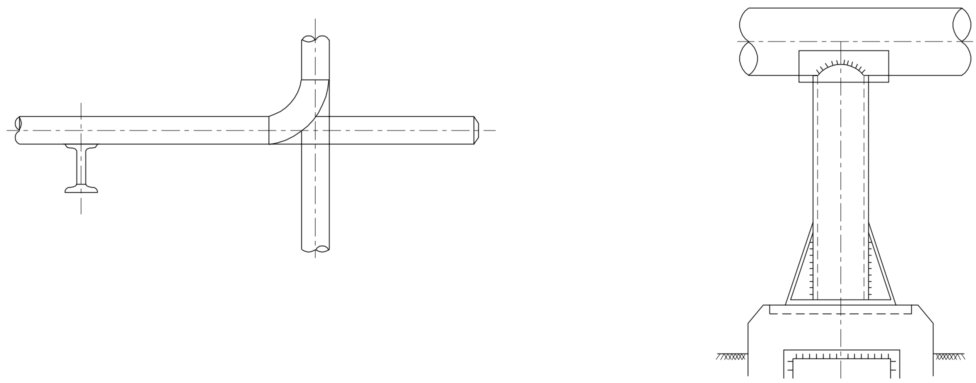
Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Steel rule / Measuring Tape	– 1 No.	Paper	–1No.
Vernier Caliper	– 1 No.	Pen	–1No.
		Isometric drawing (piping)	–1No.
		Isometric drawing (piping support)	–1No.
Equipment/Machines			
Personal Protective Equipment	– 1 Set.		

1. Look at the piping isometric drawing below and prepare BOM (Bill of material).



2. Look at the pipe support drawing below and prepare BOM (Bill of material).



Sl. No.	Material Description	Size	Quantity	Remarks

Exercise

I. Answer the following questions.

1. List out any five uses of Bill of Materials.

----

2. List out any five contents of Bill of Materials.

----

3. Calculate Pipe Outside Diameter (OD) for the pipe of Inside Diameter (ID) 580 mm and Thickness of 15 mm.

----

4. Describe pipe and tube.

----

5. Describe the pipe sizing abbreviations, NPS, NB, DN.

II. State whether the following statements are True or False.

1. For pipe sizes NPS 14 and above, Outside Diameter is the same as NPS.

   True ☐ False ☐

2. Referring to B36.10 thickness table, 10”NB -sch 60 wall thickness is 12.07 mm.

   True ☐ False ☐

3. Bill of Material contains material price / rate.

   True ☐ False ☐

4. DN50 means Nominal Outside Diameter 50mm.

   True ☐ False ☐

5. In general nominal pipe thickness specified as “STD” for carbon steel piping, it will be identical to sch 40.

   True ☐ False ☐

Notes

1.2.10 Standard Symbols of Piping Drawings – Welding Symbols

At the end of this topic, you will be able to:

1. read and interpret weld symbols
2. prepare weld joint surfaces / edges as denoted by the weld symbol
3. perform pipe fitting works to the required weld joint configuration as represented by the weld symbol.

Introduction

Piping / pipeline system includes pipe, flanges, elbows, tees, gaskets, bolts, nuts, support plates, valves, standard supports, lining pads, pressure gauges, temperature indicating gauges, etc. These shall be drawn with lines and standard symbols. Pipe fitter shall have adequate knowledge about various piping, welding, fittings, instruments, standard symbols, etc., to read and interpret the drawings easily.

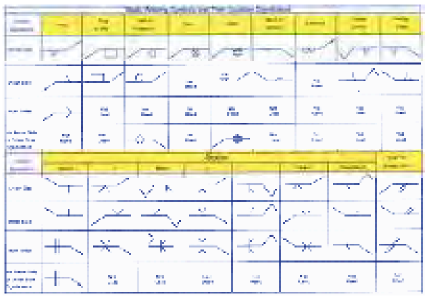


Fig. 1.2.24 Fillet weld symbol information

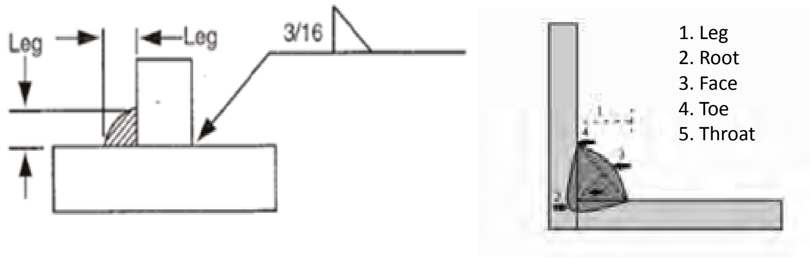


Fig. 1.2.25 Basic Welding Symbols-AWS

Complete Joint Penetration

Since many applications require welds providing complete joint penetration (CJP), there are several ways to specify this condition. One way is to use an arrow, a reference line, and add CJP in the tail of the symbol. A second way to specify the complete joint penetration is to include a single groove-weld symbol or double groove-weld symbols (must be the same weld symbol on both sides of the reference line).

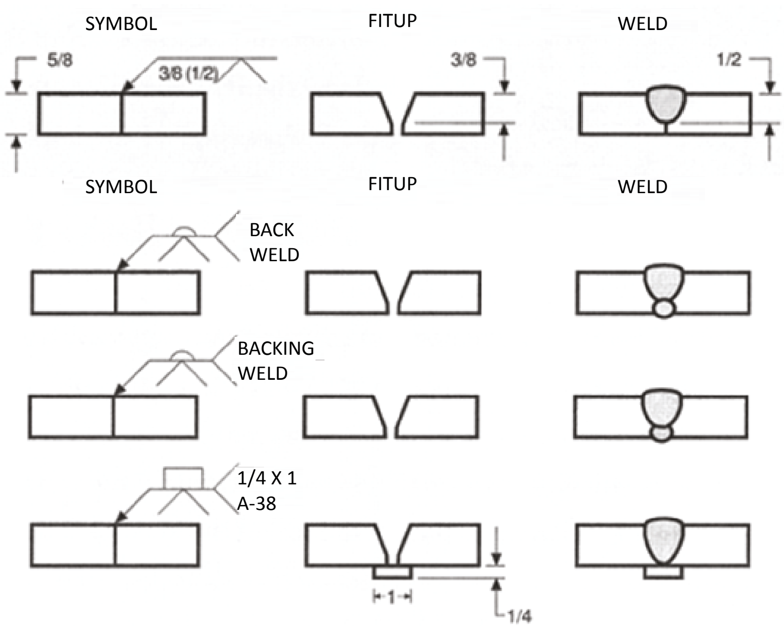


Fig. 1. 2.26 Butt weld joints penetration

Butt Joints Edge Preparation and Weld Type

Important butt joints weld preparation grooves / edge preparation with respect to weld type is as given in Fig. 1.2.28. Important weld symbols, associated joint / edge preparations and respective weld illustrations are also given.

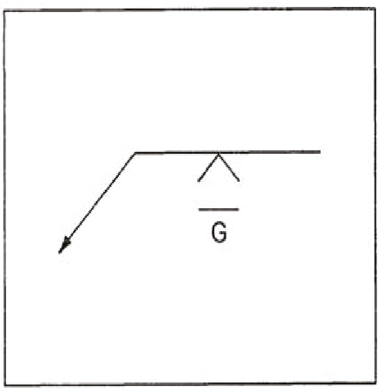


Fig. 1.2.27.-Finish and contour symbols.

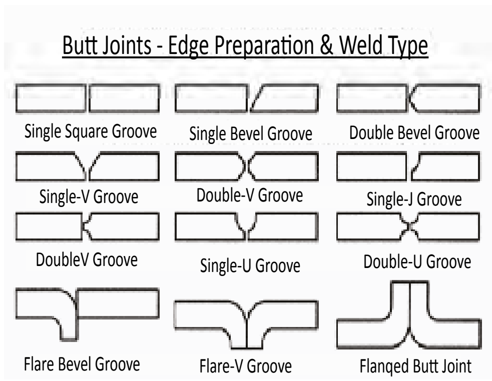


Fig. 1.2.28 Butt Joints- Edge preparation and Weld Type

Exercise

I. Answer the following questions.

1. Draw any four complete joint penetration weld symbols and draw the required edge preparations.

----

2. What is the information conveyed through weld symbols?

----

3. Draw a weld symbol for welding 6 inch NB 12.7 mm thickness pipe to be welded all around a field with a dummy plate of 200 mm square 16 mm thickness. Complete joint penetration weld with 45 degree single bevel 9 mm depth, to be welded from the pipe outside.

Notes

1.2.11 Standard Symbols of Piping Drawings

At the end of this topic, you will be able to:

1. read and interpret piping symbols
2. list the type of instruments to be installed and prepare components accordingly.

Line Symbols

The process lines are the lines where the process media actually flows through. They are represented by different types of lines. On a complete P & ID, each line will be labelled with a line number. Process lines are bolder than other lines such as those that represent electric, pneumatic or data signals. Important line symbols used to prepare drawing, are as given below:

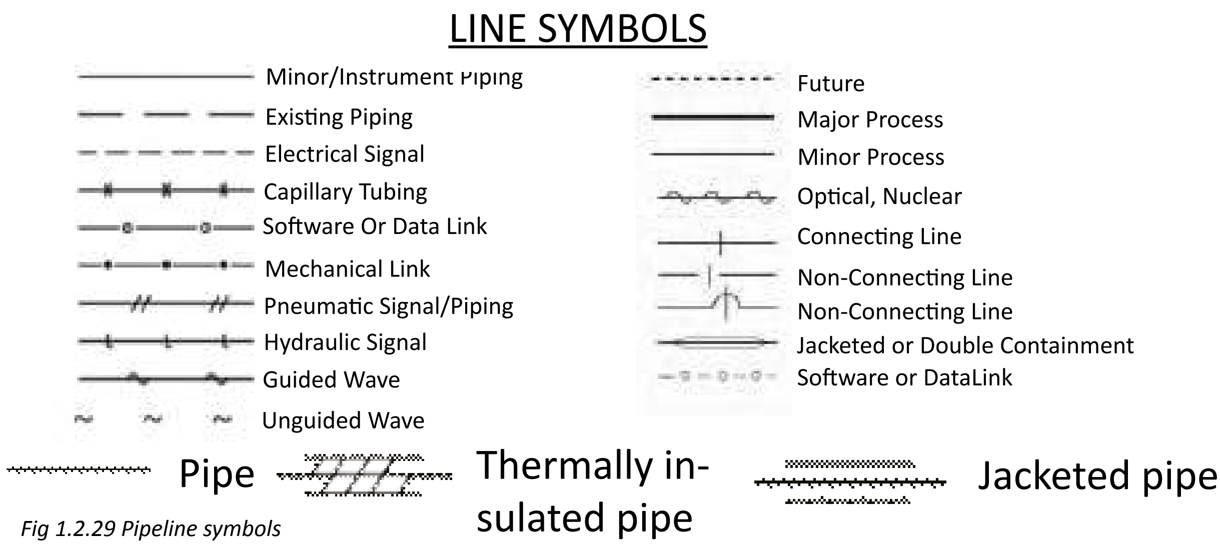


Fig 1.2.29 Pipeline symbols

To indicate pipes crossing that are not physically connected on drawings, a small "hump" to show one going "over" the other, or break one of the lines very near the other to show it going under it is used. This is not a physical representation of the actual pipes. In fact, they may not even cross in the actual system. It is merely a method to keep the lines separate when they must cross in the drawing.

Piping Isometric Symbols

The general piping symbol is always shown as the darkest line on the drawing. For example, a section of piping with a reducer or other fitting would be shown with the piping drawn darkest and the fitting represented by a lighter line.

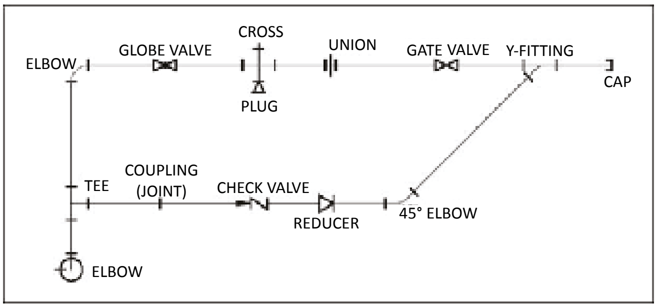


Fig. 1.2.30 Sample piping drawing with standard symbols

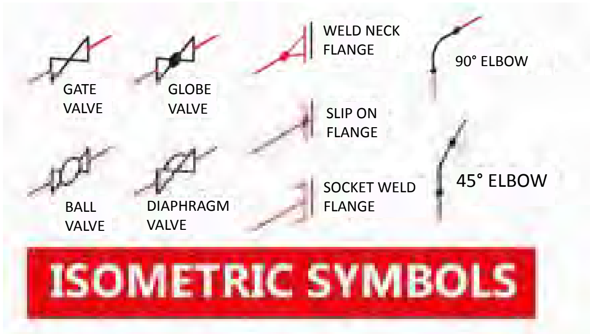


Fig. 1.2.31 Sample Isometric symbols

a. All piping drawings indicate the direction of flow with an arrow. Sample piping drawing and sample isometric symbols are shown in Fig 1.2.30 and 1.2.31.

b. Flange symbols and corrosponding images are depicted in Fig 1.2.32.

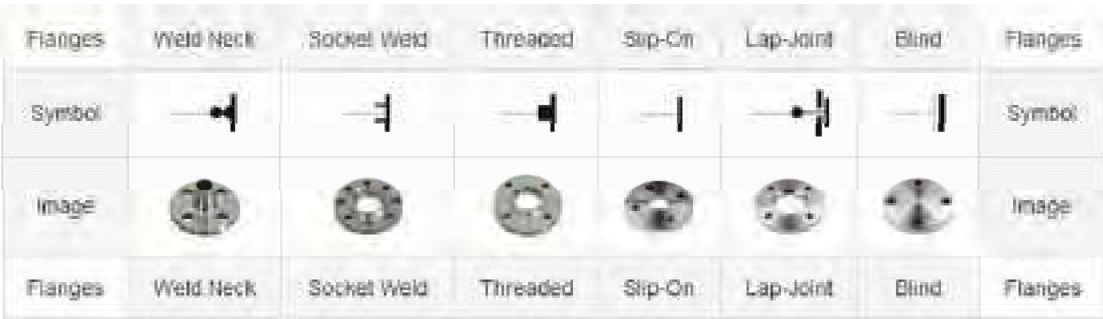


Fig. 1.2.32 T Flanges symbols and Images

c. Isometric symbol representation of various valves based on mode / method of operation and function, have been illustrated in Fig. 1.2.33.

d. Summary of valve symbols are as shown in the following Fig. 1.2.34.

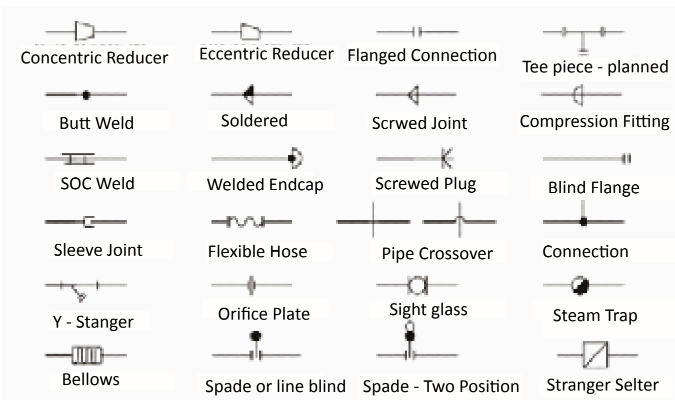


Fig. 1.2.33 – Line fittings symbols

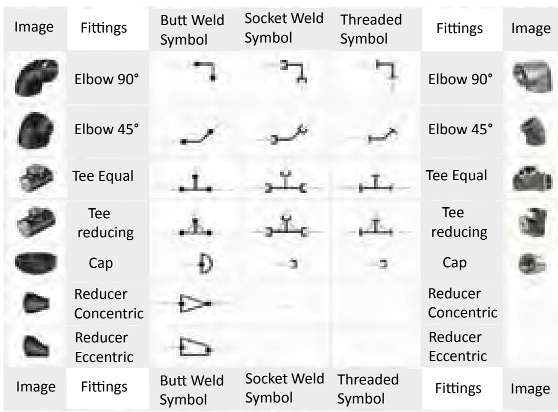


Fig. 1.2.34 Piping fittings illustration

Fig. 1.2.35 Valves Illustration

e. Isometric symbols of line fittings are shown in Fig. 1.2.35.

f. Isometric symbol representation of various fittings based on type of connections such as butt welding, socket welded or threaded connections have been illustrated along with images.

g. Piping Instruments Symbols for Isometrics, are as given below.

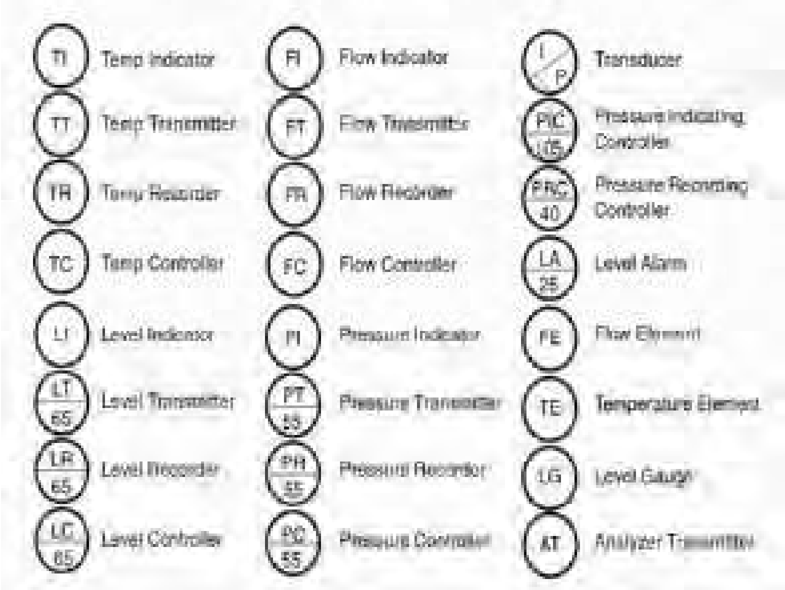


Fig. 1.2.36 Piping Instrument Symbols for Isometrics

Exercise

I. Answer the following questions.

1. Draw any five "line symbols" used in drawings, with name / description of each line.

----

2. Draw the isometric representation (symbol) of concentric reducer.

----

3. Draw the isometric symbol for globe valve.

----

4. Draw the isometric symbol for ball valve.

----

5. Draw the symbol of weld neck and slip on flanges.

----

6. Draw the elbow and Tee butt weld symbols.

----

7. Draw the simple free hand sketches of eccentric reducer.

II. State whether the following statements are True or False.

1. In piping instrument symbols for isometrics, TT stands for Temperature Transducer.

   True ☐ False ☐

2. In Piping isometric drawings, flow controller is demmoted by FC into the circle.

   True ☐ False ☐

3. The line symbol for pneumatic signal / piping is

   True ☐ False ☐

Notes

1.2.12 Hangers and Pipe Support Drawings

At the end of this topic, you will be able to:

1. define and classify different types of pipe supports
2. read and interpret pipe supports drawings
3. explain the purpose of pipe supports and their applications.

Introduction

Piping shall be fixed, supported, anchored or guided to prevent undue line deflection, excessive vibration and to protect piping and connected equipment from excessive loading and expansion stress.Pipe support location and identification numbers shall be marked on the piping drawings. Type of pipe supports include

Hangers (Rod type), Hangers (Spring type), Anchors, Saddles, Rollers, and Sliding supports, Guided type pipe supports.

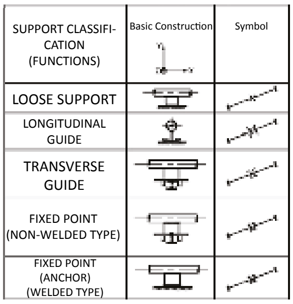


Fig. 1.2.37 Pipe support symbols (Typical)

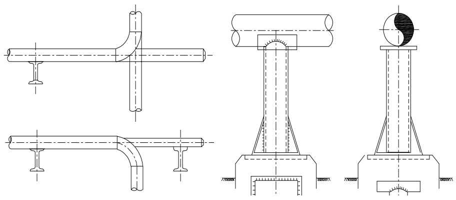


Fig. 1.2.38 Different type of pipe supports

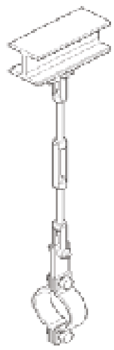


Fig. 1.2.39 Typical rod hanger

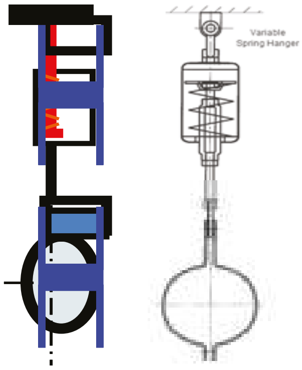


Fig. 1.2.40 Constant &Variable spring hanger and supports

Pipe supports symbols (typical) of isometric drawings are as given in fig 1.2.38. In general, pipe supports are grouped based on the type of pipe supports and single drawings are prepared duly tabulating different sizes.

Pipe support – Hanger Type

Based on the nominal pipe size, pipe fitter shall get all details and dimensions from the pipe support drawings duly reading and effectively interpreting drawings. Major pipe support types are illustrated and briefed in the next subsection.

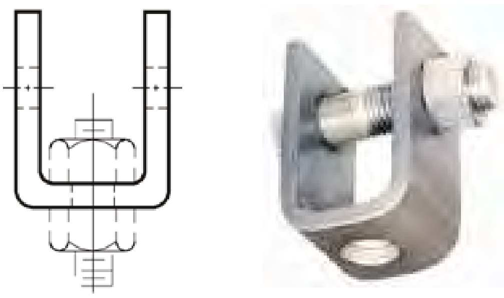


Fig 1.2.41 Lug type welded attachment

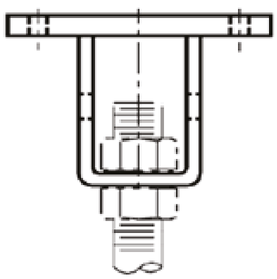


Fig 1.2.42 Plate lug

1. Hanger Rods Type

Hanger is a vertical pipe support with clamp, vertical rod and bolting. It may be a rigid, variable spring or constant support hanger. Refer Fig 1.2.41.

Rod hangers or pipe hangers are attached to the pipe by a U bolt, a clevis, a pipe clamp, etc., to structural steel located above the piping. (Refer Fig 1.2.43 and Fig 1.2.44)

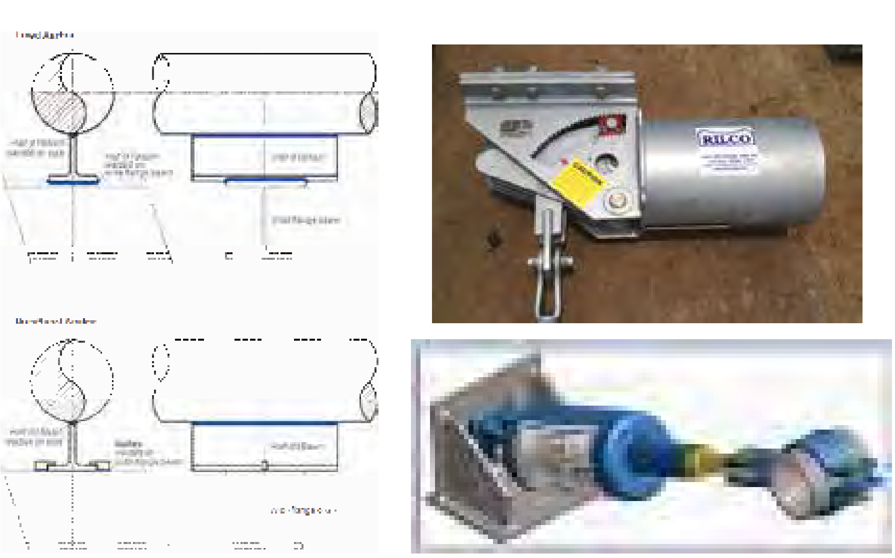
The rod hanger provides support in the vertical direction and allows limited motion in the horizontal direction. Adjustment in the vertical direction can be accomplished by threads or a turnbuckle.

2. Constant Spring Hanger

In constant spring hanger, the load remains constant throughout its travel range. But in variable spring hanger, the load varies with displacement. Spring hangers are used when thermal displacements are upwards and piping system is lifted off from the support position.

3. Variable spring hangers and supports

1. Anchors



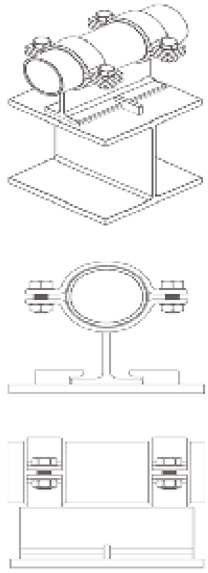


Fig. 1.2.43 Fixed and Directional Anchors

Fig. 1.2.44 Typical Pipe Shoe

Anchor is a rigid support that restricts movement in all three orthogonal directions and all three rotational directions. This is usually welded stanchion, that is welded or bolted to steel or concrete. Two types of anchors exist: fixed and directional. Refer Fig 1.2.45. Fixed anchors are used in locations where all movement of a line must be prevented. The most common way to anchor a pipe is to weld the pipe directly to a support or structural member. If the pipe to be anchored is insulated, first a pipe shoe is welded to the pipe and then the shoe is welded to the steel structure.

2. Stanchion/Pipe Shoe

A pipe shoe is a structure consisting of a saddle and integral base that is used to support the pipe by transmitting the load or forces to the adjacent structure. It can be simply fixed on steel structures.

3. Dummy leg supports

A dummy leg is an extension piece welded to an elbow to support a pipe line, and rests or anchors on some steel member. (Refer Fig 1.2.45)

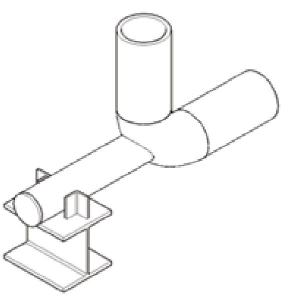


Fig. 1.2.45 Typical dummy leg / Trunnion pipe support

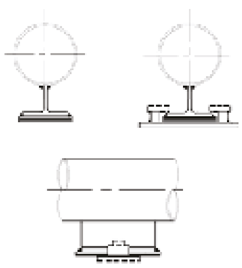


Fig. 1.2.46 Pipe Guides

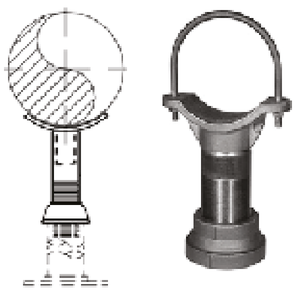


Fig. 1.2.47 Adjustable pipe support

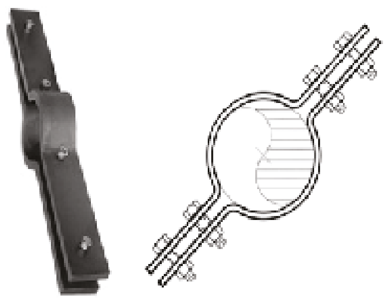


Fig 1.2.48 Extension pipe or riser clamp

4. **Guides**

   When total restriction of pipe movement is not required, pipe guides are used. (Refer Fig. 1.2.46). Pipe guides confine movement along the pipe's linea axis. Pipe guides are used, primarily, to maintain proper line spacing in a pipe rack and they prevent lateral or sideway movements. The guide allows the pipe to slide lengthwise between two angle shapes. When the pipe is supported on shoes, the angle shapes are positioned on either side of the shoe.

5. Miscellaneous pipe support devices are shown in Fig. 1.2.49 to 1.2.51.

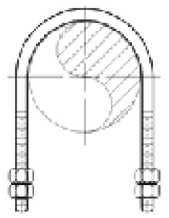


Fig. 1.2.49 Round bend U-bolt

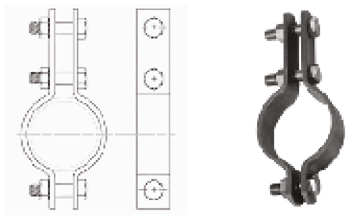


Fig. 1.2.50 Double side bolting pipe clamp

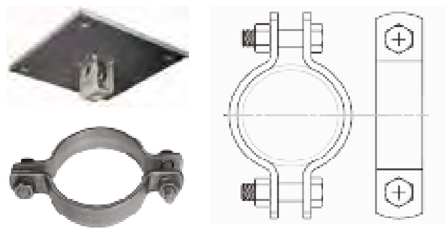


Fig. 1.2.51 Piping clamping and bolting support

Exercise

I. Answer the following questions.

1. Name any four types of pipe supports used in the piping system.

   ----

2. Name the type of pipe supports used in insulated piping system.

   ----

3. Explain fixed anchors and directional anchors.

   ----

4. Differentiate constant spring hanger and variable spring hanger supports.

II. State whether the following statements are True or False.

1. Anchor is a rigid support that does not restrict any piping movement.

   True ☐ False ☐

2. Pipe supports are devices which transfer the load from the pipe to the supporting structures.

   True ☐ False ☐

3. Spring hanger pipe supports are used to compensate for slight vertical movement in the piping system

   True ☐ False ☐

4. Fixed anchors are used in locations where movement of a piping line must be prevented.

   True ☐ False ☐

Notes

UNIT 1.3 Mathematical Skills for Pipe Fitting

Unit Objectives

At the end of this unit, you will be able to:

1. recognise mathematical applications in pipe fitting
2. apply mathematical skills with respect to pipe fitting during fabrication, laying, stringing, etc.
3. carryout calculations related to piping system such as cones, elbows / bends

1.3.1. Piping Mathematical Applications

At the end of this topic, you will be able to:

1. perform unit conversions
2. recognise basic arithmetic, algebra and geometry for pipe fitting
3. calculate area, volume, angles and length.

1. Metric System

Most countries use the metric system. The metric system uses the meter and linear units based on the meter, gram as its standards of measurement and prefixed by kilo, centi and milli, etc . All multiplies and subdivisions of the meter are directly related to the meter by a factor of ten. The more often used abbreviations for linear measurement are the Centimeter “cm” and Millimeter “mm”.

Tips

a. Kilometer (km), 1 km = 1,000 meter
b. Meter (m), 1 m = 10 dm = 100 cm = 1,000 mm
c. Centimeter (cm), 1 cm = 10 mm

2. Inch System (Imperial System) Units

Inch system is mostly used in where things are measured in feet, inches and pounds. The smallest linear measurement unit in the Inch System is the inch “in”. 1/1000 of inch is called ‘Thou’. Other units are the feet “ft” and the yard “yd”.

Tips

a. 1 yd = 3 ft = 36 in
b. 1 ft = 12 in
c. 1 m = 39.37 inches

3. Conversion of units

Inch to Inch Fraction conversion: 1/16” = 1 divided by 16 = 0.0625”

Inch Fraction to mm conversion : 0.0625” x 25.4 mm = 1.58 mm

1000 litre = 1 m^3

1 yd = 0.9144 m

1 ft = 0.30480 m

1 in = 25.4 mm

Arithmetic and its Applications

Knowledge of arithmetical calculation is needed in all areas of pipe fitting works. Fitter shall be able to perform arithmetic calculations related to piping system. Piping system requires to calculate length, diameter, perimeter (circumference), bending angles, elevation, coordinates, etc. Sometimes, pipes and cones may be required to be fabricated from plates. Hence fitter shall be able to mark the required development sizes in the plate so as to cut and roll the pipe or cones. The four basic arithmetic operations to be performed in piping works are addition, subtraction, multiplication, and division. If Pipe outside diameter (OD) and inside diameter (ID) are given, then pipe thickness will be

½ (OD-ID). If pipe OD and Thickness (t) are given , then pipe ID will be OD- 2t.

For example, if Pipe OD is 508 mm and pipe ID is 480 mm, then pipe thickness is ½ (OD-ID) = ½ (508-480) = 14 mm

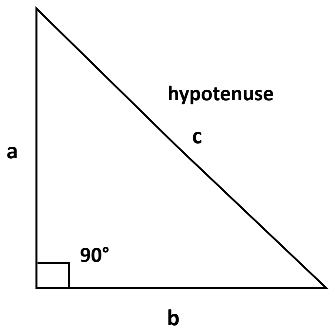
For example, if pipe OD is 610 mm and wall thickness is 20 mm, then pipe ID will be OD- 2t = 610-40 = 570 mm.

Algebra and its Applications

Basic Algebraic formulas applicable for piping include:

- $a^2 - b^2 = (a - b)(a + b)$
- $(a+b)^2 = a2 + 2ab + b^2$

The above formulae will be applicable while calculating coordinates and elevations and third side of right angled triangle. In a right angled triangle, if one side 'b' and hypotenuse 'c' dimensions are given, the other side dimension can be calculated.



a. $a^2 + b^2 = c^2$

b. $a^2 = c^2 - b^2$

c. $a^2 = (c+b)(c-b)$

d. $a = \sqrt{(c+b)(c-b)}$

Fig. 1.3.1 Right Angle Triangle - side dimension calculation

For example, in the above triangle, the dimension of the hypotenuse is 13 cm and that of one side is 5 cm, calculate the dimension of the other side.

By applying the above formula $a = \sqrt{(c+b)(c-b)}$,

$$a = \sqrt{(18x8)} = \sqrt{144} = 12$$

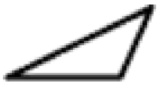
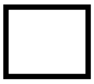
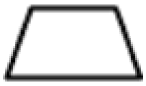
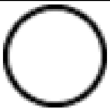
The dimension of the other side is 12 cm.

Knowledge, of geometry is essential for the pipe fitter to perform piping fabrication and installation.

A circle is a geometric form of which every point on the outside of the circle is the same distance away from the center. The distance around the edge of the circle is called the circumference. The distance from one side of the circle to the other, going through the center of the circle, is the diameter. Two times the radius is the diameter of the circle.

1. Formulae for calculating the area circumference

Important formulas for area and circle circumference calculations are as tabulated below:

Shape	Formulas for Area (A) and Circle Circumference (C)
Triangle 	A = ½bh = ½ x base x height
Square 	A = a x a = a^2 Where 'a' is side dimension of the Square
Rectangle 	A = lw = length x width
Trapezoid 	A = ½ (b_1 + b_2)h = ½ x sum of bases x height
Parallelogram 	A = bh = base x height
Circle 	(A = π value is 3.1416 or 3.142) A = πr^2 = π X Square of radius C = 2πr = 2 π radius C = πd = π X radius ('π' value is 3.1416 or 3.142)

For example 3.4: Calculate the area of trapezium shaped pipeline trench when bottom width of the trench is 400 mm, top width trench is 600 mm and the trench height is 350 mm.

Formula for trapezium area is A = ½ (b_1 + b_2)h = ½ x sum of bases x height

Applying the given values, trench area is ½ (400 + 600) x 350 =175 000 mm^2 = 0.175 m^2

2. Perimeter / Circumference Calculation

a. Perimeter of a square: s + s + s + s, where 's' is length / size of one side

b. Perimeter of a rectangle: l + w + l + w, where 'l' is length &'w' is width

c. Perimeter of a triangle: a + b + c, a, b, and c are size / lengths of the 3 sides

3. Volume Calculation:

a. Volume of a cube: s × s × s where 's' is length / size of one side (All sides are equal in cube)

b. Volume of a rectangular box: l × w × h, where 'l' is length & 'w' is width and 'h' is dimension of height

c. Volume of a sphere: (4/3) × π × $r^{3,}$ where 'r' is radius of sphere and π value is 3.1416

d. Volume of a cylinder: π × r^2 × h, where 'r' is radius of the circle of the base and 'h' is height of the cylinder.

Note: For calculation of pipe volume, inside diameter of the pipe shall be taken into account.

For example, if inside radius of pipe is 200 mm and pipelength is 1500 mm, calculate the volume of the pipe in m^3.

Formula for calculating volume of cylinder is π × r^2 × h

Applying the given values, volume of pipe is 3.1416 x 0.2^2 x 1.5= 0.1884 m^3.

4. Sector Arc length and Area Calculation

i. Length of an arc: The length of the arc is just the radius "r" times the angle "θ" where the angle is measured in radians. To convert from degrees to radians, multiply the number of degrees by π/180.

ii. Area of a sector: The area of the sector is half the square of the radius ‘r’ times the angle ‘θ‘ where the angle is measured in radians.

For example, if radius of segment is 750 mm and angle is 70˚, Calculate the arc length and sector area.

i. Formula to calculate, Length of Arc = rθ

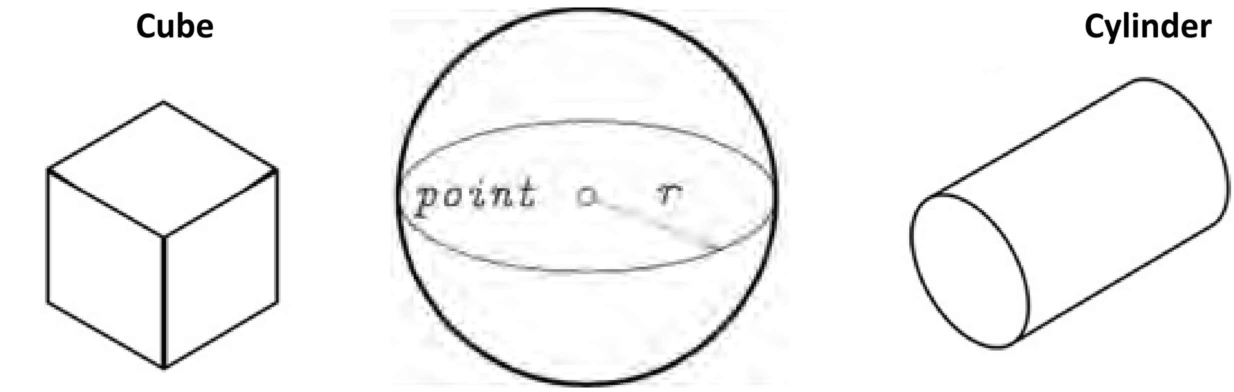


Fig. 1.3.2 Cube *Fig. 1.3.3 Sphere* *Fig. 1. 3.4 Cylinder*

Substituting given values, Length of Arc = 750 x 70 x 3.1416 /180 = 916.3 mm

ii. Formula to calculate sector area = $\frac{1}{2} r^2 \theta$

Substituting values, sector area is = ½ x 750² x 3.1416x 70 / 180 =343612.5 mm² = 0.3436 m²

5. Angles calculation

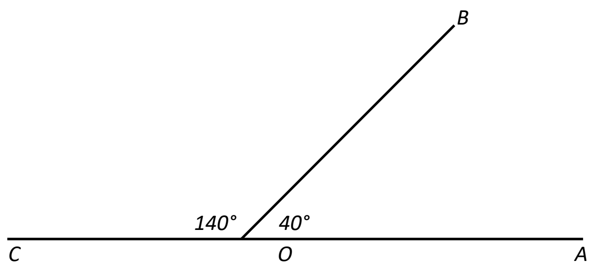
The more familiar unit of angle measurement is “degrees”. A circle is divided into 360 equal degrees, so that a right angle is 90°.

Adjacent Angles: Angles that lie on either side of a common arm are said to be “adjacent”.

For example, ∠AOB and ∠BOC have the arm BO in common. So, ∠AOB and ∠BOC are adjacent angles.

The sum of adjacent angles forming a straight line is 180º. Two such angles are also known as supplementary adjacent angles.

The sum of the three angles of triangle is 180º.



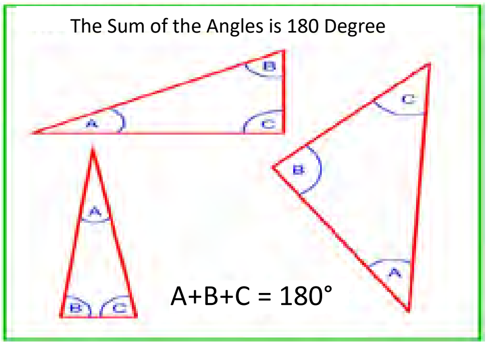


Fig. 1.3.5 Triangles- Sum of the Angles explanation

6. Trigonometry and Formulae for Right Angled Triangles

Trigonometry is the study of relationships that deal with angles, lengths and heights of triangles and relations between different parts of circles and other geometrical figures. Applications of trigonometry are also found in engineering and piping / pipeline installation.

Right-angled triangles have Hypotenuse, Base and Perpendicular. The longest side is known as the hypotenuse, the other side which is opposite to the angle is Perpendicular and the third side is Base. The six trigonometric functions are sine, cosine, secant, cosecant, tangent and cotangent. All the trigonometric ratios are based on the dimensions of the sides of the triangle and the angle of the triangle.

The most important formulae in trigonometry are those for a right triangle. If θ is one of the acute angles in a triangle, then the sine of theta is the ratio of the opposite side to the hypotenuse, the cosine is the ratio of the adjacent side to the hypotenuse, and the tangent is the ratio of the opposite side to the adjacent side.

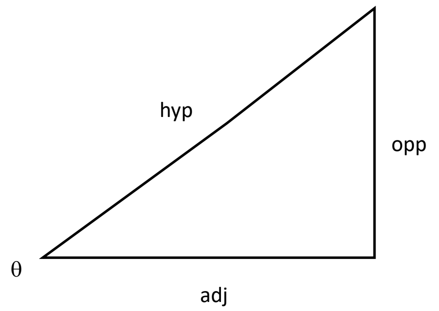
i. The sine of the angle, $\text{Sin } \theta = \dfrac{\text{the length of the opposite side}}{\text{the length of the hypotenuse}}$

ii. The cosine of the angle, $\text{Cos } \theta = \dfrac{\text{the length of the adjacent side}}{\text{the length of the hypotenuse}}$

iii. The tangent of the angle, $\text{Tan } \theta = \dfrac{\text{the length of the opposite side}}{\text{the length of the adjacent side}}$

When angles of right angled triangle are 90 degree and 45 degree, then the ratio of the sides are 1:1: $\sqrt{2}$

When the angles of right angled triangle are 30 degree, 60 degree and 90 degree, then the ratio of the sides are 1: $\sqrt{3:2}$



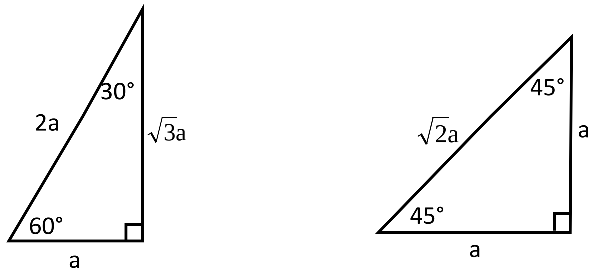


Fig. 1.3.6- Right Angle triangles Trigonometry   *Fig. 1.3.7 Easy way of calculating the sides dimensions of 45˚ and 60˚ right angle triangle*

Besides the above, there's important Pythagorean formula that says that the square of the hypotenuse is equal to the sum of the squares of the other two sides.

Exercise

I. Answer the following questions.

1. The base dimension of a triangle is 200 mm and height is 120 mm, what is the area of triangle? (Ans 12000 mm^2)

----

2. In right angled triangle, dimension of the hypotenuse is 20 meter and that of one side is 12 meter, what is the dimension of the third / other side?

----

3. A trapezoidal trench has been constructed for pipeline installation with bottom base as 500 mm and top base as 800 mm with a height of 400 mm. What is the cross–sectional area of the trench? (Ans 260000 mm^2)

----

4. Convert 2552.7mm into inch.

----

5. Convert 36 inch into millimetre.

----

6. What is the formula for calculating the volume of a sphere?

II. State whether the following statements are True or False.

1.Knowledge of geometing is not essential for pipe fitter to perform piping fabrication.

True ☐ False ☐

2. Length of an arc is the radius r times the angle θ where the angle is measured in radians.

True ☐ False ☐

3. The sum of the three angles of a triangle is 180˚.

True ☐ False ☐

4. 1 km = 1,00000 milli meter.

True ☐ False ☐

Notes

1.3.2 Piping System – Calculation Dimemsions

At the end of this topic, you will be able to:

1. able to calculate pipe diameter using both metric system and English system
2. calculate pipe bend radius and other dimensions.

Calculation of Length and Diameter of the piping system

1. Calculation of pipe diameter from pipe circumference

The constant pi, designated by the Greek letter π, is the ratio of the circumference to the diameter of a circle. Circumference equals pi times the diameter of a circle.

Pipe circumference can be measured using measuring tape. Measuring tapes are available in inch units and millimetre units. Pipe circumference can be measured using available tape and then converted to the required unit by unit conversion section.

Dividing circumference by 'π' value 3.1416, the pipe diameter can be obtained.

For example, calculate the plate size (developed length & width) required in both metric and English system to fabricate a pipe to have 1800 mm inside diameter, 16 mm wall thickness and 3000 mm length.

Pipe ID = 1800 mm

Pipe TK = 16 mm

Pipe length = 3000 mm

To calculate the required length and width of the plate

Pipe mean diameter = Pipe ID + TK

= 1800 + 16

= 1816 mm

$$\frac{1816}{25.4} = 71.5 \text{ inches.}$$

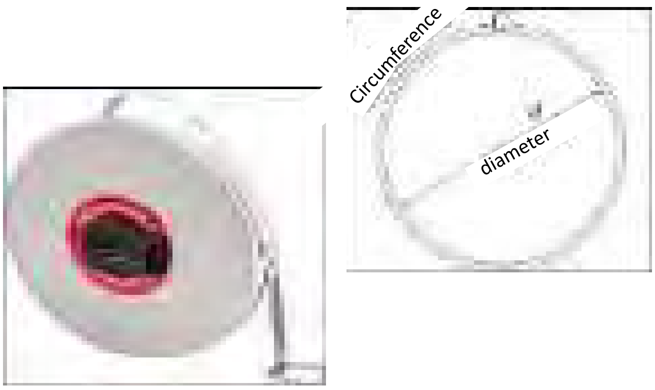


Fig. 1.3.8 Circumference measurement using measuring tape

Tips

Instructor has to explain how to read "tapes and measuring scales"

Pipe mean circumference = 3.1416 x 1816

= 5705 mm

$$\frac{5705}{25.4} = 224.6 \text{ inches}$$

Pipe mean circumference = required plate length

Pipe long = 3000 mm = (118.1 inches) = required plate width

Hence, the required plate size in mm = 5705 x 3000 x 16 mm.

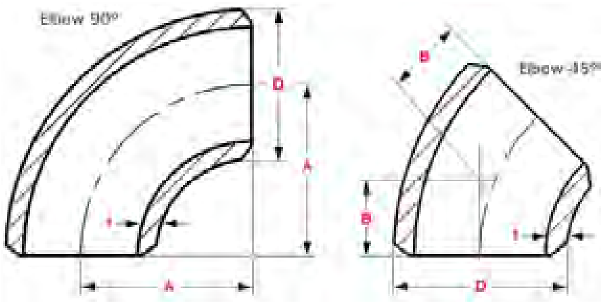
Hence, the required plate size in inches = 224.6 x 118 x 0.63 inches.

Calculation of Pipe Bends Dimensions in Piping

Dimensions of bends shall be calculated based on mean radius and bend angle. General formula for calculation of circumference for parts of Circles: C = π d x segment angle /360.

1. Standard Elbows

Standard Elbows are manufactured mostly by forging and are readily available in the market. In case of forged fitting which is referred to as elbow, the sizes are standardised as 1D, 1.25D or 1.5D . These size elbows are the most widely used.



A. Radius of standard bend

t. Thickness of standard bend

B. Mean size of standard bend

D. Outside diameter of standard bend

Fig. 1.3.9. 90° and 45° standard elbow fittings

2. Straight Pipe length calculation for 90° Bends

The length of pipe (arc) in any bend depends on the following:

degrees in angle of bend

length of bending radius

The length of arc in a pipe bend is measured along the center line of the pipe. The radius is also measured as extending to the centerline.

Length of Arc, when radius of Bend is R, L = R*2*π * θ /360.

This formula can be used for any size of bend angle. There may be a difference of few millimeters in the finished dimension due to elongation depending on the wall thickness and the method of bending including hot / induction bending. Typical pipeline has 90° bend.

a. In figure 3.11 dimension 'D' is the mean radius of bend. 'F' is the straight length at one of the bend and 'G' is the straight length of the other side of the bend. 'B' is outside diameter and 'C' is inside diameter of the pipe.

b. Length of pipe required is = G + (2 x π x D x 90) ÷ 360 + F

For example, calculate the pipe length required if mean radius of bend is 500 mm, straight length at one of bend is 200mm and the straight length of other side of bend is 250 mm.

Length of straight pipe required is =200 + (2 x π x 500 x 90) ÷ 360 + 250 = 200 +785+250 = 1235 mm.

3. Determining the pipe length for 45˚ single offset cold bends

With reference to the figure 1.3.12, the total length shall be computed as below:

T = X1 + L + Y1 = 237.9 + 117.8 + 256.1 = 611.8

This is applicable when the bend is made from pipe material.

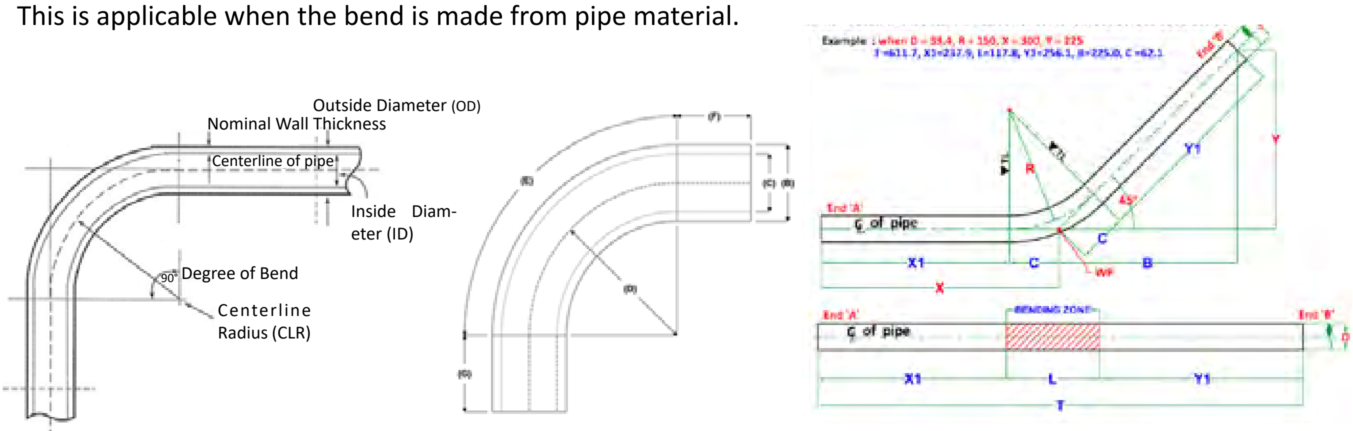


Fig. 1.3.10 Illustration of 90° pipe bend *Fig. 1.3.11. Calculation of straight pipe length for making bends* *Fig 1.3.12 Determining straight length pipe requirement for 45° single offset cold bends*

4. Determining the pipe length of a piping system having rolling offset

In a piping system, when a pipe direction changes in both the horizontal and vertical planes, it is called rolling offset. To visualize the travel of the pipe, imagine a three dimensional box with the pipe entering at one corner and exiting at the farthest diagonal corner. The nomenclatures in fig 1.3.13 are self-explanatory.

Step 1 Calculating the true offset

"True offset" is found using Pythagoras theorem. The "offset squared" plus the "rise squared" will equal the "true offset squared". Then take the square root of the result to get the true offset.

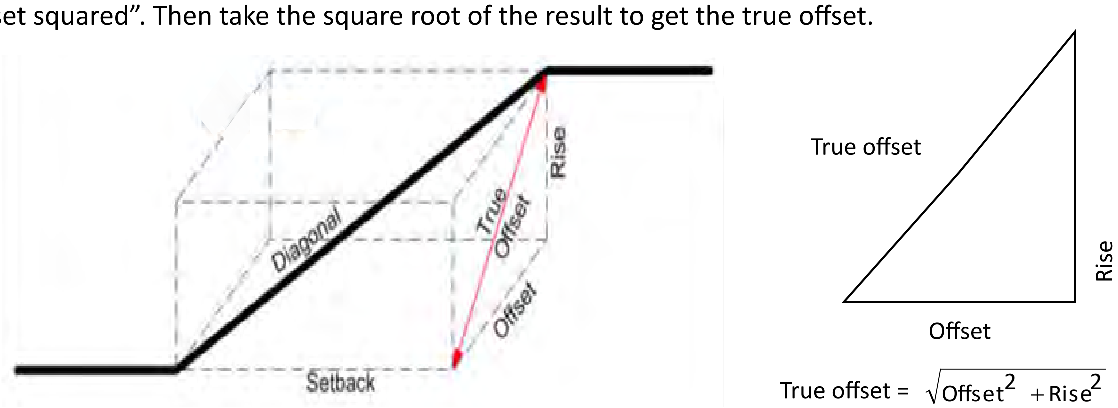


Fig. 1.3.13 Straight length pipe requirement for pipe having rolling offset in vertical and horizontal plan

Step 2 Finding the set back and diagonal

Once true offset is known, determine the setback and diagonal center to center measurements. See the table below for the most common fitting constants.

Fitting angle	60˚	45˚	22.5˚
Diagonal = true offset X	1.155	1.414	2.613
Setback = true offset X	0.577	1.000	2.414

V. Branch Connections

a. The Right Angled equal Tee: To develop the pattern for the branch pipe which is forms a right angled tee joint is to draw the semicircle at the end of the branch pipe, which represents half the circumference or girth of the pipe. Divide the semicircle into six equal parts and name the points 1 to 7. From these points project lines perpendicularly upto the end of the pipe, and on the line ABC joint. Then, set off the base line in the pattern and mark off the parts 1’2’3’4’5’6’7’.....1”, equal to the parts those around the semicircle. From these are marked points on the base line. Now, from the points on the joint line ABC draw horizontal lines into the pattern to cut the perpendiculars from the baseline. The curves drawn through these points in the pattern A’B’C’B”A” diagram should give the true form of the joint line. The full outline of the pattern is now completed.

The shape of the hole in the cross pipe can be developed by projecting the points on the joint line ABC in the elevation. Extend the lines upwards at right angles to the centre line TL. On the middle line, mark off equal distances to those on the semi-circle as at 1’,2’,3’,4’,5’,6’ and 7’. Through these points, draw lines at right angles to those drawn upwards and draw the curves through the points of meeting as shown in the diagram. Similarly, if the curve B’C’B” in the pattern can be repeated on the opposite side of the line B’B”, a contour similar to the hole will be obtained.

b. Right Angled Tee of unequal diameter pipes: To develop the pattern, describe semicircles on the bases of the front elevation and the end elevations and divide each of them into six equal parts, and number them as in the front elevation, from 1 to 7. It can be observed that the outside point numbered 1 in the front elevation will become the middle point in the end elevation. From these points on the semi-circles scribe lines perpendicular to the bases and produce them to cut the major pipe above. From the points where they cut the circle of the major pipe, from D to B, in the end elevation, horizontally project lines to meet the corresponding perpendicular lines in the front elevation. The curve drawn through the meeting points, as from A to B to C, will give the line of intersection. To “unroll” the pattern, horizontally project the base line, and mark off twelve equal parts as from 1’ to 1” equal to those round the semi-circles. Next project the points on the major pipe circle from D to B into the pattern horizontally. From these points 1’,2’,3’,4’,5’,6’,7’...1”, on the base line in the pattern, erect lines of perpendiculars to meet those horizontally projected from the major pipe circles. The curve drawn through these points A’,B’,C’,D’,A”, will give the contour of the intersection line in the pattern.

For the hole contour in the major pipe, produce the perpendicular lines in the front elevation, as shown in the diagram above the major pipe. Take the spaces round the curve from D to B in the end elevation, and then mark them off along the centre line above the front elevation. Through the points thus marked, draw lines horizontally to cut the perpendicular lines from the base. A curve drawn through the points of intersection will give the contour of the hole. Here, in this case the hole is slightly elliptical.

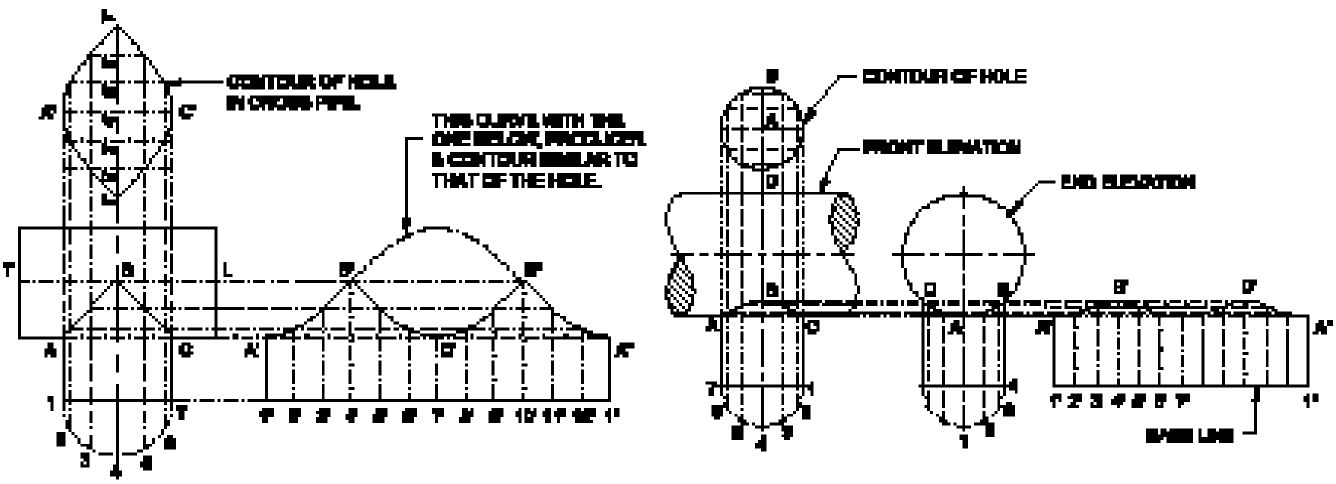


Fig. 1.3.14 Tees of equal diameter pipes

Exercise

I. Answer the following questions.

1. If the circumference of the pipe was measured as 2873 mm, what is the diameter of the pipe? (Ans 914.5 mm)

----

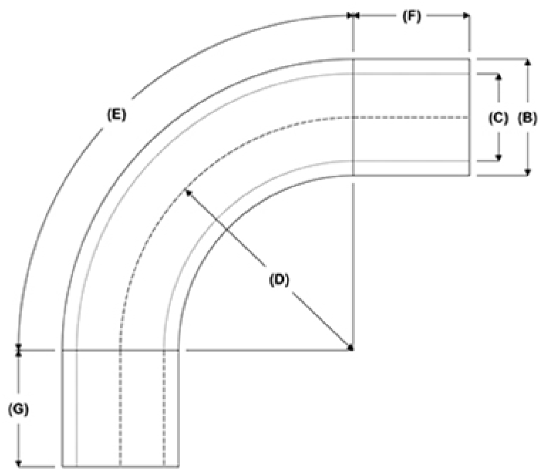
2. If the pipe inside diameter is 290 mm and pipe length is 6 meter, what is the volume of the pipe? (Ans 0.3963 m^3)

----

3. If the pipe outside diameter is 36 inch, thickness is half inch and pipe length 20 feet, what is the volume of the pipe? (133.63 ft^3)

----

4. Referring the figure given below, calculate the pipe length required if dimension mean radius of bend is 700 mm, straight length at one side of bend is 350mm and the straight length of other side of bend is 450 mm.



II. State whether the following statements are True or False.

1. Dimensions of bends shall be calculated based on mean radius and bend angle.

   True ☐ False ☐

2. Standard forged pipe bend fittings manufactured with bend radius - 1D,1.5D where D is pipe dia.

   True ☐ False ☐

3. The length of arc in a pipe bend is measured along the outer radius of the pipe

   True ☐ False ☐

4. Circumference equals π (pi) times the diameter of a circle.

   True ☐ False ☐

Notes

UNIT 1.4 Different Types of Materials Used in Pipe Fitting

Unit Objectives

At the end of this unit, you will be able to:

1. describe property and behaviour of fluids, liquids and gases
2. identify various oil and gas piping materials
3. list properties of different pipe materials and their workability
4. explain hydraulic and pneumatic system.

1.4.1 Properties and Behaviour of Fluids- Liquids& Gases

At the end of this unit, you will be able to:

1. describe property and behaviour of fluids, liquids and gases
2. identify various units of pressure, temperature, velocity and flow rate
3. recognise and explain hydraulic and pneumatic system.

Introduction

1. Pipeline materials selection depends on:
- chemical properties of process fluids
- design and operating temperatures and pressure
- required physical and mechanical properties / strengths.
2. Oil and gas piping may be made either seamless, welded or fabricated from plates depending on process requirements. Proper selection of steel pipe material is critical depending on:
- strength and durability required for application
- ductility and workability required to form into piping and join it.
3. The selected pipe must withstand the conditions of use, especially pressure, temperature and corrosion conditions. Based on flow rate, volume of fluid, working pressure, temperature and atmospheric conditions, material quality, material grade nominal pipe size and wall thickness are specified.
4. Piping pressure rating for steel pipe at different temperatures is calculated according to the applicable design code.
5. All piping and pipeline materials quality are to be given in the drawing and bill of materials. Fitter shall read the drawings carefully and confirm that the materials issued conform to the drawing requirements.

Property and behaviour of fluids, liquids and gases

The term fluid includes both liquid and gases. The main difference between a liquid and a gas is that the volume of a liquid remains definite, because it takes the shape of the surface on or in which it comes into contact with, whereas a gas occupies the complete space available in the container in which it is kept. Process fluids piping in oil and gas industry are mainly classified as:

- hydrocarbon services piping, starting from crude oils to final process / processed fluids

- gas related piping such as propane, butane, helium, hydrogen, nitrogen, oxygen, instrument air, etc., for operations
- chemicals related piping for chemical dozing, such as chlorine, anti – corrosion liquid, etc.

1. Mass Density

Mass Density is the mass per unit volume of a fluid. In other words, it is the ratio between mass (m) and volume (V) of a fluid. Density is denoted by the symbol ‘ρ’. Its unit is kg/m^3.

a) Volume = $\frac{\text{Mass}}{\text{Density}}$

b) Mass = Density X Volume

c) Desity = $\frac{\text{Mass}}{\text{Volume}}$

Density, ρ = $\frac{\text{Mass}}{\text{Density}}$ $\frac{\text{Kg}}{\text{m3}}$

In general, density of a fluid decreases with increase in temperature. Density increases with increase in pressure.

Tips

The density of standard liquid (water) is 1000 kg/m3.

2. Viscosity

Viscosity is the property of fluids which defines the interaction between the moving particles of the fluid. It is the measure of resistance to the flow of fluids. Fluids with high viscosity deform slowly. In a liquid, viscosity decreases with increase in temperature.

3. Temperature:

It is the property that determines the degree of hotness or coldness or the level of heat intensity of a fluid. Temperature is measured using temperature scales. There are 3 commonly used temperature scales. They are:

a. Celsius (or centigrade) scale

b. Fahrenheit scale

c. Kelvin scale (or absolute temperature scale)

Kelvin scale is widely used in engineering. This is because, this scale is independent of properties of a substance. Kelvin to Celsius conversion formula – The temperature T in degrees Celsius (°C) is equal to the temperature T in Kelvin (K) minus 273.

T(°C) = T(K) - 273

For Example 2; converting 300 Kelvin to degrees Celsius: T (°C) = 300K - 273 = 27 °C

4. Pressure

Pressure of a fluid is the force per unit area of the fluid. In other words, it is the ratio of force on a fluid to the area of the fluid, held perpendicular to the direction of the force. Pressure is denoted by the letter ‘P’. Its units are N/m2, Kg/cm^2, etc., depending upon the measuring system and range.

5. Specific Volume

Specific volume is the volume of a fluid (V) occupied per unit mass (m). It is the reciprocal of density. Specific volume is denoted by the symbol ‘v’. Its unit is m3/kg.

6. Specific Weight

Specific weight is the weight possessed by unit volume of a fluid. It is denoted by ‘w’. Its unit is N/m3 or kg/m^3.

7. Specific Gravity

Specific Volume, $v = \frac{V}{m} \quad \frac{m3}{Kg}$

Specific gravity is the ratio of specific weight of the given fluid to the specific weight of standard fluid. It is denoted by the letter 'S'. It has no unit.

Specific Volume, $w = \frac{Weight}{Volume} \quad \frac{N}{m^3}$

Specific gravity may also be defined as the ratio between density of the given fluid to the density of standard fluid.

$$\text{Specific Gravity, } S = \frac{\text{Specific Weight of Given Fluid}}{\text{Specific Weight of Standard Fluid}}$$

Awareness on Hydraulic System and Pneumatic System

1. Fluid Power

Liquid or Gas is referred to as a fluid. Fluid power is the method of using pressurized fluid to transmit energy.

$$S = \frac{\rho \text{ given fluid}}{\rho \text{ standrad fluid}}$$

Accordingly, there are two branches of fluid power – Pneumatics, and Hydraulics. Any media (liquid or gas) that flows naturally or can be forced to flow could be used to transmit energy in a fluid power system. The earliest fluid used was water. Hence, the name hydraulics was applied to systems using liquids. Oil hydraulic system employs pressurized liquid petroleum oils and synthetic oils. Pneumatic system employs compressed air that is released to the atmosphere after performing the work.

2. Hydraulic System

Hydraulic systems use the ability of a fluid to distribute an applied force to a desired location. Hydraulic systems use liquid to transfer force from one point to another. Hydraulic power is used in oil and gas transportation cross country pipelines, offshore oil rigs, pumping stations and water injection lifts in oil and gas industries. Liquid is incompressible. When a "squeezing" force is applied to an object, it does not change to a smaller size. Liquid, for example hydraulic fluid, possesses this physical property. Resistance to flow causes pressure. Head pressure can have an adverse effect on a hydraulic system.

Pressure: When a force (F) is applied on an area (A) of an enclosed liquid, a pressure (P) is produced. Pressure is the distribution of a given force over a certain area. Pressure can be quoted in bar, pounds per square inch (PSI) or Pascal (Pa) or kg/cm^2.

Pressure= Force ÷ area

Where force is in Newtons (N) and area is in square meters (m^2).

1 Pascal (Pa) =1 N/m^2, 1 bar= 100,000 Pa= 105 Pa. 10 bar= 1 MPa (mega Pascals)

In hydraulic systems, the force is in Newtons and the area in square millimeters. 1 N/mm2 = 1 MPa = 10 bar. To convert from N/mm^2 to bar, multiply by 10, and to convert from bar to N/mm^2, divide by 10.

For Example, a cylinder is supplied with 50 bar pressure. Its effective piston surface is equal to 350 mm^2. Find the maximum force which can be attained.

P= 50 bar = 50/10= 05 N/mm^2. A= 350 mm^2. F= P x A= 05X350= 1750 N

b. Pascal's Law

Pascal's Law is one of the basic laws of fluid power. According to the law, pressure in a confined body of fluid acts equally in all directions and at right angles to the containing surfaces. Accordingly, the pressure at any point in a body of fluid is same in any direction.

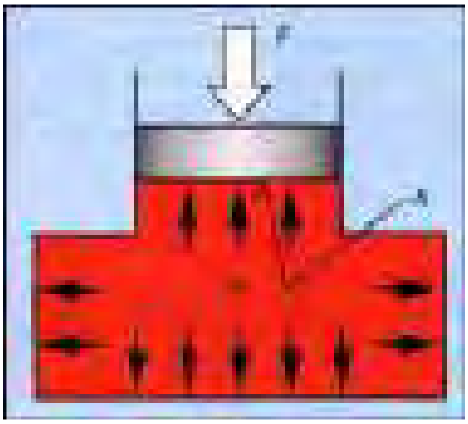


Fig. 1. 4.1. Pascals law explanation

c. Flow rate versus flow velocity

The flow rate is the volume of fluid that moves through the system in a given period of time.

Flow rate, Q = V x A

Where Q= flow rate (m^3 / Sec)

V= flow velocity (m / Sec)

A= area (m^2)

1) Pipe Diameter = $\sqrt{\dfrac{4 - \text{flow rate}}{\pi - \text{velocity}}}$

2) Velocity = $\dfrac{4 - \text{flow rate}}{\pi - (\text{pipe diameter})^2}$

3) Flow Rate = $\frac{1}{4}\pi$ - (pipe diameter)2-velocity

A fluid flows at a velocity of 4 m/s through a pipe with a diameter of 0.2 m. Determine the flow rate.

d. Continuity equation

Hydraulic systems commonly produces a constant flow rate. If we assume that the fluid is incompressible (oil), this situation is referred to as steady flow. This simply means that whatever volume of fluid flows through one section of the system must also flow through any other section. Flow is constant and the diameter varies.

$$Q = 0.0663\ m^3 / s \times \frac{1000\ L / s}{1\ m^3 / s}$$

The following equation applies in this system:

Q1 = Q2

A1 x V1 =A2 x V2

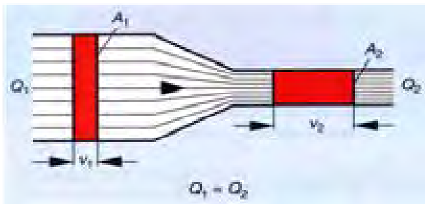


Fig. 1.4.2. Continuity equation explanation

e. Work and power

Work is the measure of a force traversing through a distance. Work = Force X Distance. When work is done in a certain time, it is called power. {Power = (Force X Distance) / Time.} A common measure of power is horsepower.

3. Pneumatic systems

Pneumatic systems are similar to hydraulic systems. In these systems, compressed air is used in place of hydraulic fluid. Pneumatic systems use air to transfer force from one point to another. Air is compressible. This describes if it is possible to force an object into a smaller space than it normally occupies. For example, a sponge is compressible because it can be squeezed into a smaller size.

A pneumatic system is a system that uses compressed air to transmit and control energy. Pneumatic systems are used extensively in various industries. Most pneumatic systems rely on a constant supply of compressed air to make them work. This is provided by an air compressor. This compressed air is then supplied to the system through a series of pipes and valves. Compressed air is the air from the atmosphere which is reduced in volume by compression thus increasing its pressure. A basic pneumatic system consists of the following two main sections:

- compressed air production, transportation, and distribution system
- compressed air consuming system

Pneumatic power is used to create/operate complex instruments and for gas lift operations in oil and gas industries.

Exercise

I. Answer the following questions.

1. What are the main differences between liquids and gases?

----

2. Define Mass Density.

----

3. Define Pressure.

----

4. State Pascal's Law.

----

5. Define flow rate.

II. State whether the following statements are True or False.

1. The term 'fluid' comprises – liquid and air.

   True ☐ False ☐

2. Liquid is compressible.

   True ☐ False ☐

3. 1 Pascal (Pa) =1 N/m^2.

   True ☐ False ☐

Notes

1.4.2 Properties of Different Pipe Materials

At the end of this topic, you shall be able to:

1. list the different process conditions and basis for material selection
2. describe on different material compositions and alloying elements
3. describe mechanical and chemical properties of various metallic materials
4. identify various pipe materials categorization and types of pipes
5. explain on different types of stainless steel.

Process Conditions and Materials Selection

1. Piping / pipeline construction materials depends on process and service conditions such as

i. Nature of Fluid – corrosiveness, toxicity, flammability, viscosity.

ii. Service conditions – pressure and temperature.

iii. Environmental condition – desert, hills, atmospheric temperate, marine, earthquake, etc.

2. Process condition that will impact the selection of material is

a. Type of fluid to be transported: For corrosive fluids, higher corrosion resistance material shall be selected as compared to non-corrosive ones. Corrosive fluids such as crude oil, sea water, ammonia, acids, etc., H_2S require high corrosion resistance material. On the other hand, normal carbon steel is enough for non-corrosive fluids such as – Lube oil, air, nitrogen, etc.

b. Temperatures of fluids to be handled are

Cryogenic, Low temperature, Medium temperature and High temperature. Increase or decrease in the service fluid temperature will greatly affect mechanical properties of the pipe material such as - impact resistance, elongation and tensile strength. Hence, special material is required for both high temperature cryogenic services.

Properties of and different pipe materials

1. Material properties

Considering both process fluid and material properties, piping material are selected from a variety of materials available in the market. Piping material is broadly classified into three categories namely, metal, non-metal, and composite, which is a combination of metal and and metal or metal and non-metal. Metals are broadly classified as ferrous (steel, cast iron) and non-ferrous (aluminium alloy, copper alloy, nickel alloy, magnesium, etc).

Non – metal pipes are broadly classified as – PVC, CPVC, PE, HDPE, GRP/GRE & Cement, etc./ MDPE.

2. Mechanical properties

The mechanical properties of a material are those which affect the mechanical strength and ability of a material. Fig 1.4.3 is the stressstrain diagram which depicts various physical properties relationships. Some of the mechanical properties are

- Ultimate Tensile Strength which is the capacity of a material to withstand when subject to tension. It defines the limit to which any further addition of load under constant strain would arrest the specimen elongation or thinning and would result in failure.
- Yield Strength is the load at which plastic deformation / permanent deformation starts. It defines the transition from elastic to plastic phase and it establishes the limiting value at which this transition occurs.
- Elasticity Elastic range is the ability of a material to resume its normal shape after the load is removed just like rubber.
- Modulus of Elasticity (Young's Modulus) is ratio of stress to strain and measured using tension tests.
- Elastic range is a range in which the material returns to its original shape after the load is released.
- Plastic range is a range in which the material is permanently deformed even after the load is released.
- Ductility is expressed in elongation of a specimen and its reduction in cross – sectional area before it's failure. It is established by measuring specimen length before elongation and minimum diameter before failure.
- Percentage Elongation is a measure of ductility.
- Hardness is the ability of a material to resist plastic deformation. Hardness is tested by Brinell or Rockwell Hardness tests, both of which are indentation type tests.
- Toughness is the ability of a material to absorb energy before fracture.
- Brittle fracture is sudden and rapid failure of a metal due to application of energy with hardly any deformation.

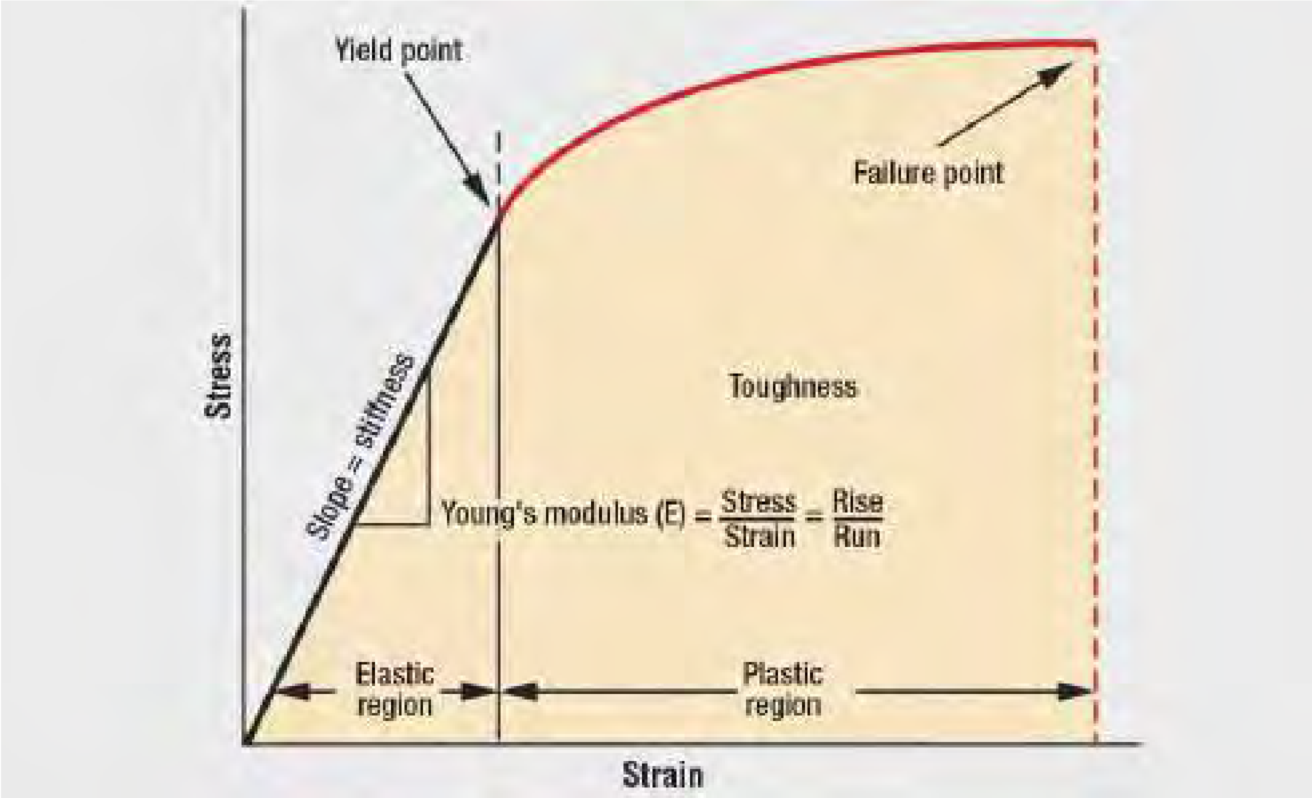


Fig. 1.4.3. Physical properties of material while performing tensile test- Stress – Strain Diagram

3. Chemical composition – Alloying elements

Some of the chemical properties of engineering materials are chemical composition, atomic bonding, corrosion resistance, acidity or alkalinity. The chemical composition of engineering material indicates the elements which are combined together to form that material. The strength, hardness, ductility, brittleness, corrosion resistance, weldability, etc., depend on chemical composition of materials. Hence, knowledge of chemical composition of engineering materials is essential. Addition of alloying elements to prevent carbon-chromium precipitation and formation of carbides, which reduces corrosion at higher temperature is called stabilization. Stabilization process can be employed to reduce corrosion.

Steel materials categorization

Steel materials are broadly categorized into four basic groups based on their chemical composition. They are carbon steel , alloy steel, stainless steel and duplex stainless steel.

1. **Carbon steel:** Carbon steel is the most utilized steel in the oil and gas industries. Based on the carbon content, carbon steels are further classified into three groups – low carbon steel/mild steel, medium carbon steel and high carbon steel.
2. **Alloy Steel:** Metls rarely used in their purest form as they have low mechanical strength. In order to achieve the desired (improved) properties such as weldability, ductility, machinability, strength, hardenability and corrosion resistance, etc., alloy steel with varying proportions of alloying elements is manufactured. Alloy steels are broadly classified into low alloy steels and high alloy steels. Low alloy steels have alloying elements less than 5%. High alloy steels have alloying elements more than 5%.
3. **Stainless Steel:** Stainless Steel is an alloy steel with alloying elements as – chromium, nickel, molybdenum etc. Stainless steel exhibits corrosion resistance due to formation of a very thin layer of (chromium Cr_2O_3 Oxide) on the surface. This layer is also known as passive layer. Increasing the amount of chromium will further increase the corrosion resistance of the material. Stainless steel also contains carbon, silicon and manganese. There are different types of stainless steel used in piping. After carbon steel, stainless Steel is the most widely used material in process industries because of its excellent corrosion resistance property and good ductility.

a. **Types of stainless steels:** There are different types of stainless steel used in industries. Based on microstructure, stainless steels are further classified as austenitic stainless steels, ferritic stainless steels, martensitic stainless steels, duplex stainless steel.

i. Austenitic Stainless Steel

- Austenitic Stainless Steel includes alloys of Cr, Ni, Fe.
- This is non-magnetic and can not be hardened by heat-treatment.
- This has excellent formability and weldability.
- This has high corrosion resistance and possess high impact strength at low temparature.
- Low-carbon stainless steels such as 316L or 304L are used to avoid corrosion problems caused by welding. "L" means that the carbon content of the alloy is below 0.03%, which prevents sensitization (precipitation of chromium carbides at grain boundaries) caused by the high temperatures involved in welding.

ii. Ferritic Stainless Steel

- Ferritic stainless steels possess a ferrite microstructure like carbon steel.
- Ferritic steels consists of Iron-Chromium alloys with molybdenum.
- These are generally magnetic and contain comparatively high carbon. Ferritic steels cannot be hardened by heat treatment.

iii. Martensitic stainless steel

- Martensitic stainless steel have higher strength and are comparatively tougher. But they are not as corrosion-resistant as the other two classes of steel.
- Mark this type of steel. These steels are machinable, magnetic and heat-treatable.

iv. Duplex stainless steels

- Duplex stainless steel consists of a two-phase microstructure consisting of grains of ferritic and austenitic stainless steel. Ferrite + Austenite mix is as 50/50 ratio. Commercial alloys ratio may vary in the range 40/60.
- Duplex stainless steel materials are characterized by high chromium (19–32%) and molybdenum (up to 5%) and lower nickel contents than austenitic stainless steels.
- This material has higher yield strength and superior resistance to stress corrosion cracking.
- It has good resistance to pitting and crevice corrosion.

Oil and gas pipes and pipe fitting materials

Piping components are mechanical elements suitable for joining or assembling into a pressure tight fluid containing piping systems. Components include pipes, tubes, fittings, flanges, gaskets, bolt-nuts, valves, expansion joints, hose pipes, traps, strainers, separators, control valves, safety valves, blind flanges, spectacle blinds and drip rings, etc.

1. Types of pipe and pipe fitting materials

The pipe is a straight pressure tight cylindrical hollow, used in the piping system to transport liquid, gas and sometimes solids. Piping class or pipe class is a document that specifies the type of components such as a type of pipe, s chedule, material, flange ratings, branch types, valve types and valve trim material, gasket and all the other component specific requirements, to be used for different fluids under different operating conditions in a plant. pipe class is developed considering operating pressure, temperature and corrosive environment.

a. Cast iron (CI)

Cast iron/ductile iron/malleable iron – are brittle, low strength material used for normal temperature applications and basic utilities like sewage system, air, water, drains, etc. Cast iron is also affected by corrosion caused by the by action of a solution of carbonic acid and acid. It is heavy and, if treated roughly, the pipe and fittings can crack. CI shall not be used on severe cyclic condition services, excessive heat, thermal shock applications, etc.

b. Galvanized steel

Normally, galvanized piping connections are threaded and screwed to avoid damage to galvanizing due to welding. Galvanized steels use is limited to about 200° F or 93° C for basic utilities like water, air, nitrogen.

c. Carbon steel pipes

Carbon steel pipes are widely used in oil and gas industries.

d. Pipeline materials:

Various pipeline materials are available. Normally, pipeline materials are classified as metallic (such as carbon steel, stainless steel), non-metallic (poly ethylene, HDPE, PVC, etc.), carbon steel pipes with cement lined. Pipeline materials are selected and used based on corrosive services like acids, caustic, process limited services, etc. Carbon steel cement lined pipe is normally used in sea / deep river water applications.

e. Stainless steel piping

Stainless piping is made of different alloys. It is commonly installed in process industries, chemical plants or in the food processing industry. Some types are highly acid resistant. Delivery length is normally 6 m.

f. Non – ferrous piping

Copper piping is used for water supply pipe. Flexible copper tubing is used in water heaters, refrigerators, etc. Flexible copper is not recommended for exterior use. Copper and copper alloys are for special usage within oil and gas operations. These materials are often used for valves and seals. This is due to properties like electrical and thermal conductivity that help to transfer heat and cold without warping, cracking, or failing otherwise.

g. Duplex stainless steel (DSS) pipelines

In oil and gas offshore facilities, duplex stainless steel pipelines are installed as DSS are corrossion resistant. At deep water exploration of offshore oil, duplex and super duplex stainless steel pipes are installed as they withstand greater pressure in severe corrosive environments. The main pipes used in the offshore oil and gas industry are duplex 2205 (22% chromium, 5% nickel) and 2507 (25% chromium, 7% nickel); and super duplex 2507 which has a higher corrosion resistance. Duplex steel is also highly resistant to chloride-induced stress corrosion cracking and has the strength to resist pressure at extreme depths.

h. PVC – Polyvinyl Chloride Pipes

PVC Pipes are made from polyvinyl chloride. PVC pipes are mostly used in plumbing, drain and vent lines. PVC pipe has been a very big deal in the plumbing industry in the last few decades, because it is lighter and easier to work with than traditional galvanized steel pipes.

i. CPVC pipes are

Chlorinated polyvinyl chloride (higher strength at moderately elevated temperature than PVC) tough and exceptionally resistant to chemical attack. PVC / CPVC requires protection from ultraviolet exposure, if installed outdoor as they start softening when subjected to high pressure.

j. GRE/GRP piping

GRP piping installations are associated with oil and gas industry processing and utility service applications in onshore and offshore. Installation of glass-reinforced plastics (GRP) piping is performed with installations associated with offshore applications on both fixed and floating topsides facilities for oil and gas industry production and processing.

K. PE / MDPE / HDPE (High Density Poly-Ethelene) pipe is used for a variety of applications, including distribution of pressurized natural gas, pipelines carrying petroleum and petroleum products and chemicals, underground loops for geothermal heating and cooling systems, distribution of compressed gases and air, potable water mains and service lines, and sanitary and storm sewer systems.

High-density polyethylene pipe is strong, durable, flexible and light weight. When fused together, HDPE offers a zero leak rate due to the seamless nature of the pipe system. HDPE pipe offers a more environmentally sustainable footprint because it is non-toxic, corrosion and chemical resistant, has a long lifespan, and is suitable for trenchless installation methods. HDPE pipe will not rust, corrode, tuberculate or support biological scale or growth, and has superb chemical resistance when compared to traditional pipe materials.

Fig. 1.4.4. Socket & Spigot Ends of pipes -non-metallic piping / pipeline such as PVC, GRE / GRP / MDPE / HDPE

Exercise

I. Answer the following questions.

1. Name any four corrosive fluids.

   ----

2. What are the mechanical and chemical properties that will directly influence the choice of material?

   ----

3. What do you understand about the terms 'Yield Strength' and 'Ultimate Tensile Strength'?

   ----

4. Draw stress–strain diagram duly illustrating mechanical properties nomenclatures.

   ----

5. What are different types of stainless steels?

II. State whether the following statements are True or False.

1. Pipe service conditions include process pressure and temperature.

   True ☐ False ☐

2. Decrease in the service fluid temperature will not affect mechanical properties.

   Ture ☐ False ☐

3. Martensitic stainless steel is magnetic.

   True ☐ False ☐

4. Galvanized pipes are generally available in the threaded form.

   Ture ☐ False ☐

5. Percentage elongation is a measure of yield strength.

   Ture ☐ False ☐

Notes

1.4.3 Metallic Piping and Pipe Fitting Materials Standards / Specifications and Applications

At the end of this topic, you shall be able to:

1. classify pipes based on manufacturing process
2. describe piping identification and traceability requirements
3. recognise different piping materials standards / specifications and applications.

Pipe materials classification based on manufacturing process

Based on manufacturing process, metallic pipes are classified into seamless and welded. Welded pipes are further classified as ERW (Electrical Resistance Weld) / EFW (Electrical Fusion Welded) and SAW (Submerge Arc Welded). SAW pipes are further classified as straight seam or Helical / Spiral SAW. Seamless pipes are stronger than other pipes. Welded pipes are manufactured from plates / coil sheets.

Fig. 1.4.5. Pipe with threaded end

Fig. 1.4.6. Pipe with plain ends

Pipes are supplied with plain, bevelled or threaded ends as required. Pipes and pipe fittings are supplied with or without heat treatment as required by product standard or specification or purchase order. Generally, hot finished fittings require heat treatment. Cold drawn / finished fittings require heat treatment.

Piping materials identification marking

Piping materials are normally marked with (by painting, hard punching or by both), material specification, material grade, heat number / cast number, size, thickness / schedule, length , manufacturer logo, etc., as required by respective material specification / purchase order. In general, no hard punching is permitted for piping material thickness less than 6 mm. For critical materials, if stamping is essential for identification and traceability, low stress stamps shall be used. Stainless steel pipes are marked by engraving or stencilling. Additionally, flanges are stamped with service pressure rating class and heat treatment marking such as 'N' for normalised, 'QT' for Quenched and Tempered. Flanges are, generally, stamped at the outer periphery / thickness area.

1. Pipes and pipe fittings are manufactured to various piping materials standards / specifications such as ASTM, API standards. Commonly used piping and pipe fitting materials are listed in Table 1.

1. ASTM A-53

Piping Materials Standards / Specification / Applications

Table 1

Sl.No	Material Specification	Material Description
1	ASTM A-53	Welded and Seamless Steel Pipe
2	ASTM A-106	Seamless Carbon Steel Pipe for High-Temperature Service. This piping is mainly used for Process piping. ASTM A 106 pipe material grades are Grade A, B and C, with maximum carbon content 0.25, 0.3 and 0.35 respectively. Bending ability decreases from grade A to C.

3	ASTM A-312	Seamless and Welded Austenitic Stainless Steel Pipe
4	ASTM A-333	Seamless and Welded Steel Pipe for Low Temperature Service. This carbon and alloy steel pipes are available both in seamless and welded without addition of filler metal in welding operation, intended for use at low temperatures. Several grades are available from Grade 1 to Grade 11.
5	ASTM A-335	Seamless Ferritic Alloy Steel Pipe for High-Temperature Service
6	API-5L	Specification for Line Pipe. In the oil and natural gas industries, API 5L steel pipes are mostly used to transport oil and gas.
7	ASTMA 234	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
8	ASTM A 420	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service
9	ASTM A 105	Standard Specification for Carbon Steel Forgings for Piping Applications
10	ASTM A 182	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
11	ASTM A 193	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications
12	ASTM A 194	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
13	ASTM B 16.5	Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
14	ASTM B 16.9	Factory-Made Wrought Butt Welding Fittings
15	ASTM B16.11	Forged Fittings, Socket-Welding and threaded
16	ASTM B16.34	Valves- Flanged, threaded, and welding end.
17	ASTM B16.47	Large Diameter Steel Flanges NPS 26 Through NPS 60 Metric/Inch Standard

Exercise

I. Answer the following questions.

1. What is meant by material yield strength?

   ----

2. What is the advantage of adding molybdenum as one of the chemical elements in material composition?

   ----

3. What does the letter "L' stand for in stainless steel material designation 316L?

   ----

4. What is the definition for LTCS?

Notes

UNIT 1.5 Preparation of Piping and Pipeline

Unit Objectives

At the end of this unit, you will be able to:

1. identify of different flanges, bends, elbows, shapes, joints, etc., used to fabricate pipes
2. identify and distinguish different types of nuts, bolts, screws, clamps, fixtures, etc., used in piping
3. recognise on different packing materials, adhesives, gaskets, o ring, ropes, etc.
4. cut gaskets using a cutting machine
5. install various valves, instruments and piping accessories
6. perform valve functional test.

1.5.1. Pipe Flanges, Pressure Rating and Their Applicability

At the end of this topic, you will be able to:

1. describe different types of flanges and materials
2. recognise with flange ratings and dimensions.

Pipe flange and purpose

A flange is a piping object made by forging or cutting steel plates used for connecting pipes, valves, pumps and other equipment to form a piping system. Flange joints are made by bolting together two flanges with a gasket between them to provide effective seal. Flange joints can be dismantled easily to provide easy access for cleaning, maintenance, inspection or modification. Flanges are usually, welded or screwed with pipe.

II. Types of flanges

1. The following flange types are mainly used in Oil and Gas industry – weld neck flange, slip on Flange, socket weld flange, lap joint flange, threaded flange, spade and spectacle flanges, blind flange.
2. **Special Flanges**

   Apart from the above standard flanges, there are number of special flanges for specific applications, such as orifice flanges, long weld neck flanges, weld flange / nipoflange, Expander flange, reducing flange.

Fig. 1.5.1 Various types of flanges

Materials for flanges

Pipe flanges are manufactured from different materials like carbon steel, alloy steels, stainless steel, cast iron, etc. In general, the material of flange and pipeline are of same or equivalent grade / specification. Flanges are available in various types and standards. ASME / ASTM standard flanges are widely used. ASME B16.5 describes dimensions, dimensional tolerances, etc.

Dimensions of flanges

Flanges have number of standard (unique) dimensions. Flange outside diameter is abbreviated as "OD". Pitch Circle Diameter is abbreviated as "PCD". It is also called 'bolt circle'.

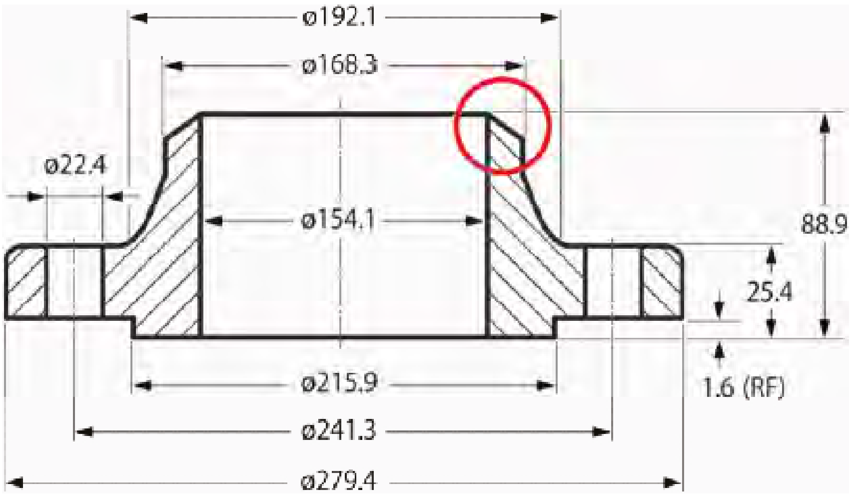


Fig. 1.5.2 Weld neck flange NPS 6, class 150, schedule 40, ASME B16.5

The above flange has 8 bolt holes, and a welding bevel of 37.5 degrees. All given dimensions are in millimeters. Pipe fitter shall measure and cross check all the above flange dimensions before commencing flange assembly.

Pressure rating of flanges and its significance

The pressure rating is the maximum allowable working pressure (MAWP) at the specific temperature for given material of a pipe, fitting or valve that if should be capable of withstanding in normal conditions. Each flange material has different pressure ratings. Flange pressure class /rating is given in pounds. Different names are used to indicate a Pressure Class. For example, 150 Lb or 150 Lbs or 150. "Class 150", means that safe working pressure for this flange at rated temperature for given material is "150 pound per square inch". Forged steel flanges, according to ASME B16.5, are made in seven primary Pressure Classes: 150, 300,400 600, 900, 1500, 2500. Inner diameter and diameter of the raised face are all the same for all ratings. But outside diameter, bolt circle and diameter of bolt holes become larger in each higher pressure class.

1.5.2. Type of Flanges

At the end of this exercise, you will be able to:

1. identify the types of flanges
2. draw a freehand sketch of a pipe flange weld neck type.

Practical

Requirements		
Tools/Instruments		**Materials/Components**
Measuring Tape	– 1 No.	Paper
Steel Rule	– 1 No.	Pencil, Marker
Vernier Caliper	– 1 Set	Different type of flanges 2" diameter
Equipment/Machines		
Personal Protective Equipment	– 1 No.	

Tips

Instructor may provide different types of flanges and explain to trainees about how to identify the flange type.

1. Look at the picture below and write the types of flanges in Table 1.

1 2 3 4 5 6

Table 1

Sl. No.	Name of the Flange type	Sl. No.	Name of the Flange type
1		4	
2		5	
3		6	

2. Draw a free hand sketch of a pipe flange - Weld Neck Type

Exercise

I. Answer the following questions.

1. Name any five types of flanges.

----

2. What is meant by flange pressure rating?

----

3. What are the different materials used for manufacturing flanges?

----

4. What are the purposes of flange connections?

----

5. What are the different flange dimensions to be cross checked by the pipe fitter prior to flange assembly?

II. State whether the following statements are True or False.

1. "Weld Neck" is a term used to describe a type of pipe

   True ☐ False ☐

2. Lap joint flange does not have raised face.

   True ☐ False ☐

3. The flange material grade shall be higher than that of the pipe.

   True ☐ False ☐

4. The abbreviation 'PCD' stands for 'Pitch Circle Diameter'.

   True ☐ False ☐

5. As the temperature increases, flange rating decreases.

   True ☐ False ☐

6. Diameter of "raised face" will be the same for all different ratings of NPS 6 flanges.

   True ☐ False ☐

Notes

1.5.3 Flanges Classification based on Pipe Attachment

At the end of this topic, you will be able to:

1. classify and distinguish flanges based on pipe attachment
2. perform a socket weld joint fitup
3. list the applications of different types of flanges.

Based on type of attachment with pipe, flanges are classified as slip on flange, socket weld flange, threaded / screwed flanges, lap joint flanges, weld neck flanges, blind flange, reducing flanges, integral flange, spade & spectacle blind flange, orifice flange, etc.

Weld Neck Flanges are easy to recognize by long tapered hub with smooth transition that goes gradually from flange thickness to pipe or fitting wall thickness. The long tapered hub provides additional reinforcement and reduces stress concentration. Weld neck flanges are attached to the pipe or fitting with full penetration weld (Butt weld) Fig. 1.5.4. These are used mainly for high pressure/ critical services and for sub-zero and / or elevated temperatures.

Slip on flange Slip on flanges are flanges slip over pipe and are also called as "SO Flange". The slip on type flanges are attached by fillet welding inside as well as outside. In general, these flanges are manufactured by forging. Details of slip on flanges are given in Fig. 1.5.5

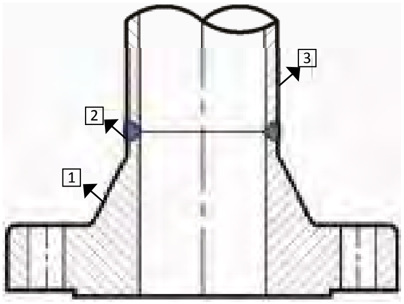


Fig. 1.5.3 Weld Neck Flanges

1. Weld Neck flange
2. Butt Weld
3. Pipe or Fitting

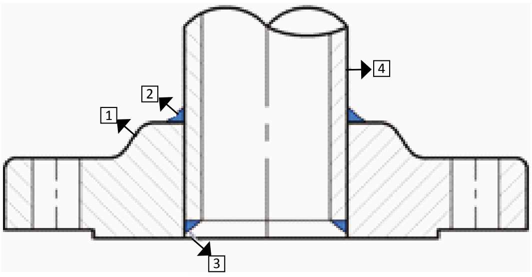


Fig. 1.5.4 Slip On Flange

1. Slip On flange
2. Fillet weld outside
3. Fillet weld inside
4. Pipe

Socket weld flange Socket weld flange has a female socket in which the pipe is fitted. This flange is mostly used for small bore lines. The connection with the pipe is done by fillet weld, at the outside of the flange. During fitup before welding, the pipe or tube shall be inserted into the socket to the maximum depth and then withdrawn approximately 1/16” (1.6 mm) away from contact between the end of the pipe and the shoulder of the socket to create a space between flange or fitting and pipe. (Refer dimension ‘X’ in Fig. 1.5.6. The purpose of the clearance in a socket weld is usually to reduce the residual stress at the root of the weld that could occur during solidification of the weld metal.

Threaded / screwed flanges Threaded flange has threads inside the flange bore which fits on the pipe with matching male thread on the pipe. Refer Fig. 1.5.7. Screwed fittings are made in carbon / stainless steel and duplex stainless steel and up to 4inches diameter in instrument air galvanised piping system. Threaded / screwed on flanges are used on smaller piping such as instrument air, utility air / water services ,and galvanized steel, where welding cannot be carried out. Threaded flanges are used for special uses with their main advantage being that they can be attached to the pipe without welding. Sometimes, a seal weld is also performed in conjunction with the threaded connection. A threaded flange or fitting is not suitable for a pipe system with thin wall thickness, because cutting thread on the thin pipe is very difficult.

Lap joint flange A stub is end always used with a lap joint flange, as a backing flange. The stub ends are welded with pipes and flanges and kept loose over the same (Refer Fig. 1.5.8.). Lap joint flanges are of same common dimensions as any other flange. However, it does not have a raised face. These flanges are nearly identical to a slip on flange with the exception of a radius at the intersection of the flange face and the bore to accommodate the flanged portion of the stub end.

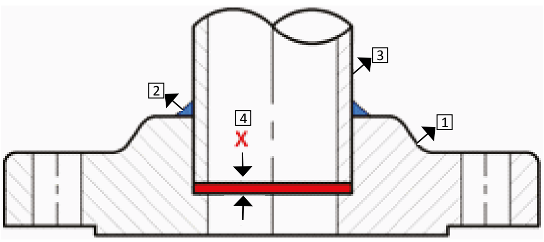


Fig. 1.5.5 Socket weld flange assembly

1. Slip On flange
2. Fillet weld outside
3. Fillet weld inside
4. Pipe

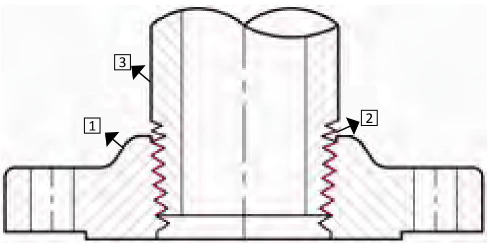


Fig.1.5.6 Threaded Flange Connection

1. Threaded flange
2. Thread
3. Pipe or Fitting

Blind flanges Blind flanges are manufactured without a bore, drilled with all relevant bolt holes and used to close / blank off the ends of piping, valves and pressure vessel openings, etc. (Refer Fig. 1.5.9).

Reducing flanges Reducing flanges are used to connect between larger and smaller sizes without using a reducer. In case of reducing flanges, the thickness of flange should be that of the higher diameter (Refer Fig. 1.5.10). A reducing flange consists of a flange with one specified diameter and has a bore of a different and smaller diameter. Except for the bore and hub dimensions, the flange will have dimensions of the larger pipe. There are several types of reducing flanges including weld neck reducing flanges, slip on reducing flanges and threaded reducing flanges.

Stubend

Lap Joint Flange

1. Lap Joint flange
2. Stub End
3. Butt weld
4. Pipe or Fitting

Fig. 1.5.7 Lap joint flange with stub end connection

1. Blind flange
2. Stud Bolt
3. Gasket
4. Other flange

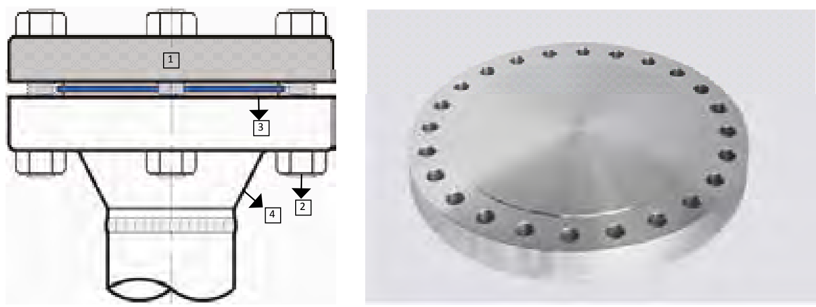


Fig. 1.5.8 Blind Flanges (plain &bolted)

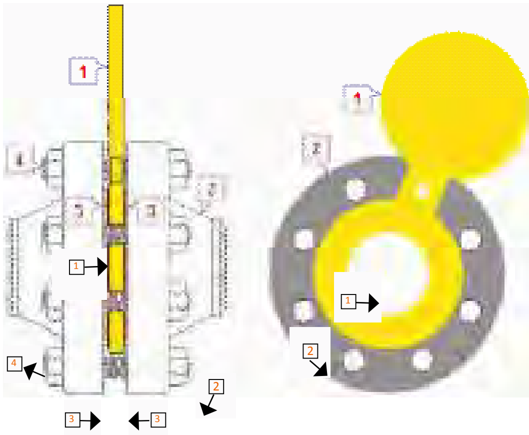
Integral Flange Integral flanges are those, which are cast along with the piping component or equipment (Fig. 1.5.11). Integral flange also called “long weld neck flange (LWN flange)”, is used for very high pressure situations. In this case, the weld is far from the ring to avoid bending stresses and weld stress being combined.

Spade & Spectacle blind flanges Spade and spectacle comprise combination of spade and blind together. Spade fits into the space between two flanges and gives flow through the spade (Fig. 1.5.12 and 1.5.14). A spectacle blind is a steel plate cut into two discs of a certain thickness. The two discs are attached to each other by section of steel similar to the nose piece of a pair of glasses. One of the discs is a solid plate, and the other is a ring, whose inside diameter is equal to that of a flange Fig. 1.5.13 & 1.5.14). Spectacle blinds are, generally, applied to permanently separating pipe systems and or just to connect with each other. Spectacle blinds are installed in systems which need to be separated from other installations from time to time when need arises in situations like maintenance / isolation.

Spades and ring spacers Spades and ring spacers are basically the same as spectacle blinds, except that both are not attached to each other. Spades and spacers are installed in systems where frequent closing / opening is not necessary. Depending on the flange size and the pressure class, spades can weigh high. To prevent unnecessary weight to flange connections, two separate parts of spades and ring spacers are considered.

Fig. 1.5.9 Integral Flange (Long Weld Neck Flange)

Fig. 1.5.10 Reducing Flanges



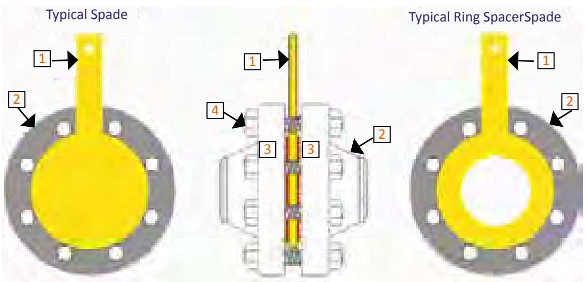
1. Spectacle Blade
2. Flanges
3. Gasket
4. Stud Bolts

Fig. 1.5.11 Spade and Spectacle blinds

Fig. 1.5.12 Spectacle blind flange -open

Fig. 1.5.13 Spectacle blind flange – closed

1. Spade   3. Gasket
2. Flanges   4. Stud Bolts



1. Ring spacer   3. Gasket
2. Flanges   4. Stud Bolts

Fig. 1.5.14 Spade and Ring Spacer

Orifice flanges Orifice flanges are used with orifice meters for the purpose of measuring the flow rate of either liquids or gases in the respective pipeline (Refer Fig. 1.5.15). Pairs of pressure "Tappings", mostly on 2 sides, directly opposite each other, are machined into the orifice flange. When installing the orifice plate flange, the pressure taps need to be at the same elevation to each other. Orifice flanges are installed where orifice plate or flow nozzle needs to be installed. Orifice flanges, generally, come with either raised faces or RTJ (Ring Type Joint) mostly in weld neck configuration.

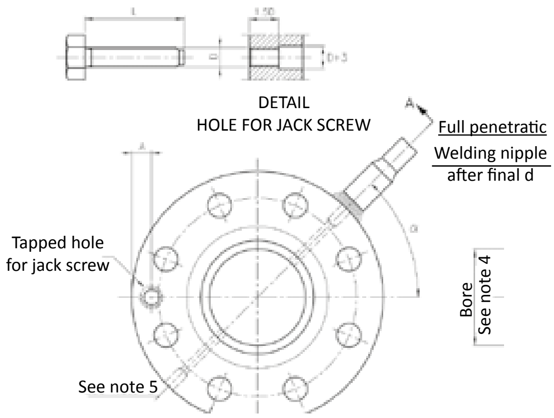


Fig. 1.5.15 Orifice flanges

1.5.4 Marking, Drilling and Reaming of Flange

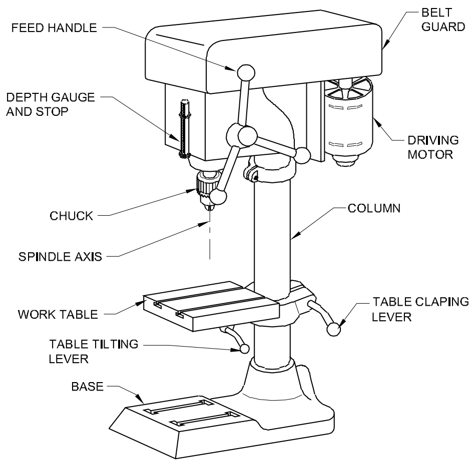
At the end of this exercise, you will be able to:

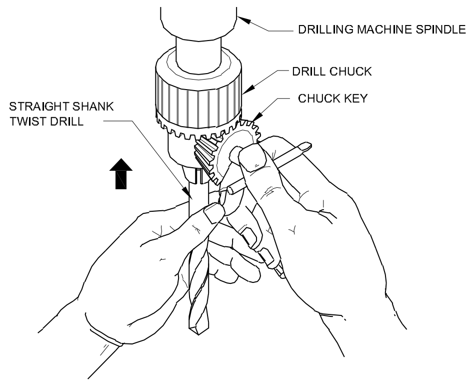
1. perform marking and punching
2. carryout drilling and reaming
3. verify PCD of flange (Pitch Centre Diameter).

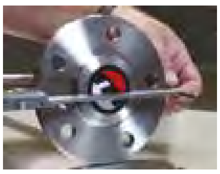
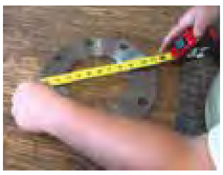
Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Dot punch	– 1 No.	CS- Flange # 150 rating	– 1 No.
Round File	– 1 No.	**Equipment/Machines**	
Divider	– 1 No.	AG-Grinding Machine	- 1 No.
Measuring Tape	– 1 No.	Drilling Equipment	- 1 No.
Steel rule	– 1 No.	Drill Chowk with 12mm	- 1 No.
Vernier Caliper	– 1 No.	Drill bit Q12mm	- 1 No.
Try square	– 1 No.		
Ball peen hammer	– 1 No.		
Drill bit	– 10mm.		
Scriber	– 1 No.		

- check and select CS/MS – material according to the drawing
- grind and file to size 10mm x 153mm
- check the thickness and diameter of the flange using vernier caliper
- make the PCD axis x,y
- mark the hole centres for the drill hole by using scriber and dot punch centre punch
- then using the same radius, from the entre of the axis hole, draw a arc on
  PCD on either side of both axes of hole centre
- make a punch mark intersection of the PCD circle and the radious arc
- fix the job/flange on the machine vice
- fix the 12mm drill in drill chuck
- set the spindle speed for 12mm drill
- use coolent while drilling
- finish the job and deburr all corners so that you get equally spaced six holes
- check the drilled hole size using vernier caliper
- apply thin coat of oil and preserve it for evaluation





Tips

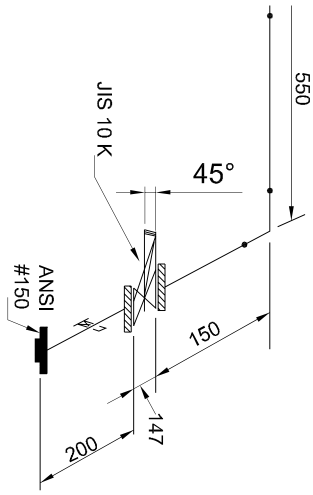
Safety

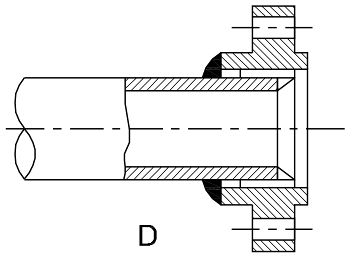
Use appropriate PPE.

Do not remove burr/chips with bare hands.

Do not try to change the drill bit while the drilling machine main switch is ON. Instructor or may explain with step by step instruction, how to carryout pipe to flange "socket weld" fit up

1. Look at the isometric drawing below and carryout pipe to socket weld flange fitup and alignment.





Tips

1. All dimensions are in millimetre.
2. With the given materials, candidate is required to fit up pipe to socket weld flange.
3. Candidate is to check the tool items according to the tools list provided.

Exercise

I. Answer the following questions.

1. Name any five flanges classified based on pipe attachment type.

----

2. How is socket weld joint fitting performed?

----

3. Explain the construction of lap joint flange connection.

----

4. What are the applications of spades and spectacle blinds?

----

5. What are the installation requirements for orifice flanges?

----

6. Draw a free handsketch of spectacle and blind flange assembled condition.

II. State whether the following statements are True or False.

1. The long tapered hub of weld neck flange increases stress concentration.

   True ☐ False ☐

2. Weld neck flanges are attached with pipe either by fillet weld or by butt weld.

   True ☐ False ☐

3. Normally slip on flanges are welded with pipe by full penetration butt welding.

   True ☐ False ☐

4. Threaded piping /flange is used in airlines instruments.

   True ☐ False ☐

5. Threaded pipe can be attached with pipe without welding.

   True ☐ False ☐

Notes

1.5.5 Flanges Classification Based On Facing and Face Finish

At the end of this topic, you will be able to:

1. classify and distinguish flanges based on flange face and finish
2. describe ring type joint flanges
3. describe the significance of flange face finishes.

Flanges classification based on facing

Different types of flange faces are used as contact surfaces to seat the sealing gasket material. ASME B16.5 and B16.47 address various types of flange facings, including the raised face, flat face, ring type joint groove, etc.

i. Flat face (FF)

The flat face flange has a gasket surface in the same plane as the bolting circle face. Flat face flanges are never to be bolted to a raised face flange.

ii. Raised face (RF)

The Raised Face flange is the most common type used in oil and gas piping applications. It is referred to as a raised face because the gasket surfaces are raised above the bolting circle face. Pressure rating of the flange determines the height of the raised face. This face type allows the use of a wide combination of gasket designs including flat ring sheet types and metallic composites such as spiral wound and double jacketed types.

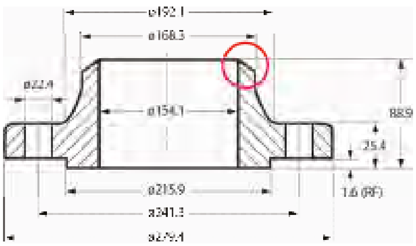


Fig. 1.5.16 Flange – Flat Face

Fig. 1.5.17 Raised Face Flanges image and dimensional details

iii. Ring type joint flanges

A ring type joint (RTJ) flange is a type of flange that uses a metal ring that sits in a groove as a gasket to seal the flange pair. RTJ flanges are usually manufactured in blind, slip on, threaded and weld neck as needed. RTJ flanges are typically used in high pressure (class 600 and higher rating) and/or high temperature services above 800°F (427°C) and in offshore piping systems. The flanges seal, when bolts are tightened, duly compressing the gasket between the flanges into the grooves. Raised face in RTJ flange does not serve as any part of the sealing means.

Fig. 1.5.18 Ring Type Joint Flange & Ring Gasket

iv. Tongue and groove (T&G) flanges

The tongue and groove faces of flanges must be matched. One flange face has a raised ring (Tongue) machined onto the flange face while the mating flange has a matching depression (Groove) machined into is face. Tongue and groove facings are standardized in both large and small types. They differ from male and female in that the inside diameters of the tongue and groove do not extend into the flange base. Thus they retain the gasket on the inner and outer diameter. These are commonly found on pump covers and valve bonnets.

Types of flange face surface finishes

The flange face finish concept refers to the type of roughness of the flange face. The ASME B16.5 code requires that the flange face (raised face and flat face) shall have a specific roughness to ensure that this surface is compatible with the gasket and provides a high quality seal. Depending on the type of gasket used in the connection, different flange surface finishes are used to optimize gasket performance. The common flange face finishes are stock finish, concentric serrated, spiral serrated and smooth finish.

Fig. 1.5.19 Tongue-and-Groove (T&G)

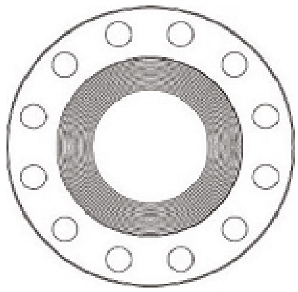


Fig. 1.5.20 – Flange with serrated finish face

a. Stock finish

This is a continuous spiral or phonographic groove, suitable for practically all general services. Stock finish is a widely used flange surface finish, which is practically suitable for all ordinary service conditions. Under compression, the soft face of gasket will embed into this finish, which helps to create a seal between the mating surfaces.

b. Serrated finish

Serrated finish flange is required when non-metallic gasket is to be installed. The serration on flanges is specified by the number, which is the arithmetic average roughness height (AARH). There are two types of serrations namely concentric and spiral (phonographic). The serration is generated by 90 degree tool, which creates "V" geometry groove with 45 degree angled serration.

i. Spiral serrated

This is also a continuous or phonographic spiral groove. It differs from the stock finish in that the groove is typically generated using a 90 deg tool which creates a “V” geometry with 45° angled serration.

ii. Concentric serrated

As the name suggests, this finish is prepared with concentric grooves. A 90° tool is used and the serrations are spaced evenly across the face.

c. Smooth Finish

Flange faces with a smooth finish should show no apparent sign of tool markings when viewed with naked eye. Smooth finish are typically made for gaskets with metal facings such as double jacketed, flat steel and corrugated metal. Flange face roughness will be between Ra 3.2 and 6.3 micrometers (125 - 250 micro inch).

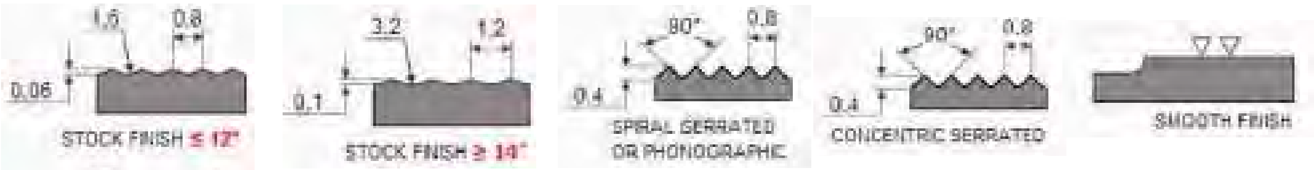


Fig. 1.5.21 Flange face finish configuration and their roughness

d. Surface finish notation AARH

AARH stands for arithmetic average roughness height. It is used to measure the roughness (rather smoothness) of surfaces. Sometimes AARH is referred also as RA which stands for roughness Average and means the same. 125 AARH means 125 micro inches will be the average height of the ups and downs of the surface. 63 AARH is specified for Ring Type Joints. 125-250 AARH (it is called smooth finish) is specified for spiral wound gaskets.

1.5.6 Flanges Face and Finish

At the end of this exercise, you will be able to:

1. identify type of flange face and finish.

Practical

Requirements		
Tools/Instruments		**Materials/Components**
Measuring Tape	– 1 No.	Paper
Try Square	– 1 No.	Pencil
Steel rule	– 1 No.	Flange chart or different type of flanges 2”.
Equipment/Machines		
Personal Protective equipment	– 1 Set	

Tips

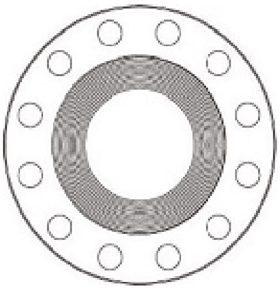
Instructor may provide different types of flanges with various finished surfaces, and explain to trainees about the method of identification.

Look at the picture below and write the type of flange surface finish conditions in Table 2.

1

2

3



4

5

Table 2

Sl. No.	Type of flange surface finish condition
1	
2	
3	
4	
5	

Exercise

I. Answer the following questions.

1. Name any three flange types that are classified based on flanges facing.

----

2. What are the applications of raised face flanges?

----

3. What are the different types of flange face serrations and how are they formed?

----

4. Explain the significance of RTJ flanges.

----

5. Describe the surface finish notation AARH.

II. State whether the following statements are True or False.

1. Flat face flange can be bolted to flat face or raised face flange.

   True ☐ False ☐

2. Raised face height is same on pressure rating flanges of the same size.

   True ☐ False ☐

3. The purpose of raised face is to decrease the pressure containment capability of the joint.

   True ☐ False ☐

4. Ring type joints shall not be used in offshore piping systems.

   True ☐ False ☐

5. The raised face of the ring type joint flange does not serve any part of sealing means.

   True ☐ False ☐

6. AARH refers to "Arithmetic Average Roughness Height".

   True ☐ False ☐

7. RA refers to "Raised Face Area".

   True ☐ False ☐

Notes

1.5.7 Types of Pipe Bends, Elbows and Shapes

At the end of this topic, you will be able to:

1. classify and distinguish different types of pipe fittings
2. identify applications of pipe fittings
3. describe the significance of pipe fittings.

Pipe fittings classifications

1. A pipe fitting is a constituent part used in a piping system for
   - making connections
   - changing direction,
   - branching or for change of pipe diameter, which is mechanically joined to the system
   - changing the pipe specification from one material to another.
2. Pipe fittings classification based on end connections are butt weld fittings, socket weld fittings, screwed, Flanged, spigot socket fittings.
3. Fittings classifications by name is
   - bend angles (90° and 45° elbows)
   - reducing elbows
   - short and long radius bends
   - equal and unequal tees
   - concentric and eccentric reducers
   - stub ends / end caps.

Fig. 1.5.22 Various Pipe Fittings

1. Elbow 90° long radius
2. Elbow 45°
3. Elbow 90° short radius
4. Elbow 180° long radius
5. Elbow 180° short radius
6. Tee straight
7. Tee reducing
8. Reducer concentric
9. Reducer eccentric
10. End cap
11. Lap joint Stub End

Pipe fittings details

1. Butt weld fittings

Butt weld pipe fittings are the most commonly available ones in carbon steel, stainless steel, nickel alloy, aluminum and high yield strength material. Butt weld fittings are available as elbows, tees, caps, reducer and outlets (olets). These fittings are the most common type of welded pipe fitting and are specified by nominal pipe size and pipe schedule. Butt weld fittings are made from seamless or welded pipe and are forged (through multiple process) to get the shape of elbows, tees and reducers, etc.

2. Elbows & bends

The function of an elbow is to change direction or flow in a piping system. Elbows are split into two groups, namely long radius and short radius. Comparatively, small pressure drop will occur in long radius bend whereas, high pressure drops will occur in short radius bends. There are 5 standard elbows: 45°, 90° and 180° elbows all these three are long radius version, and in addition, the 90° and 180° elbows both in the short radius version. The center to face distance is equivalent to the radius through which the elbow is bent. The center to face distance for a long radius elbow, abbreviated as LR always is "1½ x nominal pipe size (NPS) (1½D)", while the center to face distance for a short radius elbow, abbreviated as SR is equivalent to nominal pipe size.

a. 90˚Elbow

Butt weld long radius 90 degree elbow is used for 90 degree turn on piping in butt weld piping system. Long radius elbows are preferred due to their low pressure drop. They can also be cut at lesser degree, if required in piping layout. Their center line radius is 1.5 times the nominal pipe diameter. Butt weld short radius 90 degree elbows are used where space is limited. They are available only in 90 degrees but they can be cut to lesser degree, if required as per piping layout. Center line radius of short radius elbows is same as nominal pipe diameter.

3D elbows as an example, are calculated with:

3(D) x 2(NPS) x 25.4

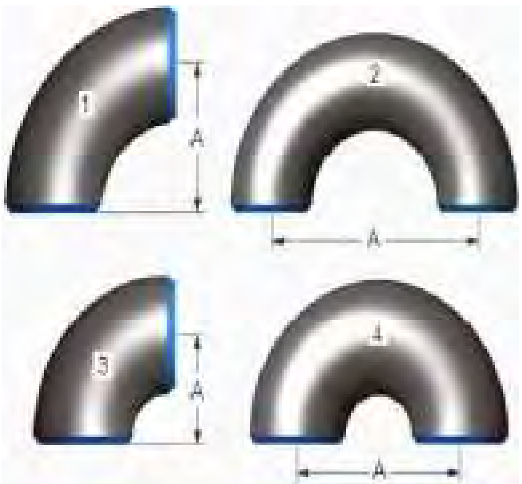


Fig. 1.5.23 Types of standard elbows

b. 45° Elbow

The function of a 45° elbow is the same as a 90° elbow, but the measurement of dimensions is different from that of the 90° elbow. Butt weld long radius 45 degree elbow is used for 45 degree turn on piping in butt weld piping system. Long radius elbows are preferred due to their low pressure drop. They can also be cut at lesser degree, if required in piping layout. Their center line radius is 1.5 times the nominal pipe diameter. Only long radius 45 degree elbows are available. The radius of a 45° elbow is same as the radius of the 90° LR (1½D). However, the center to face dimension is not equivalent to the radius as in 90° LR elbows. This is measured from each face to the point of intersection of the center lines perpendicular to each other, distances **"B"** on the image Fig 1.5.24. This is due to the smaller degree of bend. Short radius 45° elbows are not available.

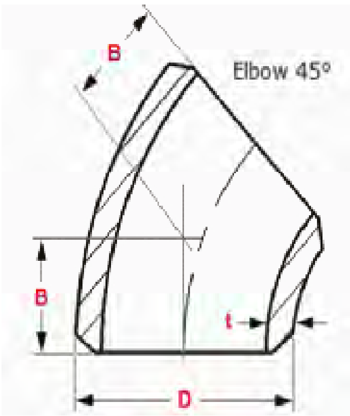


Fig. 1.5.24 45˚Elbow Dimensioning

Fig. 1.5.25 Reducing Elbows

c. Reducing elbows

Reducing Elbow is an elbow with different diameters on the ends Fig 1.5.25.

3. Tees straight and reducing

The primary purpose of a Tee is to make a 90° branch from the main run of pipe. There are two types namely the equal tee and reducing tee. The equal tee (or straight tee) branch has the same diameter as the runpipe. A straight or equal butt welding tee is available for all common diameters Fig 1.5.26. Butt weld straight tees are used for branch connection of same size that of headers. Butt weld reducing tees are used for branch connection of smaller size than that of header. Dimensions and Standards of Tee connections are if a tee specified NPS 3, it is equal or straight tee. If a tee specified as NPS 3 x 2, it is a reducing tee, intended for different sizes.

4. Butt weld concentric reducers

Concentric reducers are used preferably in vertical piping Fig 1.5.27.

5. Butt weld eccentric reducers

These are mostly preferred in horizontal piping, as they keep bottom of pipe unchanged Fig 1.5.28.

6. WeldOlet, Threadolet And SockOlet

These are basically self-reinforced fittings Fig 1.5.29. Weldolet is used for butt weld branch connection where standard tee is not available due to size restrictions and the piping is of critical / high-pressure service. A threadolet is the same basic design as a weldolet. Weldolet is used when welding a pipe or fitting directly to the branch fitting and a threadolet is used when thread is required to install threaded pipe or fitting. Sockolet is used for socket welding branch connection.

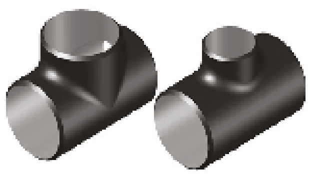


Fig. 1.5.26 Straight and Reducing Tees

Fig. 1.5.27 Butt Weld Concentric Reducer

Fig. 1.5.28 Butt Weld Eccentric Reducer

Fig. 1.5.29 WeldOlet, Threadolet and SockOlet

1.5.8 Type of Pipe Fittings and Dimensions

At the end of this exercise, you will be able to:

1. identify the type of fittings
2. check the dimensions of fittings.

Practical

Requirements	
Tools/Instruments Measuring Tape – 1 No. Steel rule – 1 No. Wire brush – 1 No. Try Square – 1 No. Spirit level – 1 No. **Equipment/Machines** Personal Protective equipment (PPE) 1 complete set	**Materials/Components** Paper Pencil 2" ϕ – 90° Elbow long radius – 1 No. 2" ϕ – 45° Elbow – 1 No. 2" ϕ – Tee Straight – 1 No. 3" X 2"– Reducer concentric – 1 No.

Tips

Instructor may provide different types and sizes of pipe fittings and explain to trainees about how to identify and measure the size of fittings.

Look at the picture and write the name of fittings, measurement and document fittings dimension.

Sl. No.	Name of the fittings	Size	
		NB. Dia (ϕ)	Length in mm
1.			
2.			
3.			
4.			
5.			

Exercise

I. Answer the following questions.

1. What are the purposes and applications of pipe fittings in piping systems?.

----

2. What are the major classifications of pipe fittings?

----

3. What are the advantages of butt weld fittings?

----

4. Differentiate long radius elbow and short radius elbow.

----

5. Differentiate – weldolets, sockolets and threadolets.

II. State whether the following statements are True or False.

1. Pipe fittings can be used in piping works, for changing direction flow.

   True ☐ False ☐

2. If the piping system requires changes in pipe diameter, pipe fitting shall not be used.

   True ☐ False ☐

3. Butt weld fittings are made from seamless or welded pipe.

   True ☐ False ☐

4. Long radius pipe bend makes high pressure drop than low radius bend.

   True ☐ False ☐

5. Reducing elbow will have different diameter at both ends.

   True ☐ False ☐

6. Pipe fitting "Equal Tee" is used for same diameter of run pipe (header) and different diameter of branch connection.

   True ☐ False ☐

Notes

1.5.9 Types of Pipe Joints / Joining Methods

At the end of this topic, you will be able to:

1. describe features of different fabrication joint types
2. choose and employ appropriate jointing methods
3. perform appropriate joints preparation.

Piping fabrication joint types

Piping fabrication and installation is made with different joint types based on material and process conditions. Following are the different piping joint types being employed in oil and gas industry and associated miscellaneous services. welding, bolting, bonding, screwing / threaded.

Types of welding joints.

a. Butt joints: Item to be welded is kept in the same plane and are joined at the edges. Unless otherwise specified, these types of butt joints are considered to be groove welds with full penetration.

b. Tee joints: one part is perpendicular to the other in the approximate shape of the letter ''T".

c. Lap joints: consists of two overlapping parts.

d. Corner joints: parts in a corner joint form a right angle and are joined in the corner.

Fig. 1.5.30 shows different types of weld joints. Each type of welding joint has different parameters to meet different requirements.

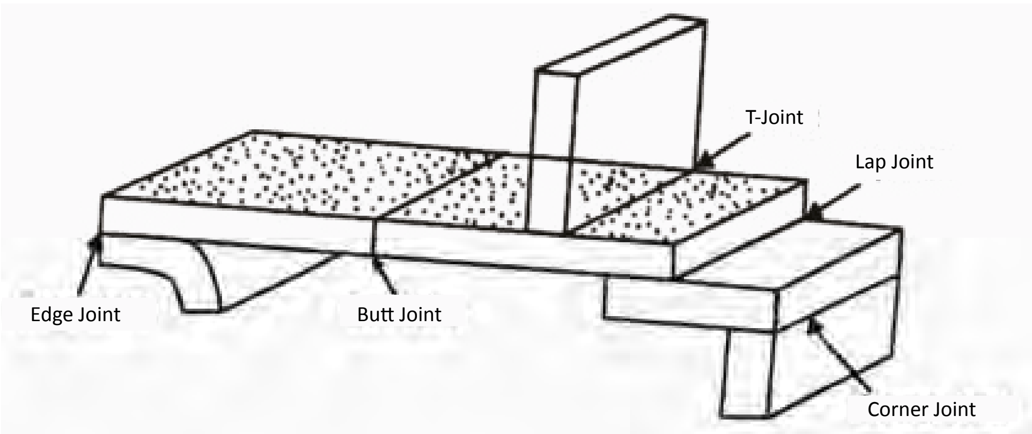
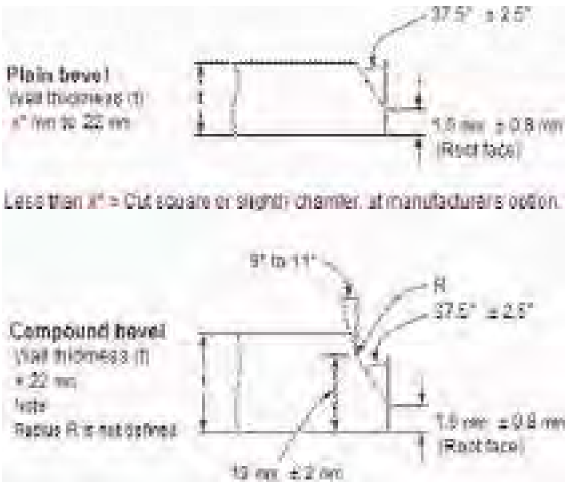


Fig. 1. 5. 30 Basic types of Welded Joints

f. Most employed pipe welds: Two major types of welds used to join metallic piping materials are, butt weld and fillet weld.

i. Butt welded joints groove preparation



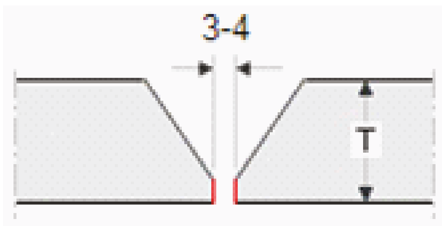


Fig. 1.5.31 Butt Weld Grooves Preparation

This is groove type weld used to join two metal pieces that are positioned next / adjacent to each other, by duly fusioning and melting the joining faces and edges with or without addition of filler metal. A butt joint is the most universally used method of joining pipe to itself, fittings, flanges, valves, and other equipment. When the material to be welded exceeds 5" in thickness, the ends of pipes, fittings and flanges must be chamfered / edge prepared at approximately 37.5°, flared on a small upright side (Root face) to form welding bevel. The most used bevels are the plain bevel of wall thicknesses (t) 4 to 22.5 mm, and the compound bevel of wall thicknesses above 22 mm. During joining pipe to pipe or pipe to elbow, a gap of approximately. 3-4 mm should be created for higher thicknesses, to obtain a proper weld penetration. If filler metal diameter is less, then the root gap can be reduced accordingly. Based on the groove formation, the different types of butt welds are:

square butt weld, bevel groove weld, V-groove weld, J-groove weld, U-groove weld, flare-V-groove weld, flare-bevel-groove butt weld.

ii. Joining by fillet welds

This is not a type of joint. It is fillet-type weld (Tee joint, lap joint, corner joint, etc).

Fillet welding refers to the process of joining two pieces of metal together whether they are perpendicular or at an angle. Fillet weld is aesthetically triangular in shape and may have a concave, flat or convex surface depending on the welder's technique. These welds are commonly referred to as

a) Tee joints when two pieces of metal are fitted perpendicular to each other;

b) Lap joints where two pieces of metal overlap and are welded at the edges.

c) If two metal pieces are joined at edges and perpendicular to each other, it is called corner fillet weld.

Fillet welded joints such as tee, lap and corner joints are the most common connection in welded fabrication. Bevel preparation is not needed. However, surface preparation to sound metal is needed for proper fusion. Fillet weld assemblies are simple to make. In piping system, slip on flanges welding, seal welding of threaded joints (if required), socket weld of piping and pipe supports welding are normally welded by fillet weld.

Bolted joint connections

Bolted joints are extensively used in piping industry. A bolted flange connection may be made with flange, bolts / studs, gaskets, washer, etc. The correct placement of gasket and proper tightening of bolts in a flanged joint will ensure a leak – free joint. Piping bolted connections are mostly made either by studs bolts or hexagonal head bolts.

Bonding joints

Bonded joints are very common in many piping and pipeline systems, in which the bond behaviour of the joint interface and degree of surface preparations are of crucial importance. Permanent bonding joints are made using adhesives / resins. Adhesives / resins are added in the joining surfaces at controlled environment and temperature as recommended by the manufacturer and cured. Different types of bonding joints include lamination joints, bell and spigot joints. Dissimilar metals, composite metals and PVC, GRE / GRP metals can be joined by bonding process.

Threaded / screwing joints

a. Threaded joints are detachable joints of two or more component parts either directly connected with each other or by standardized fasteners like bolts, nuts and screws. Threaded joint in piping means, pipes are connected by screwing with the help of threads provided for each pipe, having internal threads in one pipe and the other having threads externally.

b. Types of threads: There are two types of threads namely, straight thread and tapered threads. Threaded joints in process piping may be made by tapered threads. Pipe thread "NPT" (National Pipe Thread) is mostly used with sealant.

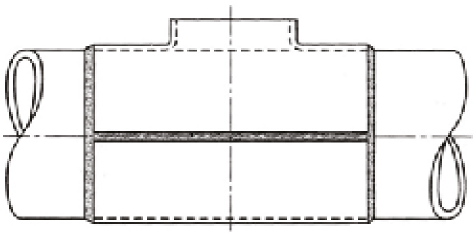


Fig. 1.5.32 Fillet welding of pipe sleeve ends

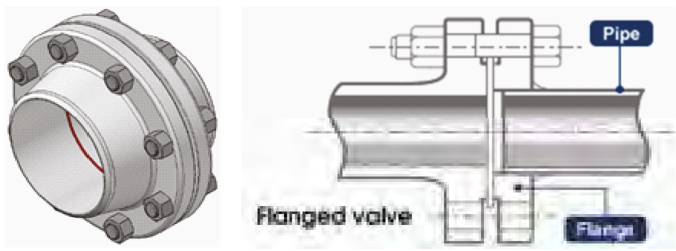


Fig. 1.5.33 Bolted Joints

c. Types of threaded joints

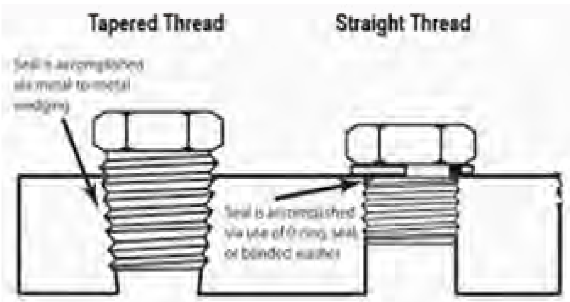
Different types of threaded joints are as discussed here.

Direct joints

The component parts to be joined have internal or external thread and are directly screwed together. No additional fastening elements are needed. This types of joints are performed in plant piping, airlines instrument etc.

Indirect joints

The component parts to be joined are held together by standardized components like bolts, screws and nuts. Locking devices and washers may be used additionally.



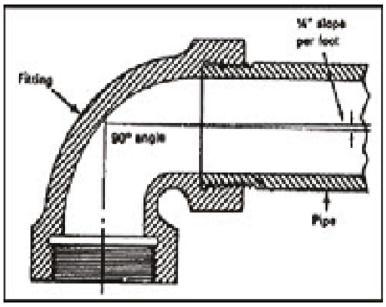


Fig. 1. 5.34 -Type of threads

Fig. 1.5.35 Typical threaded joints in piping

Where a component part has a female thread, the joint may be made without a nut. The walls of the workpiece must be sufficiently thick for this kind of joint. This type of joints are performed in skid mounting, pump mounting, etc.

Fastening joints

The component parts are to be joined directly or indirectly only for the purpose of connecting them. The vee-thread, ISO metric vee-thread or Whitworth thread are the preferred types of threads. Both threads are self-retaining.

Adjustable joints

The component parts are joined for the purpose of connecting them and transmitting movements or forces. The preferred types of threads are round threads, ACME standard screw thread or saw-tooth thread. Valve stem and gland joints are of this type. These are less self-retaining – indicates 1 round thread, 2 ACME standard screw thread and 3 saw-tooth thread.

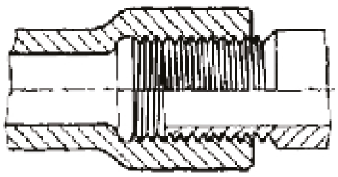


Fig. 1 5.36. Direct joint

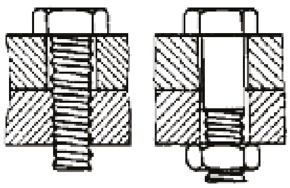


Fig. 1. 5.37 Indirect joint

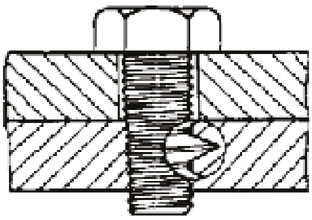


Fig. 1 5.38 Screwed joint fastening

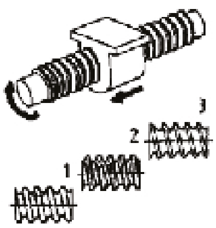


Fig. 1.5.39 Adjustable joint

1.5.10 Edge Preparation and Fitup

At the end of this exercise, you will be able to:

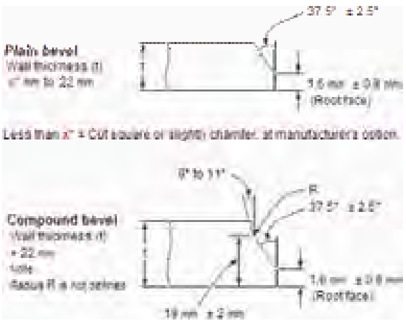
1. prepare pipe to pipe edge beveling and joint fitup
2. prepare plate to plate edge beveling and joint fitup.

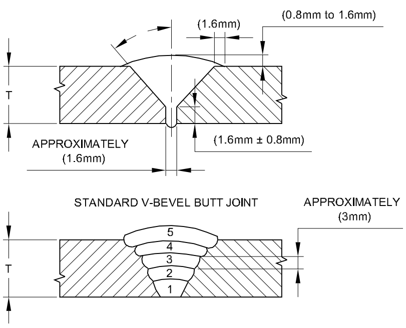
Practical

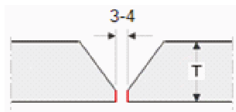
Requirements			
Tools/Instruments		Welding Equipment	– 1 No.
Measuring Tape	– 1 No.	Oxy-Acetylene Gas cutting	– 1 No.
Steel rule	– 1 No.	**Materials/Components**	
Try Square	– 1 No.	Paper	– 1 No.
Spirit level	– 1 No.	Scriber	– 1 No.
Flat file	– 1 No.	Approved shop drawing	
Hack saw	– 1 No.	2” ϕ –SCH 80 pipe – 400 mm long	– 1 No.
Equipment/Machines		10 X 100 X 300 long-plate	– 2 No.
Personal Protective Equipment	– 1 No.		
Grinding Machine	– 1 No.		

Tips

The instructor will guide the trainee on how to select suitable tools and equipment for use in pipe fitting works, and demonstrate how to prepare pipe and plate beveling, (edge preparation).







Exercise

I. Answer the following questions.

1. Name any four type of joints normally used in piping.

----

2. List out different type of weld joints

----

3. Draw the sketches for the following weld joints fit-up:

----

i. Two Numbers of 20 mm thick plates joining full penetration butt weld with double V groove

ii. Two Numbers of 16 mm thick plates joined together to perform full penetration butt weld “T” joint with single bevel

4. List out different type of butt welds.

____

5. Describe bonding joints and their applications.

____

6. What are all the items can be welded by fillet welds, in piping system, provided if mentioned in the drawing?

____

II. State whether the following statements are True or False.

1. "Bonding" is one type of pipe joining method.

   True ☐ False ☐

2. In piping works, butt joints are made with partial penetration welds.

   True ☐ False ☐

3. Edge type joints comes under the category of "Groove type weld".

   True ☐ False ☐

4. Fillet weld is one type of joint.

   True ☐ False ☐

5. Lap and corners joints can be welded by fillet welding.

   True ☐ False ☐

6. In general, Slip on Flanges are welded by "Butt welding".

   True ☐ False ☐

7.. 'NPT' is the abbreviation for 'Nominal Pipe Thread".

   True ☐ False ☐

Notes

1.5.11 Types of Bolts, Nuts and Screws - Pipe Clamps & Fixtures

At the end of this topic, you will be able to:

1. explain different pipe fasteners and differentiate the same
2. describe features of different pipe joint clamps
3. choose appropriate pipe clamps for pipe joint fitup.

Types of bolts, nuts and screws – pipe fasteners

In piping, Bolting is a term used to perform flange joints connection using appropriate fasteners. Stud bolt, nuts, machine bolts and washers are known as bolting material or fastener. In oil and gas industry, stud Bolts and hex Bolts are mostly used for flange connections. The stud Bolt is a threaded rod with 2 heavy hexagon nuts, while the hex Bolt has integral head with one nut. Fasteners are coated to increase the wear resistance, prevent damages and avoid field coating / painting of fasteners.

Fig. 1 5.40 Coated Fasteners

a. Studs (stud bolt)

Stud has a thread on full lengths or at both ends. While joining flanges, the length of stud bolt should be enough to cover entire nut plus 1.5 to 3 threads exposed either side. Long studs must be avoided as it increases the chance of corrosion and other damage to the exposed threads, which would make subsequent removal difficult. Length of the stud depends on the flange thickness, type of gasket, nuts size and the maximum exposed thread requirements.

Fig. 1.5.41 Stud bolts (threads – full length and at both ends)

Fig. 1.5.42 Machined bolt with nuts & washer

b. Machine bolts / hexagonal bolts

Bolts have a thread at one end and hexagonal head on another end as shown in fig 5.50.

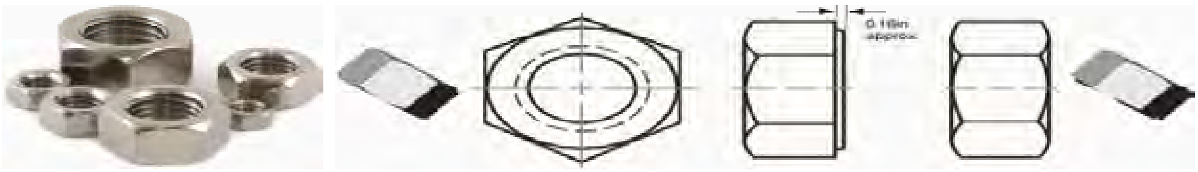


Fig 5.43 Hexagonal Nuts

c. Hex N uts

Commonly, hexagonal heavy series nuts are used with studs and bolts. The non-bearing face of a nut is chamfered, while load bearing face is finished with a washer face or may be chamfered. In general, the height of a nut for a stud bolt is the same as the diameter of the thread rod.

d. Washers

i. A washer is a thin, mostly circular sheet / plate material with a hole at the center. Standard washers purposes to distribute the load / pressure evenly over the flange surface, so that the flange is not damaged.

ii. Different types of washers are used such as flat / plain, splits washer (helical spring washer), and conical springs (bellevelle spring washer).

- Plain washers, which spread a load and prevent damage to the surface being fixed or provide some sort of insulation such as electrical insulation.

- spring washers / conical washers, which have axial flexibility and are used to prevent fastening or loosening due to vibrations
- locking washers, which prevent fastening or loosening by preventing unscrewing rotation of the fastening device, usually, locking washers are also spring washers.

Fig. 1.5.44 Flat and spring washers

Fig. 1.5.45 Conical washer

e. Screws

Screws are not normally used in piping / pipeline works. It is used only in miscellaneous secondary structures of process plants.

g. Materials for stud / bolts

Bolting material can be divided into three groups – high strength, intermediate strength and low Strength. The material qualities for studs and bolts are specified in ASME / ASTM standards with grades. Frequently used grades are A193 / A320 / A307 for bolts / studs and A194 for the nuts.

Fig. 1.5.46 Types of screws with different head formations

Fig. 1.5.47 Identification marking in bolts and nuts

h. Marking of stud / bolts / nuts

ASTM material Standard A193 and A320 specify marking requirements for stud and bolt. Marking is to be done at the ends of the stud or on the bolt head. In the case of hex head bolt, both the symbols are marked on the bolt head. For nuts, marking should be done on the nut's non-load bearing face. Due to limited space, only manufacturer's identification mark and material grade / class are marked with a unique identifier on stud and bolt.

II. Various pipe fitting fixtures and clamps

1. Rigid clamps

Rigid clamps are usually made from hard iron or steel which makes these clamps suitable for pipe clamping and allows fast locking and unlocking. Pipes can easily be inserted into these clamps and locked to an accurate position.

2. Adjustable clamps

Steel, aluminum and plastic often comprise the base material for these clamps. The main advantage of adjustable clamps is that they can be used for a wide range of pipe sizes. The size of the clamp can be changed easily in accordance to the diameter of the pipe by tightening or loosening the screw attached to the clamp. This allows the clamp to be reused for another pipe which has a different diameter.

3. **C-clamp**

   The popular C-clamp is the standard go-to clamp for many occasions. Its simplicity and availability are unmatched. Every clamp collection starts with a few sizes of C-clamps.

Fig. 1.5.48 Adjustable Clamp fixing

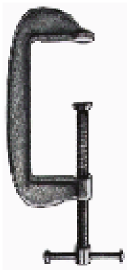


Fig. 1.5.49 C Clamp

Fig. 1.5.50 Simple Clamping

Fig. 1.5.51 F Clamp

Fig. 1.5.52 Pipe clamp fixture

4. **F- clamps**

   The F-clamp is designed for various pipe diameter fixtures. The F-clamp has a slider bar that allows the opening capacity to be easily adjusted to accommodate a wide range of diameters. This has made the F-clamp another very popular clamp and is used when a C-Clamp's opening capacity is too small.

5. **Pipe clamp fixture**

   The pipe clamp fixture is similar to the F-clamp, except instead of using a sliding bar it uses to a sliding pipe. This allows for the pipe clamp to fit any opening capacity as needed to suit appropriately the pipe size.

6. **Chain type clamps**

   Chain type clamps align and reform pipe diameters as small as 1 in. (25 mm) and as large as 20 ft (6 m). The inside or outside of the pipe can be aligned with these clamps. Chain clamps allow pipe, elbow, tee, flange, and other fittings to be held safely and securely in place during the alignment and welding process.

7. **Cage clamps**

   Cage Clamps are available for pipe sizes 2 to 60 in. (51 to 1524 mm) as shown in fig 5.62. These rigid frame clamps are designed for rapidly aligning the outside diameter and come in two basic styles. The tack type cage clamp is used to align pipes for tack welding. The no-tack type allows the joint to be completely welded without removal of the clamp. These clamps are designed to align only one pipe size per clamp. The clamps are available in hand lever, ratchet, and hydraulic models. Full-circle steel-type clamps are available for pipe sizes 6 to 72 in. (152 to 1829 mm) and have multiple contact points to handle aligning, reforming or rounding applications. These clamps are designed to put pressure on the high point of the pipe or shell and bring them into alignment. The welder is able to do a 100% weld and grind without removal of this type of clamp.

9. **Internal hydraulic and pneumatic alignment clamps** are used mainly for pipeline applications and are available for pipe sizes 6 to 60 in. (152 to 1524 mm). These clamps cover a range of one to six pipe sizes,

Fig. 1 5.53 Chain type clamping

Fig. 1.5.54 Cage clamps

Fig. 1.5.55 Frame type clamping

Fig. 1.5.56 Internal alignment clamps

depending upon the make and model. These clamps allow to complete full circle weld without obstruction. An automated welding system in conjunction with the clamp, increases productivity and lowers weld rejects. Wherever possible, internal clamps shall be used due to the following reasons:

a. The internal clamp gives smoother alignment for both pipe joint ends and leads to better weld root.

b. The internal clamp use the pushing technique, reduce the need of additional or temporary tack welds.

c. Internal clamps increase the production rate and yields better quality fitting.

1.5.12 Different Type of Fasteners and its Dimension

At the end of this exercise, you will be able to:

1. identify the different types of fasteners and measure the dimensions
2. record the names and grade of fasteners
3. identify the different type of washers.

Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Measuring Tape	– 1 No.	Paper	
Steel rule	– 1 No.	Pencil	
Thread gauge	– 1 No.	Marker pen	
Wire brush	– 1 No.	M12, M16, M20–studs-	–1 EA
Equipment/Machines		M12, M16, M20–nuts-	–1 EA
Personal Protective Equipment	– 1 No.	Plain washer's 14/20	–4 Nos.
		Spring washers 18mmID	–2 Nos.

Tips

The instructor should provide a chart for the different sizes and grades of bolt, nuts, washers and explain how to identify the type, size and grade of fasteners.

Identify the fastener size and record in Table 4.

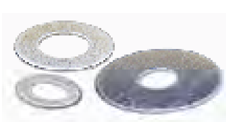

1


2


3


4


5


6

7

8


9


10


11


12

Table 4

Sl. No.	Name of the fasteners used in piping	Size of the fastener's	Sl. No.	Name of the fasteners used in piping	Size of the fastener's
1.			7.		
2.			8.		
3.			9.		
4.			10.		
5.			11.		
6.			12.		

1.5.13 Pipe Edge Preparation and Alignment

At the end of this exercise, you will be able to:

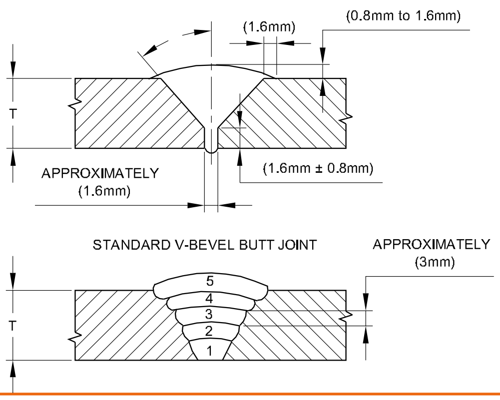
1. perpare pipe edge beveling and check the bevel angle
2. assemble pipe to pipe fit up, using F-Clamp for alignment.

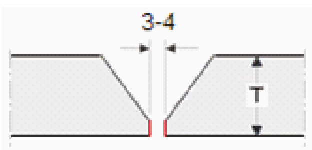
Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Measuring Tape	– 1 No.	Paper	
Try Square	– 1 No.	Pencil	
Spirit level	– 1 No.	Marker pen	
Welding hand shield	– 1 No.	Welding electrode	– 2 Nos.
Wire brush	– 1 No.	4" ϕ – Carbon steel pipe 600 mm long	– 1 No.
Scriber	– 1 No.	**Equipment/Machines**	
F.Clamp	– 1 No.	Personal Protective Equipment (PPE)	- 1 Set.
Spacer wire	– 1 No.	Welding equipment with accessories	- 1 No.
Bevel protractor	– 1 No.	Grinding machine with accessories	- 1 No.
Hi-Low gauge	– 1 No.		

Tips

The instructor should demonstrate pipe end beveling and guide the trainee about how to use grinding machine for beveling, and how to check bevel angle.





Exercise

I. Answer the following questions.

1. What are the fasteners used in oil and gas industry piping works?

----

2. What are the different coating / plating performed for fasteners to prevent corrosion and improve wear resistance?

----

3. What is the difference between stud bolt and hexagonal bolt?

----

4. Describe different types of washers and their applications.

----

5. What are the advantages of internal alignment clamps?

Notes

1.5.14 Pipe Joining Packing Materials - O-Ring, Ropes and Adhesives

At the end of this topic, you will be able to:

1. define packing materials related to piping
2. describe features of different pipe joint clamps
3. choose appropriate pipe clamps for pipe joint fitup.

O ring is a mechanical packing gasket. It is a loop of elastomer with a round crosssection (in some applications – square / rectangular), designed to be seated in a groove and compressed during assembly between two or more parts, creating a seal at the interface. O ring seals prevent fluids from escaping through the gaps in mating surfaces. Because the material is soft, the O ring is mechanically squeezed to plug any gap between the two mating hardware pieces. The flexible nature of O ring materials accommodates minor imperfections in the mounting parts. But, it is still important to maintain good surface finish of those mating parts.

Fig. 1.5.57. O rings

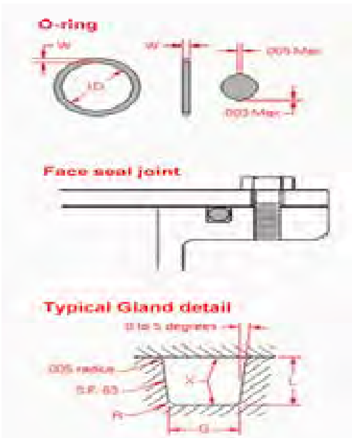


Fig. 1.5.58 Typical O ring sizing and sealing arrangements

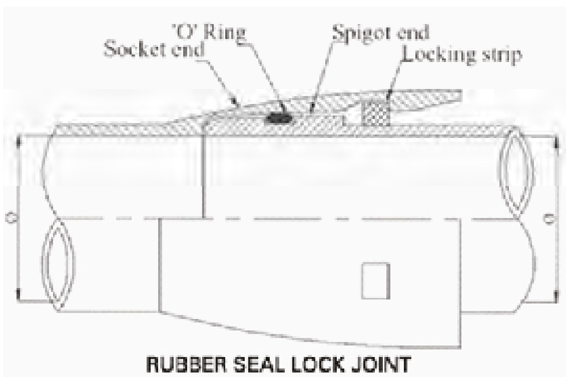


Fig. 1.5.59 O ring positioning in Spigot joint

b. O ring materials

O Rings can be made from plastic or metal. O rings are made from different materials as listed below:

- synthetic rubbers – thermosets
- butadiene rubber (BR)
- butyl rubber (IIR)
- chlorosulfonated polyethylene (CSM)
- epichlorohydrin rubber(ECH, ECO)
- ethylene propylene diene monomer (EPDM)
- eluoroelastomer (FKM)
- nitrile rubber (NBR, HNBR, HSN, Buna-N).

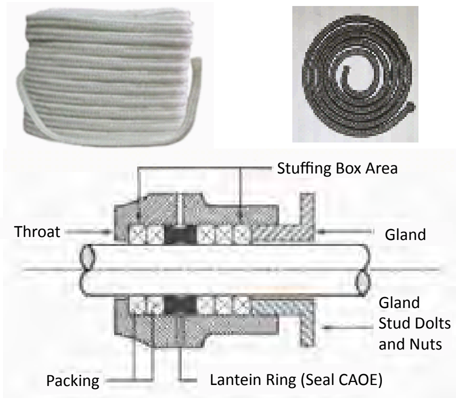


Fig. 1.5.60 Rope packing

Rope packing

Rope packing is made by graphite PTFE. In piping works, ropes are rarely used (such as valve gland / stuffing box stem assembly) where sealing is required on the moving parts. Unless otherwise specified in the drawing, manufacturer recommendations shall be followed for the rope materials selection and installation.

a. **Adhesive** is a substance that is capable of holding materials together in a functional manner by surface attachment that resists separation. Various joints are made using adhesives. Most of the PVC, GRE/ GRP, PE piping are joined by applying adhesives. An adhesive in the form of a liquid or a tacky solid is placed between the surfaces to be joined, which are then mated and heat or pressure or both applied to accomplish the joint. The best choice of adhesive depends on the materials to be bonded.

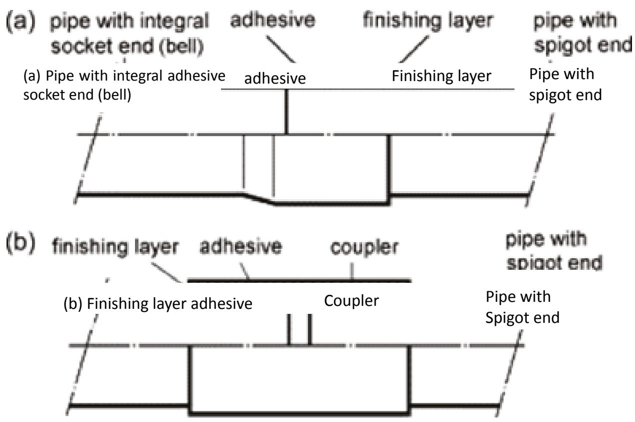


Fig. 1.5.61 Spigot joints made with adhesives

b. **Adhesive types:** Adhesives can be divided into two broad groups – structural adhesives and non-structural adhesives.

Tips

Note: non-structural adhesives, also known as glues or cements, are used for low load applications.

c. **Adhesive shelf life and working life:** Adhesives are characterized by their shelf life, which is defined as the time that an adhesive can be stored after manufacture and still remain usable, and by their working life, defined as the time between mixing or making the adhesive and when the adhesive is no longer usable.

d. **Structural adhesives**

Structural adhesives have high load carrying characteristics. Structural adhesives, developed to produce high strength are generally composed of synthetic resins or combinations of synthetic resins and elastomers. Common synthetic resins used are epoxy, phenol and resorcinol. Structural adhesives like plastics are classified into two groups-Thermoplastic and thermosetting.

i. Thermoplastic adhesive

Thermoplastic adhesives may be re-softened by heating repeatedly at high temperatures, which is decided by their chemical structures. They also lose bond strength due to decomposition. Most commonly used thermoplastic adhesives are the polyamides, vinyls and non-vulcanizing neoprene rubber.

For structural applications, vinyls have proved very versatile. For example, polyvinyl acetate can be used to form strong bonds with metals, glass and porous materials.

ii. Thermosetting adhesives

Thermosetting resins are the most important materials from which metal adhesives are formed. Thermosetting resins are available to give strong, waterproof and heat- resistant joints. There are two general types of thermosetting structural adhesives the phenolic-resin base and the epoxy-resin base adhesives. Epoxy resins are amongst the newest thermosetting resins and are widely acclaimed as they combine the properties of excellent action, low shrinkage, high tensile strength, toughness and chemical inertness. They can be cured at room temperature without any volatile by-products and can develop strengths between 15 to 30 MPa. Amongst the latest arrival on the scene is the oily metal epoxy that bonds directly to oily metals as received with normal protective oil layer on them.

e. Adhesive joints types

The main types of joints employed for adhesive bonding are lap joint and the tongue and groove configuration which can be used for butt, corner or fillet joints.

i. Lap joints

An adhesive joint performs best when loaded in shear as is the case in lap joints – three well-known types of which are shown in Fig. 1.5.63. In thin gauge metal bonds, joint designs can provide large bond areas. Thus, it is possible to produce joints that are as strong as the metal.

ii. Butt joint

A square butt joint performs poorly for adhesive applications because of low effective area and high stress concentration. However, there are several ways by which the contact area between the adhesive and the adherend can be increased. These include scarf edge preparation, double butt lap, single strap, double strap, bevelled double strap and recessed double strap.

iii. Fillet or T-Joint

Like the square butt joint, the common T-joint may not provide adequate bonding area and hence, fillet T joints are not applicable for piping.

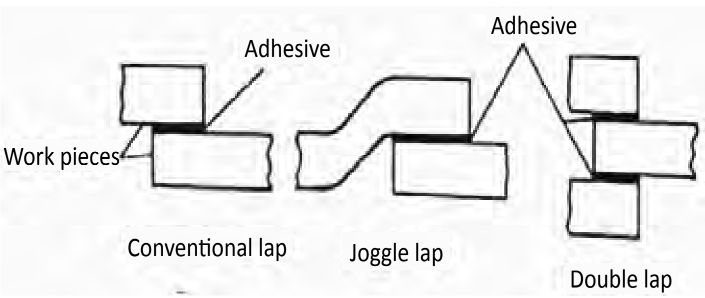


Fig. 1.5.62 Typical lap joints by adhesive bonding

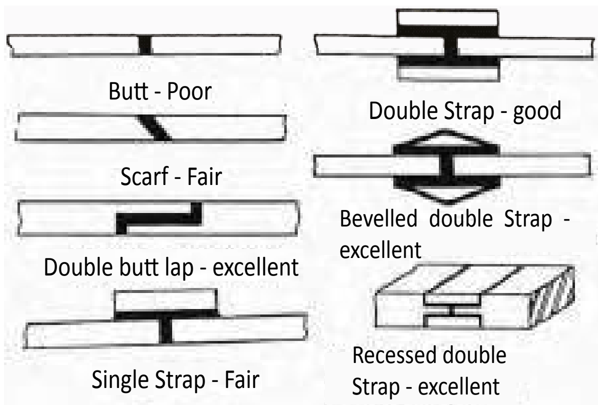


Fig. 1.5.63 Typical butt joints by adhesive bonding

iv. Corner joints

The corner joints are subjected to both peel and cleavage stresses and the joint is relatively weak. Hence, this is not applicable for piping.

f. Tube / pipe joints

Adhesive bonding is used for tube / pipe joints some of which are shown in Fig. 1.5.64. Large bonded areas give strong joints with clean appearance but processing may be complicated with some while edge preparation may be costly for some others. The strength developed in an adhesive joint depends upon the joint design, type of loading, service temperature, adherend material, etc.

1.5.15 Adhesive Storage and Handling Conditions

At the end of this exercise, you will be able to:

1. check the adhesive storage and handling conditions
2. identify the adhesive shelf life and potlife.

Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Special rubber gloves	– 1 Pair.	Paper	
Special goggles	– 1 No.	Pencil	
Equipment/Machines		Marker pen	
Personal Protective Equipment	– 1 No.	Adhesive pen	– 1No.
		MSDS	– 1No.

Exercise

I. Answer the following questions.

1. Name any four types of O ring materials.

----

2. Describe O ring functions and applications.

----

3. What are the factors that are likely to affect / influence the adhesive joint strength?

----

4. Define adhesive shelf life and work life.

----

5. What is the significances of epoxy resin base thermosetting adhesives?

II. State whether the following statements are True or False.

1. O ring can be used for both static applications and dynamic applications.

   True ☐ False ☐

2. Butadiene rubber can be used for making O ring.

   True ☐ False ☐

3. The strength of joint may be influenced by contact angle between the adhesive and metal.

   True ☐ False ☐

4. Phenolic resin based adhesive is a type of thermoplastic structural adhesive.

   True ☐ False ☐

5. Epoxy resin base adhesives are thermosetting adhesives.

   True ☐ False ☐

Notes

1.5.16 Gaskets

At the end of this topic, you will be able to:

1. describe features and significance of different types of gaskets
2. recognise constituent parts / materials of the gaskets
3. identify the gasket with respect to the manufacturer marking
4. select appropriate type of gaskets for installation
5. cut the gaskets without affecting quality.

Gaskets Purpose

Flange gaskets are used to create a static seal and maintain leakage proof sealing between two flanges faces, at all operating conditions. A gaskets fills the microscopic spaces and irregularities of the flange faces. Then it forms a seal that is designed to keep liquids and gases. Correct installation of damage-free gaskets and damage-free flange faces is essential for a leak-free flange connection.

Gasket Types

a. Three major types of gaskets are used to achieve the leak proof sealing between the flanges of piping works. They are:

- non-Metallic Gaskets that include compressed non-asbestos fibre gasket (CNAF), PTFE and rubber, teflon
- metallic gaskets that include oval ring and octagonal ring-ring type joint
- composite / semi–metallic gaskets that include, spiral wound gaskets, cam profile gaskets and metal jacketed gasket.

Non-metal gaskets are manufactured as long sheets and the required size of gaskets are cut from the sheet. Spiral wound gaskets are made by winding of metal and filler metal. Metallic gaskets are made from forged ring or cut from metal sheet and machined.

b. Based on the type of construction, gaskets are classified as full face, spiral wound metallic, Ring type, Metal jacketed, Inside bolt circle.

Non - metallic gasket

a. Non-metallic gaskets are usually composite sheet materials, used with flat-face and raised-face flanges in low pressure class applications. These gaskets are also known as a soft gasket. In earlier stages, compressed asbestos fibre (CAF) gaskets were mainly used.

b. ASME B16.21 covers types, sizes, materials, dimensions, dimensional tolerances, and markings for non-metallic flat gaskets. Non-metallic gasket is manufactured from flexible materials such as compressed non-asbestos fiber (CNAF), PTFE / teflon, rubber / elastomer, mica / glass fiber, ceramic fiber and graphite.

Advantages and applications of non-metallic gaskets

- Non-Metallic gaskets can be easily compressed with low tension bolting.
- These types of gaskets are used with low-pressure class flanges such as 150 and 300 and also in low temperature. However, graphite gasket can be used up to 500˚ C .
- Rubber and elastomer gaskets are not used in hydrocarbon services, but used in utility lines.
- Non-metallic gaskets are cheapest and easily available.
- Full-face gasket types are suitable for flat-face (FF) flanges. Flat ring gasket types are suitable for use with raised faced (RF) flanges.

The above Fig.1.5.62 shows full face gasket and inside bolt

circle gasket. Full face

gasket can be used only with FF flange and is normally used for utility lines.

Fig. 1.5.64 Non-Metallic gaskets types

Semi-metallic gaskets

Semi-metallic gaskets are composites / combination of metal and non-metallic materials. Different types of combination of materials are possible based on service requirement. Spiral wound, metal lacketed, and cam profile gasket are well known in composite gasket category. Semi-metallic / composite gaskets are used on raised face, male-female and tongue-and-groove flanges.

The metallic portion is intended to offer strength and resiliency, while the non-metallic portion provides conformability and sealability. Often used semi-metallic gaskets are

spiral wound, camprofile, variety of metal-reinforced / jacketed graphite gaskets.

ASME B16.20 covers materials, dimensions, dimensional tolerances, and markings for metallic and semi-metallic gaskets.

Fig. 1.5.65 - CNAF & PTFE Gaskets

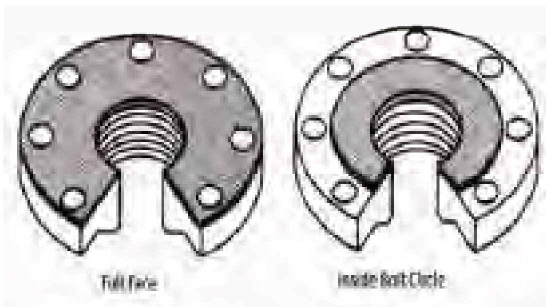


Fig. 1.5.66 – Full Face & Inside Bolt Circle Images

a. Spiral wound gasket

The most widely used composite type gasket is a spiral wound gasket. It is suitable for wide range of pressure and temperature classes. The selection of material of construction for Gasket winding depends upon the:

- corrosive nature and concentration of fluid being carried

- operating temperature of the fluid
- relative cost of alternate winding material.

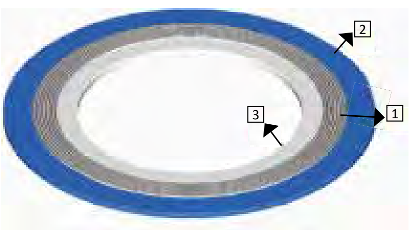
There are three components in spiral wound gasket, – inner and outer ring, filler material, and winding material. Spiral wound gaskets are available with or without inner ring. The inner ring is used to provide additional support to the winding material. The winding is an alternative layer of filler material and winding material. The filler material is soft material such as graphite and PTFE and winding material is a thin sheet of stainless steel or other exotic material. PTFE is not used for high temperature services. Stainless steel or other exotic material is used as the winding material. Outer ring of spiral wound gasket is mostly manufactured from Carbon steel or stainless steel. The most commonly used material for spiral wound metallic gasket winding are austenitic stainless steel 304 with asbestos filler, austenitic stainless steel 316 with asbestos filler, austenitic stainless steel 321 / 347 with asbestos filler or Exotic material such as monel, titanium. Duplex can also be used as per service requirements. It is customary to select inner ring material to be the same as the metal winding. Depending on the type of metal filler combinations, spiral wound gaskets are suitable for raised face, flat faced and lap joint flanges at pressures up to 7000 kPa (1000 PSI) and temperatures up to 500°C.

b. Gaskets marking

Gasket materials are generally marked with size, pressure class, manufacturer logo, filler and winding material, inner and outer ring material. Spiral wound gaskets are painted in accordance with ASME / ANSI B16.20. Metallic winding material is indicated by solid colour on the cantering ring. Non-metallic filler used between metal winding is indicated by stripped colour. Refer Fig. 1.5.67.

C. Cam profile gaskets

These gaskets are used in applications where high pressures and temperatures are to be maintained and consequently high bolt loads need to be controlled. Cam profile or grooved gaskets are used in all industrial applications. Cam profile gaskets are used in industrial power plants, petro chemical industry. Cam profile gaskets consist of a metal core (generally, stainless Steel) with concentric grooves on either side with sealing materials. The sealing layers (depending on the service duty) can be graphite, PTFE (teflon), CAF or metal (aluminium or silver). The sealing layers protect the flange surfaces from damage in addition to providing an effective seal.



Stuffing Box Area

1. Sealing Element
2. Outer Ring
3. Inner Ring

Fig. 1.5.67 Typical Spiral Wound Gasket

Fig. 1.5.68 Spiral wound gasket with cross-sections

d. Metal jacketed gasket

Metal jacketed gasket comprise metallic or non-metallic filler material enclosed by thin sheet of metal jacket / outer shell. The filler material gives the gasket resilience, while the metal jacket protects the filler and resists pressures, temperatures and corrosion. There are different ways to cover filler material as shown in the following Fig 1.5.69. Jacketed gaskets are easily fabricated in a variety of sizes and shapes and are an inexpensive gasket for heat exchangers, shell, channel, and cover flange joints. Metal jacketed gaskets are commonly used in heat exchangers and valve.

Flat jacketed gaskets are used at higher temperatures than plain flat gaskets. They require lower bolt loads than flat metal gaskets. For very high temperature services, graphite filler is used.

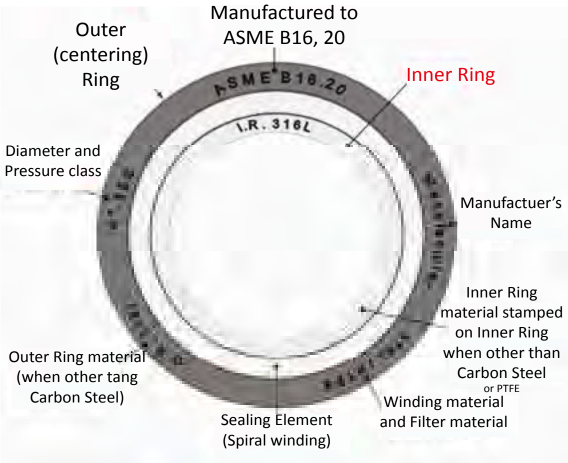


Fig. 1.5.69 Typical identification marking in gasket

Fig. 1.5.70 Camprofile gasket

V. Metallic gaskets

Metallic gaskets are fabricated from one or a combination of metals to the desired shape and size. Metallic gaskets can be made from forged ring or cut from metal sheet and machined. High tension bolting is required for metallic gaskets. Metallic gaskets are very robust.

a. **Materials of construction:** List of material that can be used for metallic gaskets is given in ASME B16.20. Some of the materials are soft iron, low carbon steel, 4-6% Chrome, ½ Mo, Stainless steel Type 304,316,347,410, Monel, and Inconel.

Metallic gaskets are used in high pressure class flanges and for high temperature. Often used metallic gaskets are ring type joint gaskets (RTJ). They are always applied to special, accompanying flanges which ensure good, reliable sealing with the correct choice of profiles and material.

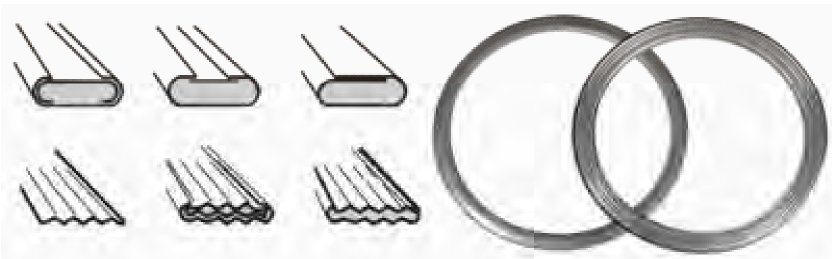


Fig. 1.5.71 Metal jacketed gasket

b. Ring type joint gaskets

Materials of construction are selected to match the flange material and to be resistant to the corrosive and erosive media. In addition, the material hardness of the RTJs is to be less than the hardness of the flanges to ensure the RTJ is deformed and not the flanges when assembled.

Fig. 1.5.72 Types of RTJ Gaskets

Fig. 1.5.73 Ring Type Joint gasket installation Image

Ring type joint gaskets are designed to seal by initial line contact or wedging action between the mating flange and the gasket. By applying pressure on the seal interface through bolt force, the softer metal of the gasket flows into the micro fine structure of the harder flange material, creating a very tight and efficient seal. It is machined to tight manufacturing tolerances in accordance with the relevant standards, to ensure correct installation.

i. RTJ gasket function

The RTJ gasket fits in a groove machined on the flange face of both mating flanges. Under axial compressive load, ring type joints plastically deform and flow into the irregularities of the flange groove. Since the load bearing area of the ring type joint is relatively small, very high surface stresses result between the sealing faces of the ring type joint and the groove. These stresses are further increased on the style RX and BX rings which allows very high internal pressures to be sealed. The seal is maintained by the action of axial load upon the gasket.

ii. Types of RTJ gaskets:

Two types of the metallic gasket are used with RTJ flange – octagonal and oval. Most applied type is style R ring that is manufactured in accordance with ASME B16.20 used with ASME B16.5 flanges, class 150 to 2500. Style R ring type joints are manufactured in both oval and octagonal configurations. The octagonal cross section has a higher sealing efficiency than the oval and is the preferred gasket. Oval and octagonal RTJs with the same ring size designation can be interchangeable in standard flanges with flat bottomed ring grooves. Oval and octagonal RTJs are designed to seal pressures of up to 6,250 psi in accordance with ASME B16.20 and up to 5,000 psi in accordance with API 6A pressure ratings.

iii. RTJ applications / uses

The hardness of the ring should always be less than the hardness of the flanges. The ring type joint gaskets are used where high integrity seal is essential. They are mainly used in piping and valve assemblies of petroleum industries, refining industries, oil fields, offshore piping, drilling and completion equipment. Ring type joints are also commonly used on pumps, valves and pipe work assemblies along with some high pressure vessel joints in various process plants.

c. Serrated gaskets

Serrated gaskets are flat metal gaskets which have concentric grooves machined into their faces. The reduced surface area provided by the grooves allows an efficient seal at lower bolting loads. They are commonly used with smooth faced flanges where gaskets of soft material would be unsuitable.

d. Insulating gaskets

Gaskets made of non-conductive material together with insulating sleeves around bolts and are used where it is necessary to provide electrical isolation between parts of a line.

Selection of gasket

Hardness of the gasket shall always be less than flange material by at least 50 BHN. If gasket hardness is more than flange, while tightening the flange, the gasket will damage the serration and joint might leak.

Gasket cutting processes

a. General instruction for cutting gasket

- Ensure that gasket material issued for cutting is the correct material to be cut.
- Ensure that cutting area is clean. It shall not have stones and burrs which may damage the gasket.
- Make a template as per the required dimensions and use. If template is already there, check the template dimensions for conformity.
- Mark the locations / positions accordingly.
- Use a hollow punch and hammer to punch out all the bolt and stud holes.
- Cut out the inner part of the gasket.
- Cut the outer perimeter of the gasket.

Fig. 1.5.74 Manual cutting method

b. **Manual cutting methods** are very common and generally performed in plants for jobs that require custom gaskets to be cut in the field. The material can be cut with a utility knife, scissors or shears or even by a battery operated device.

1.5.17 Different Type of Gaskets

At the end of this exercise, you will be able to:

1. identify different types of gaskets
2. draw the sketches of spinal wound gaskets.

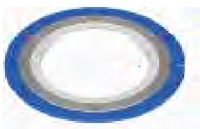
Tips

Instructor should provide the gasket chart and explain methods of identification to trainees.

Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Measuring Tape	– 1 No.	Paper	
Steel rule	– 1 No.	Pencil	
Compass drawing tool box	– 1 No.	Marker pen	–1No.
		Gasket Chart	–1No.
Equipment/Machines			
Personal Protective Equipment	– 1 No.		

a) Identify different types of gaskets



1.

2.

3.

Sl. No.	Name of gaskets used in Piping
1.	
2.	
3.	

b) Draw the sketch of spiral wound gasket and name the constituent parts.

c) Draw the free hand sketch of oval and octogonal gasket duly showing the cross section.

Exercise

I. Answer the following questions.

1. List out major group / types of gaskets with examples for each type.

----

2. Name any four types of non-metallic gaskets.

----

3. Describe the construction of spiral wound gasket.

----

4. Explain the construction of metallic jacket gasket.

----

5. Draw the sketch of spiral wound gasket.

----

6. In general, what are the details that need to be marked on the gasket by the manufacturer?

----

7. Explain the functions and effective sealing principles of ring type joint gaskets.

II. State whether the following statements are True or False.

1. Non-metallic gaskets shall not be used on raised face flanges.

   True ☐ False ☐

2. Full face gasket can be used only with flat face flange.

   True ☐ False ☐

3. Spiral wound gasket is a type of composite gaskets.

   True ☐ False ☐

4. Corrosive nature and fluid concentrations are also a deciding factor of gasket winding material.

   True ☐ False ☐

5. Spiral wound gaskets can be made with or without inner ring.

   True ☐ False ☐

6. PTFE filler metal is not used for high temperature services.

True ☐ False ☐

7. Non–metallic filler used between metal winding is indicated by stripped colour.

True ☐ False ☐

8. Ring type joint gasket material hardness shall be more than the hardness of flange material.

True ☐ False ☐

9. Hexagonal and oval shapes are the two types of RTJ gaskets.

True ☐ False ☐

10. Metallic serrated gaskets have spiral grooves machined in their surfaces.

True ☐ False ☐

Notes

1.5.18 Valves Installation

At the end of this topic, you will be able to:

1. describe different types of valves
2. explain different types of valve functions
3. install different types of valves including pressure relief valves.

Introduction to valves

Valves are mechanical devices that control the flow and pressure within a system or process. Some valves are self-operated while others are operated manually or with an actuator or pneumatic or hydraulic system. valve operations can be controlled by hand-lever, hand-wheel, motor operated, chain operator, gear operator, remote operation etc. Common types of valves are gate valve, globe valve, ball valve, butterfly valve, needle valve, plug valve, diaphragm valve, non-return valve, knife edge valve, drain valve, float valve, flush bottom valve, pinch valve, isolation valve, pen stack valve etc.

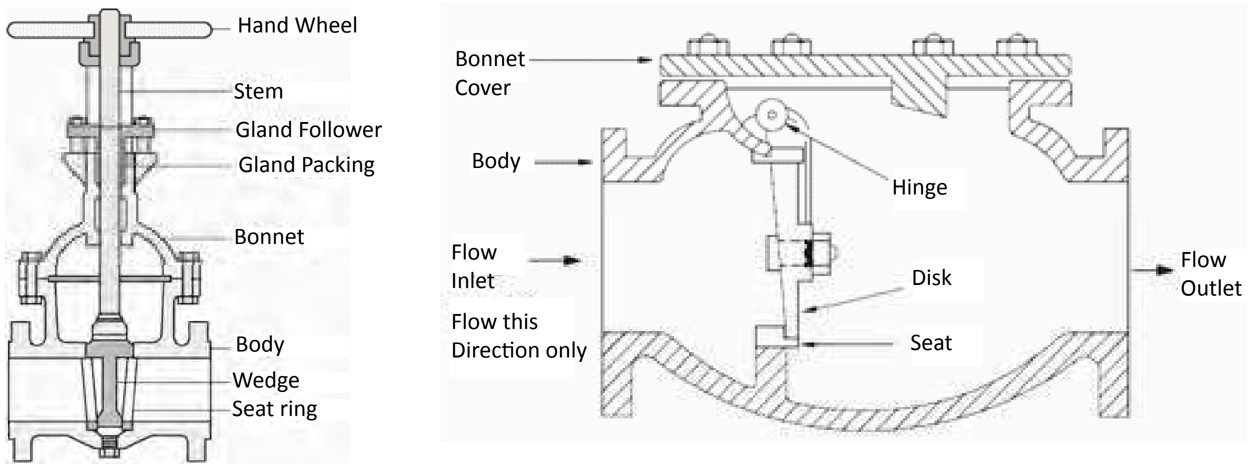


Fig. 1.5.75 Typical Valves with parts details (Left side Butterfly valve & right side – Swing check valve)

Valves classification

The following are some of the commonly used valve classifications, based on mechanical motion:

i. Linear motion valves: The valves in which the closure member as in gate, globe, diaphragm, pinch and lift Check Valves, moves in a straight line to allow, stop, or throttle the flow.

ii. Rotary motion valves: When the valve-closure member travels along an angular or circular path, as in butterfly, ball, plug, eccentric and swing check valves, the valves are called rotary motion valves.

iii. Quarter Turn Valves: Some rotary motion valves require approximately a quarter turn, 0° through 90° motion of the stem to go to fully open from a fully closed position or vice versa for example ball valve, plug valve, butterfly valves.

Functions of valves

Each type of these valves have a number of models with different features and functional capabilities. Based on the functions, the valves are classified as

i. Stopping and starting flow (for example, gate valves, globe valves, ball valve, butterfly valve, etc).

ii. Reduce or increase a flow (for example, globe valve).

iii. Controlling the direction of flow (for example, Check valve, shuttle two way / three way / four way valves, angle-globe valves for a 90-degree change in direction of flow).

iv. Regulating a flow or process pressure (for example, globe, needle, butterfly, diaphragm, piston, punch).

Relieve a pipe system of a certain pressure (PRV, PSV)

Isolation (gate, ball, plug, piston, diaphragm, butterfly, pinch).

Control valve functions: - Control valves are valves used to control conditions such as flow, pressure, and direction of flow.

i. Pressure control valves – A pressure control valve is used to reduce the amount of pressure in a tank or system of pipes.

ii. Flow control valves – Used to control fluid flow.

iii. Directional control valves such as check valves (non – return valve) and directional valves allows flow in the intended direction and stop flow in the reverse direction.

Valve rating

All pipes entering and leaving the process unit shall have a block valve and flanges provided to allow for spading (spades or spectacle blinds) at the boundary of the process unit also called battery limit. Pressure-temperature ratings of valves are designated by class numbers. ASME B16.34 (for valves-flanged, threaded, and welding end) is one of the most widely used valve standards. It defines three types of classes: standard, special, and limited. ASME B16.34 covers Class 150, 300, 400, 600, 900, 1500, 2500, and 4500 valves.

Fig. 1.5.76 Globe valve images

Fig. 1.5.77 Ball Valve Images

Valves installation procedures

Valves will be supplied with manufacturer's instruction for valves installation, operating and maintenance. Fitter shall always follow the manufacturer installation instruction for valves installation. Depending on the type of valve, some valves will have specific and special instructions for installation due to criticality and operating conditions. Valves in horizontal pipes shall be positioned with their stem on or above the horizontal, except as follows:

i. Butterfly valves shall be positioned with the stem horizontal in services where fouling substances could collect in the lower shaft bearing.

ii. Gate valves should be positioned with the stem horizontal in services where fouling substances could collect in the bottom.

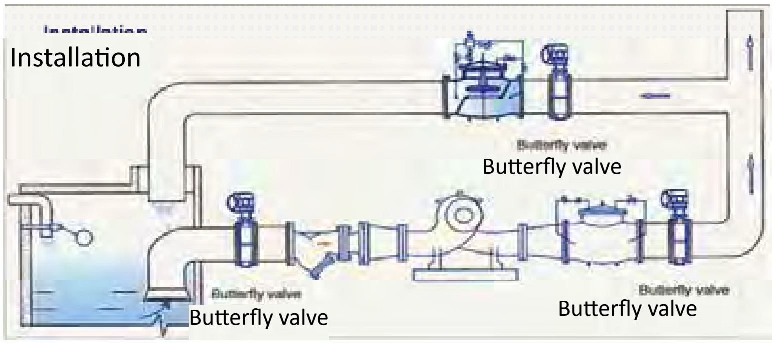


Fig. 1.5.78 Typical Butterfly valves installation

Valves flanges bolt tightening procedures

a. Observe the tightening sequences. Using a torque wrench, tighten each bolt within the required range as per specification / manufacturer recommendation.

b. Loosely install stud bolts. Identify proper bolting sequence and number bolts accordingly. Each bolt should be numbered so that bolt torque sequences can be easily followed.

c. Failure to follow proper bolt torque sequences can result in cocking flanges. Then, regardless of the amount of subsequent torqueing, they cannot be brought back to parallel. This can lead to a leaky joint.

d. Torque the bolts. Bolts should be torqued in a proper bolting sequence, in a minimum of four stages as specified here:

i. Torque the bolts up to a maximum of 30% of the final torque value required following the recommended bolt torque sequence.

ii. Care should be taken not to over tighten the valve onto the pipe, as it is possible to distort the internal parts of the valve.

iii. Repeat Step i, increasing the torque to approximately 60% of the final torque required.

iv. Repeat Step i, increasing the torque to the final torque value.

e. Retorque all studs. All studs should be retorqued using a rotational pattern of retorqueing to the final value of torque until no further rotation of the nuts can be achieved. This may require several retorqueings as torqueing of one stud causes relaxation in adjacent studs. Continue torqueing until equilibrium has been achieved.

Fig. 1.5.79 Typical Gate Valve installation arrangement

Fig. 1.5.80 Typical Globe Valve installation arrangement

Pressure relief valve (PRV) and safety relief valve installation (SRV)

a. Introduction to PRV & SRV

A Pressure relief valve is a safety device designed to protect a pressurized vessel / pipeline or system during an overpressure event. In the piping industry, there are two different names assigned to relief valves:

i. PRV (Pressure Relief Valve) release excessive liquid more than set point. Released fluid may be recirculated. The term PRV is used when dealing with liquids and opens gradually with gradual increase in pressure.

ii. PSV (Pressure Safety Valve) also known as PRV, release pressure more than set point to safeguard the equipment / piping system. The term PSV is used when dealing with incompressible fluids, especially, gas phase where the opening must be spontaneous with the sudden increase in pressure.

Both relief valves are set to open at a predetermined set pressure to protect equipment / piping system from being subjected to pressures that exceed design limits. Relief valves close at reset pressure. Hence, functionally the name PRV and PSV are used interchangeably.

The pressure relief valve must open at a predetermined set pressure, flow a rated capacity at a specified overpressure, and close when the system pressure has returned to a safe level.

b. Spring loaded pressure relief valve

The basic spring loaded Pressure Relief Valve has been developed to meet the need for a simple, reliable, system actuated device to provide overpressure protection. The spring load is adjustable to vary the pressure at which the valve will open. When a pressure relief valve begins to lift, the spring force increases. Thus system pressure must increase if lift is to continue.

Fig. 1.5.81 Pressure relief valves

1.5.19 Ball Valve Installation

At the end of this exercise, you will be able to:

1. perform any size and type of ball valve installation in piping system.

Practical

Required Tools Instruments:	**Required Materials / Components:**
Measuring tape Steel rule Spanner set Torque wrench	Required Materials / Components: 1. 2” Ø ball valve - 1 No. 2. 2” Ø pipe spool with flange - 1 No. 3. 2” Ø spiral wound gasket - 2 Nos. 4. M12 stud bolt with two nuts each - 12 set






Work instructions

1. Follow valve manufacturer instruction, if any. Look for special warning tags and identification plate if any, to ensure that the valve is suitable for the intended service.
2. Remove the valve end caps installed by the manufacturer for transporting purpose. Check inside the valve to ensure that any material / shipping blocks used in shipping are removed.
3. Visually check the valve for any damages and cleanliness. Check for any foreign material that should not be inside the valve and remove.
4. Open and close the valve to ensure that no damage has occurred in transporting the valve.
5. Check the valve name plate, valve specification and confirm with the drawing requirements. Be sure the rating of the valve is as specified in the approved drawing.
6. Ensure that all pressure / functional tests of valves have been completed and cleared for installation.
7. Check the flow direction specified in the drawing and if it has been marked on the valve body and follow the same for all installations.
8. Check the valve orientation specified in the drawing as well as if specified in manufacturer instruction.
9. Make sure that piping / pipeline and flange faces are clean. Any foreign material such as metal filings, pipe scale, welding slag, welding rods, etc., can damage the disc or seat.
10. Inspect the valve flange ends to ensure that there are no raised burrs or edges that would not seal properly.
11. Install the gasket according to the manufacturer / approved drawing requirements.
12. Handle the valve only with apparatus that will not damage the valve and adequately support it using safe and proper technique.
13. Pipes shall be supported effectively and rigidly so as to avoid any distortion / damages.
14. Align the pipe work and spread the flanges enough to allow the valve body to be easily inserted between the flanges without contacting the pipe flanges.
15. Insert the valve between the flanges, without damaging the seating faces.
16. Always lift the valve by locating holes or by using a nylon sling on the neck or the body. Never lift the valve by the actuator or operator mounted on the valve.
17. Identify what type of bolts were provided and ensure that it meets the approved drawing requirements.
18. Clean all bolts and nuts with solvent and lint – free cloth. Visually inspect all threads to insure removal of all foreign material, corrosion products, burrs and previous lubrication. Lubricate all thread contact areas and nut facings.
19. Place the valve between the flanges, centre it, insert the bolts and hand-tighten them.

1.5.20 Pressure / Safety Relief Valves Installation

At the end of this exercise, you will be able to:

1. perform any size pressure or safety relief valves installation in piping and equipment system.

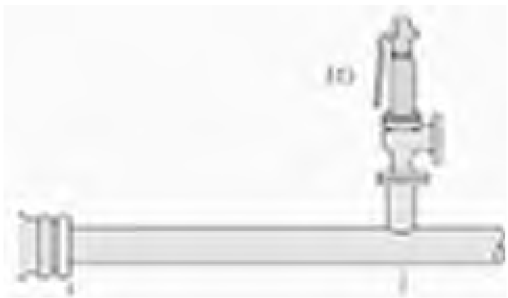
Practical

Required	
Tools / Instruments: Measuring tape Steel rule Spanner set Feeler gauge torque wrench **Required Equipment / Machines:** PPE	**Materials / Components:** 1. 2” Ø pressure relief valv – 1 No. 2. 2” Ø pipe spool – 1 No. 3. 2” Ø spiral wound gasket – 2 No. 4. M12 stud bolt – 12 Nos. 5. M12 nut – 24 Nos.




Work instructions

1. Correlate the valve name plate details with respect to valve requirements specified in the approved drawing.
2. Check the valve for any damage. For flanged valves, use new gaskets and tighten mounting studs evenly.
3. Check and ensure that preset pop up pressure value of the valve pressure is valid. If not , the pop up pressure shall be reset.
4. If calibration is expired, the PRV / SRV shall be calibrated prior to installation.




5. Before installation, flange faces or threaded connections on both the valve inlet and the vessel and/or line on which the valve is mounted must be thoroughly cleaned of all dirt and foreign materials.
6. Because foreign materials that pass into and through safety valves can damage the valve, the systems on which the valves are tested. It has to be finally installed, inspected and cleaned.
7. New systems in particular are prone to contain foreign objects that inadvertently get trapped during construction and will destroy the seating surface when the valve opens. The system should be thoroughly cleaned before the safety valve / pressure relief valve is installed.
8. The gaskets used must be dimensionally correct for the specific flanges. The inside diameters must fully clear the safety valve inlet and outlet openings so that the gasket does not restrict flow.

9. The inlet piping should be short and direct. The inlet should never have a smaller diameter than the valve itself. This will constrict the flow of steam, air or other media.
10. Mount PRVs are designed to function in a vertical position, which means upright and with the spindle vertical. A valve installed in any position other than vertical might not perform correctly.
11. For flanged valves, draw down all connection studs or bolts evenly to avoid possible distortion of the Valve body. Bolt tightening sequence has to be followed (evenly and gradually applying tightening force on opposite bolts).
12. For flanged valves, be sure to draw the bolts down evenly. This is, especially crucial for cast iron valves. If valve flange tighten one side all of the way and then the other, not should it be able to tighten it completely, but crack the valve. Use torque wrench to ensure optimum torque.
13. Avoid overtightening the valve. This can damage both inlet and outlet threads and cause leakage.
14. Do not apply a wrench to the valve body of threaded valve. Use hex flats provided on the inlet bushing.
15. The valve should be mounted vertically in an upright position either directly on a nozzle from the pressure vessel or on a short connection fitting of piping that provides a direct, unobstructed flow between the vessel / pipe and the valve. Installing a safety Valve in other than this recommended position will adversely affect its operation.
16. Never install PRV on a fitting having a smaller inside diameter than the inlet connection of the valve.
17. The discharge piping should always be supported. If it is not supported, it can weigh down and warp the valve, which will cause the valve not seated properly. This can lead to excessive leakage.

Tips

Safety: Under no circumstances should any additional load be applied to the easing lever nor should the valve be gagged in order to increase the seat tightness. This will affect the operating characteristics and can result in the safety valve failing to lift in overpressure conditions.

1.5.21 Pressure Gauge Installation

At the end of this exercise, you will be able to:

1. perform any size pressure relief or safety relief valve installation in piping and equipment system
2. install temperature gauge following work instruction.

Practical

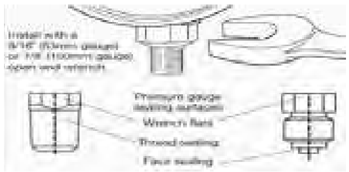
Required	
Tools / Instruments: Thread tape Spanner / Wrench, Pressure Gauge, Temperature Gauge – as required **Required Equipment / Machines:** Personal protective equipments (PPE)	**Materials / Components:** 1. 2” Ø pressure relief valv – 1 No. 2. 2” Ø pipe spool – 1 No. 3. 2” Ø spiral wound gasket – 2 Nos. 4. M12 stud bolt – 12 Nos. 5. M12 nut – 24 Nos.




Work instructions

1. First make sure you have the right type of gauge for the application. Ideally, select a gauge where its normal operation will be around 50% to 60% of full scale.
2. Always follow manufacturer instruction, if any.
3. Check the gauge and ensure that there is no damage and that the leading needle is at zero.
4. Check the calibration validity of the pressure gauge before installation. If calibration has expired, arrange for recalibration.
5. Pay attention to how you screw the gauge in. Do not turn the case by hand to tighten. Use open end or adjustable wrench always flats of the gauge socket to tighten the gauge into the fitting or pipe.
6. Apply sufficient torque to prevent leaks.
7. Notice the type of threads on the gauge before you seal it. If the gauge has parallel threads, seal it using rings, washers or suitable profile seals.
8. If the gauge has tapered threads, additional sealing means, PTFE tape are recommended. This is standard practice for any pipe fitter because tapered threads do not provide complete sealing on their own.
9. Thread seal tape will not only prevent leakage past the thread, but will allow you to have the gauge facing in a good direction.
10. Install in such a way that pressure indicators are visible either from grade, permanent ladder or platform.



Tips

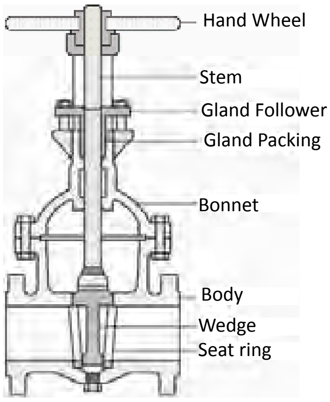
Safety: Torque applied to a diaphragm seal or its attached gauge, tends to loosen one relative to the other, can cause loss of fill and subsequent inaccurate readings. Always apply torque only to the wrench flats on the lower seal housing when installing filled, diaphragm seal assemblies or removing the same from process lines.

1.5.22 Different Type of Gaskets

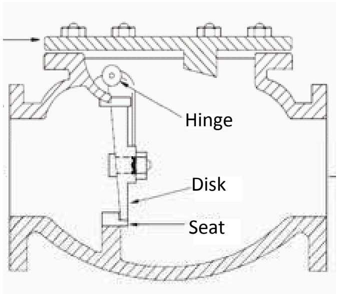
At the end of this exercise, you will be able to:

1. identify the different type of valves
2. perform 2” ϕ ball valve installation with piping spool assembly
3. perform 2” ϕ check valve installation with piping spool assembly.

Requirements			
Tools/Instruments		**Materials/Components**	
Measuring Tape	– 1 No.	2” ϕ Ball valve	– 1 No.
Steel rule	– 1 No.	2” ϕ Piping spool with flanged assembly	– 4 No.
Spanner sets	– 1 No.	2” ϕ Spiral wound Gasket	– 2 No.
Torque wrench	– 1 No.	100mm X M12	– 16 No.
Equipment/Machines		2” ϕ Check valve studs and nuts	– 1 No.
Personal Protective Equipment	– 1 No.		



1



2


3


4


5


6

a) Identification of valve type

Sl. No.	Name of the valves used in piping
1.	
2.	
3.	
4.	
5.	
6.	

Tips

Instructor should provide different types of valve chart and explain to trainee of the method of identification.

b. Perform the installation of 4” ϕ inch dia ball valve with flanged piping spool assembly.
c. Perform the installation of 4” inch diameter check valve with flange piping spool assembly.

Exercise

I. Answer the following questions.

1. Name any six types of valves normally installed in piping systems.

   ----

2. Name any four valves meant for stopping and starting flow.

   ----

3. Write down the general instructions for valves installation.

   ----

4. What are all the specific requirements for butterfly valves installation?

   ----

5. What are the specific requirements for check valves installation?

   ----

6. Describe valve flanges bolt installation and tightening procedure.

   ----

7. What are the specific requirements for PRV-Installation?

II. State whether the following statements are True or False.

1. Globe valve is a rotary motion valve.

   True ☐ False ☐

2. Check valve can control the direction of flow.

   True ☐ False ☐

3. Butterfly valves stem shall be in vertical position in services where fouling substances could collect in the lower shaft bearing.

   True ☐ False ☐

4. Check valves close with forward flow.

   True ☐ False ☐

5. If the check valve is installed in the horizontal position, the valve must be installed with the cover oriented to the bottom.

   True ☐ False ☐

Notes

1.5.23 Valves – Functional Tests

At the end of this topic, you will be able to:

1. describe different functional tests required at manufacturer premises
2. check the required functional tests performed at manufacturer premises and act accordingly
3. perform valve body (shell) test and seat test
4. state the acceptance criteria of valve functional tests.

Tests at manufacturer's premises

Hydrotest shall be completed and certified by valve manufacturer prior to release from the manufacturer premises. API 598 states that for shell and back seat tests, no visible leakage is permitted. If the fluid is a liquid, there shall be no visible evidence of drops or wetting of the external surfaces (no visible leakage through the body, body liner, if any, and body-to-bonnet joint and no structural damage).

Low pressure closure test

Low pressure closure test is an optional test only and not mandatory. It shall be performed using air / gas at 5 to 6 bar. For the low pressure closure and low pressure back seat tests, the test fluid shall be air or inert gas.This test shall be performed at the manufacturer's premises and is not required to be performed at the site.

High pressure closure test

The procedure for the high-pressure closure test shall be the same as the procedure for the low pressure closure test except that, in the case of a liquid test, leakage shall be detected with drops. Test pressure is 1.1 times that of the rated pressure. This test shall be performed at the manufacturer's premises and is not required to be performed at the site.

Instruction for Pressure Testing of valves at field / site

The body leak test and seat integrity test shall be performed at the site prior to installation if required by project / site specifications. When a liquid is used as the test fluid, the valve shall be essentially free from trapped air during the test.

A test manifold comprising inlet valve, outlet valve, provision for pressure gauge and relief valve fixing along with provisions for connecting to respective flange sizes, shall be connected to the valve to be tested. The test manifold shall have been hydrotested 1.2 times of the maximum valve hydrotest pressure. Two pressure gauges shall be installed – one at test manifold and other at blind flange side of the valve. Normally, pressure gauge range shall be not more than two times or not less than 0.25 times of the actual test pressure. If water is used for hydrotest, the same shall have been tested and certified prior to hydrotest. Additionally, stainless steel valves, testing chloride content shall not exceed 50 ppm. Pressure gauge calibration status and correct working ranges of gauges shall be verified. All gauges shall have valid calibration and calibration sticker. Safety pressure relief valve set at 1.1 times the test pressure shall be fixed so as to avoid over pressurising. Adequate provision for venting of high points and draining of the test medium shall be provided. Test pressure is applied as directed by procedure or code until test limiting pressure is reached. During hold period, a methodical check for leaks is conducted.

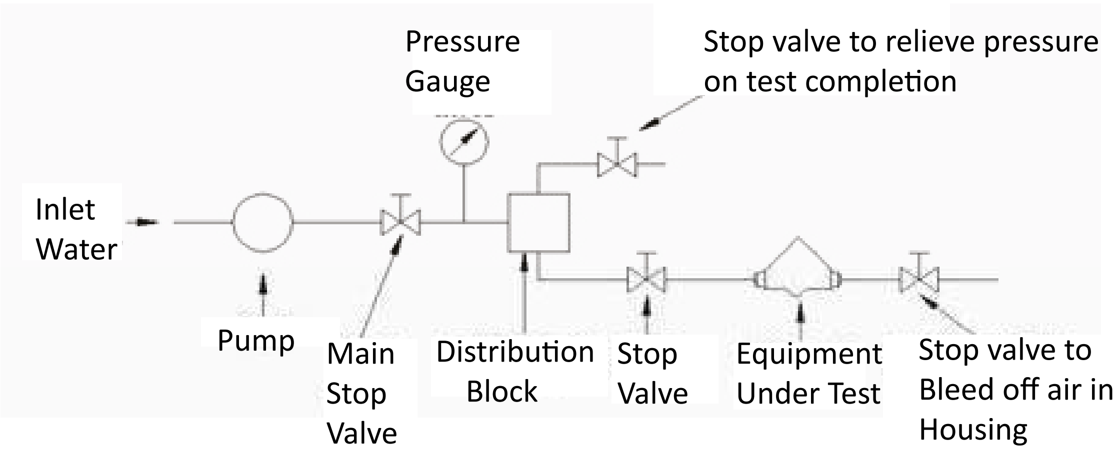


Fig. 1.5.82 Typical Pressure Test Manifold Diagram

a. Back seat test

The backseat test is required for all valves (except for bellows seal valves) that have the back seat feature and shall be performed by applying pressure inside the assembled valve with the valve ends closed, the valve fully partially open, and the packing gland loose or packing not installed. Testing shall be performed prior to shell testing. If the back seat test is performed after the shell test, the packing shall be installed and/or packing glands re-tightened after the back seat test.

The back seat shall then be closed and a minimum pressure of 1 .1 times the valve pressure rating is applied for the test duration. Monitoring for leakage shall be through a test access port or by monitoring leakage around the loosened packing. No visible leakage is permitted at this test pressure.

b. Seat test of valves

Unless otherwise specified, seat test shall be performed for both sides. In addition to the above general instructions, specific instructions for seat test are as given below:

Testing flange to be fixed on one side of the valve. Valve shall be connected with test manifold. Test fluid shall be filled without air entrapment.

Valve seat shall be kept under fully closed condition.

Seat test pressure shall be gradually applied and kept on hold for the specified duration. The test pressure for all seat tests shall not be less than 1.1 times that of the valve pressure rating.

Check the leakage through seat in opposite side of the pressurised side.

Follow the same procedure while checking the another seat except for globe and butterfly valves.

c. Hydrostatic Shell Test

In general, hydrostatic shell testing shall be performed on the fully assembled valve prior to painting valves. But this can be exempted for field hydrotest and paint removal is not required at the site. In addition to the above general instructions, further work instructions for shell test are as listed below:

- Testing flange is to be fixed on both sides.
- Valve shall be connected with test manifold.
- Valve ends shall be closed. The valve seat shall be kept partially open. Any packing gland shall be kept tight enough to maintain the test pressure.
- Test fluid shall be filled without air entrapment.
- Gradually apply the pressure inside the assembled valve.
- The test pressure shall be 1.5 times that of the valve pressure rating. The test pressure holding duration shall not be less than that specified in applicable code / specification.
- Check the leakage through body, bonnet sealing area, gland packing area.
- No visible leakage is permitted during the hydrostatic shell test.

  All valves need to be checked for cleanliness and dryness. Nozzle, outlets, flanged or butt welded, saddle, bracket locations and orientations against assembly drawings are checked and operation of valve indicator and correct functioning are also to be checked.

d. API 598 – valve inspection & testing

API 598 covers the inspection, examination, supplementary examination and pressure test requirements for resilient –seated, non-metallic –seated, and metal to metal seated valves of gate, globe, plug, ball, check and butterfly valves.

e. API 6D – specification for pipeline valves

API 6D specifies requirements and provides recommendations for design, manufacturing, testing and documentation of gate valve, plug valve, ball valve and check valve types for application in pipeline systems meeting requirements of petroleum and natural gas industry for pressure ratings less than PN 420.

When API 598 covers general testing requirements for valves manufactured to API 602, API 608, API 609 etc., API 6D specifically applies to valves manufactured for petroleum and natural gas pipe lines.

h. Acceptance criteria

Maximum allowable leakage API 598

Back seat test – no visible leakage

Hydrostatic shell test – No visible leakage

Seat test – no visible leakage

Relief valves setting at site maximum allowable leakage API 6D

- Back seat test – no visible leakage
- Hydrostatic shell test – no visible leakage

Relief valve shall be set at the required pop up pressure at the site. The instruction for setting the predetermined pressure is as given below:

- make sure there is no pressure to the valve.
- break and remove the pressure tag wire
- unscrew the cap by loosening the set screw.

Valve Type	Shell		Back seat		LP-Closure		HP-Closure	
	API 598	API 6D	API 598	API 6D	API 598	API 6D	API 598	API 6D
Gate	YES	YES	YES	YES	YES	NA	OP	YES
Globe	YES		YES		OP		YES	
Plug	YES	YES	NA	YES	YES	NA	OP	YES
Check	YES	YES	NA	YES	OP	NA	YES	YES
Floating Ball	YES	YES	NA		YES	NA	OP	YES
Trunnion Mounted Ball	YES	YES	NA	NA	YES	NA	OP	YES
Butterfly	YES		NA		YES		OP	

YES - Required NO - Not Required OP - Optonal NA - Not applicable for the valve

adjust the setscrew clockwise to increase the set pressure, anticlockwise to decrease the set pressure. Recommended adjustment is one full turn maximum at a time

test the valve by pressurizing through the inlet port

depressurize the valve before making any further adjustments

replace the cap after adjustment is completed

- Rewire the pressure tag. Replace the pressure tag if it reads other than the set pressure.

Exercise

I. Answer the following questions.

1. Describe pressure test manifold with a line diagram.

   ----

2. Explain back seat test.

   ----

3. Write down the work instructions for a valve body (Shell) hydrotest.

   ----

4. Write down the work instructions for pressure relief valve pop up pressure setting to the predetermined pressure at the site.

II. State whether the following statements are True or False.

1. Low pressure closure test can be performed using air / gas.

   True ☐ False ☐

2. In general, test pressure for high pressure closure test is 1.1 times that of the rated pressure of the valve.

   True ☐ False ☐

3. High pressure closure test of valves need not be performed at the site.

   True ☐ False ☐

4. Unless otherwise specified, the valve body / shell hydrotest pressure shall be 1.5 times that of the valve pressure rating.

   True ☐ False ☐

Practical

1. Perform valve body test and seat test of 4 inch NB diameter ball valve.
2. Perform valve body test of 4 inch check ball valve (materials required – 4 inch NB ball valve, 4 inch NB check valve, test manifold, two pressure gauges, one safety pressure relief valve, eight set of studs and nuts, 2 spiral wound gaskets, torque wrench, spanners.)

Notes

1.5.24 Gauges, Instruments and other Installation accessories

At the end of this topic, you will be able to:

1. distinguish different piping gauges, instruments and accessories
2. install gauges and instruments into the piping system
3. install piping related miscellaneous accessories.

General instructions

The pressure and temperature rating of the fittings are very important. Whenever accessories are supplied for installation, the pipe fitter shall check the rating and ensure it is not lower than the piping rating and as specified in the drawing. Check for calibration expiry date of the gauges / instruments to be installed. If calibration has already expired or will expire very soon, recalibration shall be arranged. The inner diameter of the gasket shall not exceed the inner diameter of the meter/meter run. Select a gasket type that is centred by its outer ring. An inner ring should prevent soft material from protruding into the pipe, causing flow pattern disturbance.

Pressure gauges installation

Pressure gauge is used to read the system pressure on the spot. Pressure gauges are of various ranges and various units such as bar, kg/cm^2, psi, kpa or in combination, etc. Pressure transmitter is used to send pressure signal to distributed control system (DCS) for further processing and action. Pressure indicators shall be visible either from grade, permanent ladder or platform. Pressure gauge installation shall be in such a way that it should be readable without a portable ladder. Pressure gauge on platforms should be at least readable from a fixed ladder. Pressure gauges in piping systems at such equipments as pump discharge lines must be located as close to the equipment as possible. A suitable thread sealant is required for NPT threads such as pipe dope or teflon tape. Never use any part of the pressure gauge other than the wrench flats that is on the gauge socket. Always tighten with an open end or adjustable wrench on the wrench flats. Failure to do so, will severely damage the pressure gauge.

Temperature measurement gauges installation

Measuring temperature of a fluid in pipe and vessels is achieved by installing local temperature gauges or by temperature transmitter which send their output to the process control room. Temperature gauges consist of a metallic probe which is inserted into the pipe or vessel through a nozzle arrangement. Dial gauge connected to the probe shows temperature on a circular scale. Both centigrade and Fahrenheit scale temperatures gauges are available in various temperature ranges. If temperature must be read remotely, thermocouple type of temperature transmitters are used. They have a metallic probe same as gauge indicators, but instead of a dial attached to the other end, they have a terminal head which houses electronic circuits which transmit temperature signal to process control room for process control and display on screen.

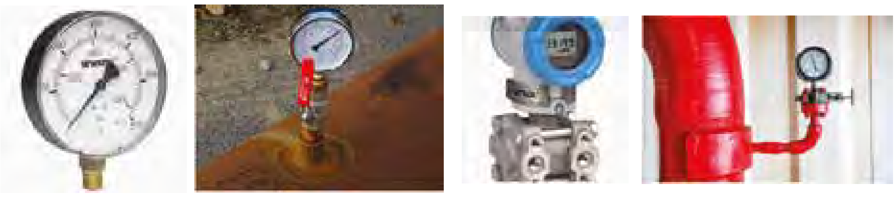


Fig. 1.5.83 Typical pressure gauge and transmitter installation

Fig. 1.5.84 Temperature Gauge

Fig. 1.5.85 Temperature Transmitter

Thermowells (TW) fittings installation

Thermowells are part of piping work. The type, length and material of the required thermowell are dictated by the specification. Flanged thermowells are generally used. Welded thermowells shall only be installed if due to high velocity and density of the fluid, the bending forces are too high for flanged thermowells or if they are subject to vortex vibration. To prevent water ingress into the assembly head, the thermoelement assembly shall be mounted in the horizontal position or in a tilted position with the head facing upwards.

a. General guidelines on installation of thermowell

The thermowell shall be located as close as possible to the place where the temperature is desired . When the steam and water are mixed directly, thermowell must be far enough from the point of the mixing to ensure that the temperature measurement is based on the complete mixing. If the pipe is wrapped with insulation, a thermowell with sufficient extension length shall be used. While installing the TW, immersion length, type of mounting–elbow, perpendicular or angle, height from floor for maintenance, clearance above the thermowell assembly for maintenance, shall be considered.

Automatic control valve

Control valves automatically regulate pressure and/or flow rate, and are available for any pressure. Globe valves are normally used for control, and their ends are usually flanged for ease of maintenance. Depending on their type of supply, the disk is moved by a hydraulic, pneumatic, electrical or mechanical actuator. The valve modulates flow through movement of a valve plug in relation to the port (s) located within the valve body. The valve plug is attached to a valve stem, which in turn, is connected to the actuator.

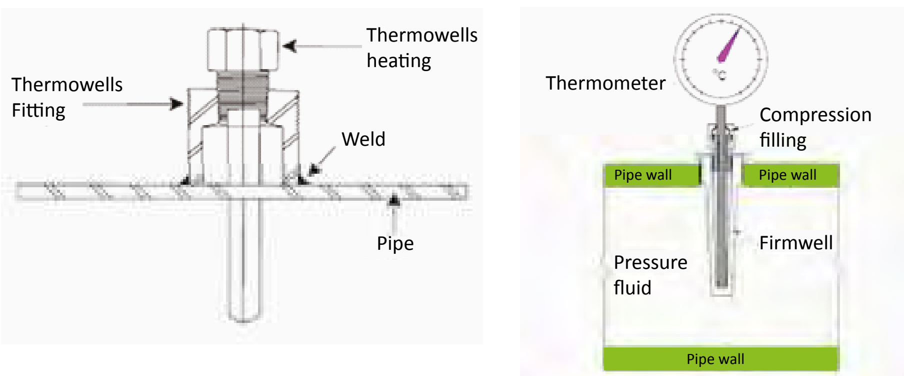


Fig. 1.5.86 Typical thermowell installation

Fig. 1.5.87 Typical automatic control valve arrangement

Flow measurement instruments installation

1. Ultrasonic, electromagnetic and coriolis flow meters can be used in unidirectional and bi-directional service.
2. Flow meters sense the amount of flow passing through a particular pipe and sends this information to process controller which then applies process logic and sends control information to control valves or pump control unit.
3. A variety of flow meters are used in process industry depending on type of fluid, operating temperatures and pressures, required flow accuracy and economy.
4. Ultrasonic flow meters can be installed at any point in the pipe run. In horizontal lines, nozzles shall be in the horizontal plane to avoid the collection of debris. The meter shall not be installed directly downstream of sources of aeration, such as cavitating pumps, throttling valves or an aerating mixing tank. Upstream and downstream straight lengths shall be as specified by the supplier.

Piping related miscellaneous accessories installation

All piping related accessories shall be installed as per drawings.

1. Drain and vent Connections

In general, test drain and vent connections shall be installed at all low and high points in piping, respectively. Drain/vent connection shall be installed as close as possible to the block valves and spades, for draining, venting and testing purposes. Vents and drains shall be as short as possible. All drain and vent points shall be closed with a blind flange or a cap. Dead leg shall be avoided in oil and gas piping. If necessary additional drain shall be installed with valve to avoid dead leg.

2. Sampling connections

The sampling point shall be positioned so that the valves are easy to operate and taking the sample will not impair the safety of personnel or plant or cause environmental impact. Good locations for sampling are typically the discharge of pumps and the suction of compressors. Sample points shall have two valves – one at the take-off point from the process pipe and another at the sampling point. The block valve at the take-off point shall be of the same size as a standard drain valve. The sampling valve size shall be maximum DN 15 and shall have good throttling properties.

3. Strainers installation

Permanent strainers shall be installed in all pump suction pipes. Y-type strainers shall be used for permanent installation in vertical suction pipes. In horizontal suction pipes, Y-type or bucket type strainers may be used. Bucket type strainers shall be used for suction pipes DN 450 and larger. In a vertical suction pipe, the Y-type strainer shall be installed pointing away from the pump. In a horizontal suction pipe the Y-type strainer shall be installed pointing downwards or at an angle of maximum 45° from vertical, in order to improve access for cleaning.

Exercise

I. Answer the following questions.

1. Explain thermowell fittings installation.

   ----

2. Write down the step by step installation for electromagnetic flow meter.

   ----

3. Describe pressure gauge installation.

II. State whether the following statements are True or False.

1. The inner diameter of the gasket shall not exceeded the inner diameter of the meter / meter run.

   True ☐ False ☐

2. Pressure transmitters is used to send pressure signal to the distribution control system.

   True ☐ False ☐

3. Temparature transmitter are used to read the temparature remotely.

   True ☐ False ☐

4. While installing ultrasonic flow meters in horizontal lines, nozzles shall be in the horizontal plane.

   True ☐ False ☐

5. In electromagnetic flow meter, it shall be ensured that the flow tube is always filled with liquid.

   True ☐ False ☐

6. Spiral wound metal gasket shall be used for magnetic flow meters.

   True ☐ False ☐

Notes

Unit 1.6 Identify Tools and Tackles

Unit Objectives

At the end of this unit, you will be able to:

1. identify appropriale tools and tackles for pipe fitting works
2. recognise and use diffrent tools
3. handle different types of equipment used for pipe fitup works.

1.6.1 Different Measuring and Marking Tools

At the end of this topic, you shall be able to:

1. name the different measuring tools and uses
2. name the different marking tools and uses.

I. Measuring tools and instruments:

1. Measuring Tape
2. Steel rule
3. Vernier Caliper & Micro Meter
4. Try Square
5. Bevel Protractor, Hi-low gauge
6. Centre Punch
7. Scribers

Fig 1.6.1 Measuring Tape (Metal)

Fig 1.6.2 Steel rules

Measuring tape

Measuring tape is a flexible ruler. It is made of ribbon, cloth, plastic, fiber, glass metal strip with lines for measurements. It is a very common measuring tool. The available range are 3,5 and 10m.

Types

1. Metal tape

Engineer's steel rule: Steel rules are made of spring steel or stainless steel. The edges are accurately ground to form straight edges. The surface of the steel rule is satin chrome finished to reduce glare and to prevent rusting.

Micrometer

Sometimes known as a micrometer screw gauge, is a device incorporating a calibrated screw. It is widely used for accurate measurement of components in mechanical engineering and machining as well as an mechanical trades.

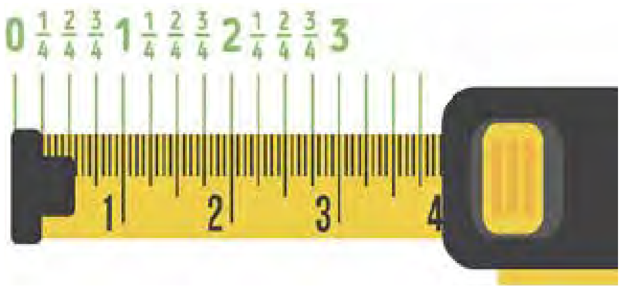


Fig 1.6.3 Measuring Tape (Metal)-inch unit

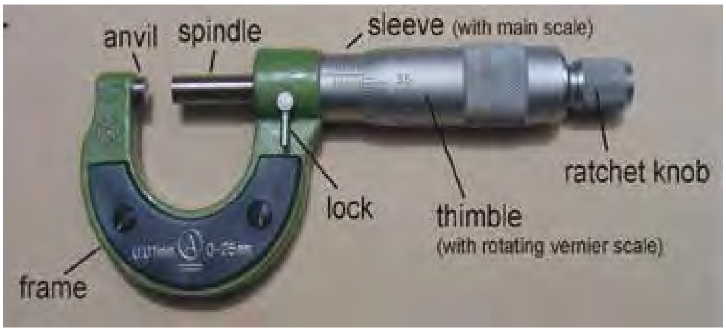


Fig 1.6.4 Micro Meter

The vernier principle: The basic principle of the vernier is that the smallest unit of size to which a vernier can be read is equal to the difference in the length between the divisions of the two scales.

The magnification on the vernier scale is given by two scales sliding over each other. The eye can detect which divisions on one of them is smaller than those on the other. The eye can detect which of these divisions are in line with each other, and it enables to read a vernier to 0.02 mm accuracy. The value of 1 main scale is 0.1 unit. In vernier scale 9 such units are taken and divided into 10 equal parts.

Hence the value of 1 vernier scale is 0.9/10=0.09 units. Now, by applying the vernier principle, the smallest unit of size is 1 M.S.D. - 1 V.S.D. (i.e.) 0.1 - 0.09=0.01 unit.

Definition of the least count: The least count is the smallest possible measurement that can be taken with the precision instrument. The zero of the vernier scale is between 0.2 to 0.3 units on the main scale and number 2 graduation of the vernier scale Fig 1.6.6 is coinciding with the 4th division of the main scale. Thus the reading is 0.2 + 2 * 0.01=0.22.

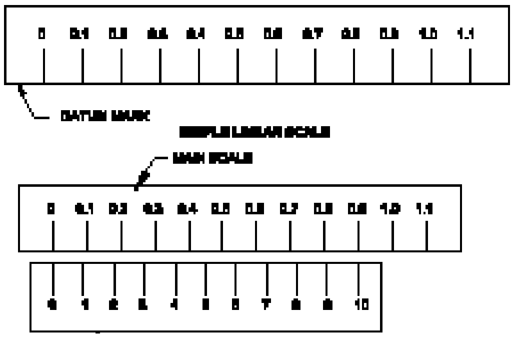


Fig 1.6.6 The Vernier scale (50 Divisions)

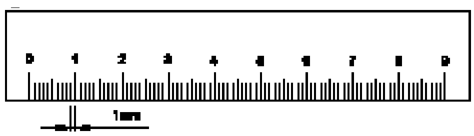


Fig 1.6.5 Vernier Scale

Fig 1.6.7 Main Scale Division into Millimetres

A typical 50 division vernier scale as used in modern metric measurements as shown in Fig. 1.6.6. The main scale of this instrument is graduated in mm. In the case of 150 mm capacity, vernier calipers the main scale, is graduated in ½ mm instead of in 1 mm. For the purpose of the vernier scale 24 such divisions are taken and divided into 25 equal divisions. So, the value of 1 vernier scale division is $\frac{1}{25}$ The purpose of a vernier 49 such divisions are divided into 50 equal divisions. So the value of vernier scale division works out to 49/50 mm.

Least count = 1 M.S.D. - 1 V.S.D.

$$\frac{1}{2}\text{ mm } \frac{12}{25}\text{ mm } = \frac{25-24}{50} = \frac{1}{50} = 0.02\text{mm}$$

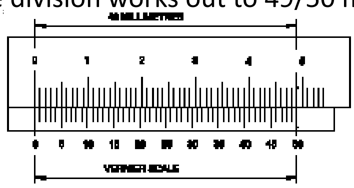


Fig 1.6.8 Main scale division into millimeters each 10th being number ed

Measurement of reading: 0mm as 'o' of vernier scale shall coincide.

Measurement of reading: 'o' of vernier is to the right of the main scale and lies between 'o' and 1st division of the main scale. The 3rd division of the vernier scale coincides with a division on the main scale. Hence, measurement is 0 mm + 3 * 0.1 mm = 0.3 mm.

Measurement of reading: 'o' of the vernier scale lies between the 44th and 45th divisions of the main scale and the 4th division of the vernier scale coincides with a division of the main scale. Hence, the measurement is 44 mm + 4 * 0.1 mm = 44.4

Measurement of reading: 'o' of the vernier scale lies between the 53rd and 54th divisions on the main scale, and the 8th division of the vernier scale coincides with a division on the main scale. Hence measurement is 53 mm + 8 * 0.1 mm = 53.8 mm.

Universal vernier caliper and its application:

One of the precision instruments having the principle of vernier applied to it is the universal vernier caliper. It is known as a universal vernier caliper because of its application to take outside, inside and depth measurements.

Its accuracy is 0.02 mm.

1. Beam
2. Fixed jaw for external measurements
3. Movable jaw for external measurements
4. Movable jaw for internal measurements
5. Blade for depth measurement
6. Main scale
7. Vernier scale
8. Fine adjustment screw
9. Set of locking screws.

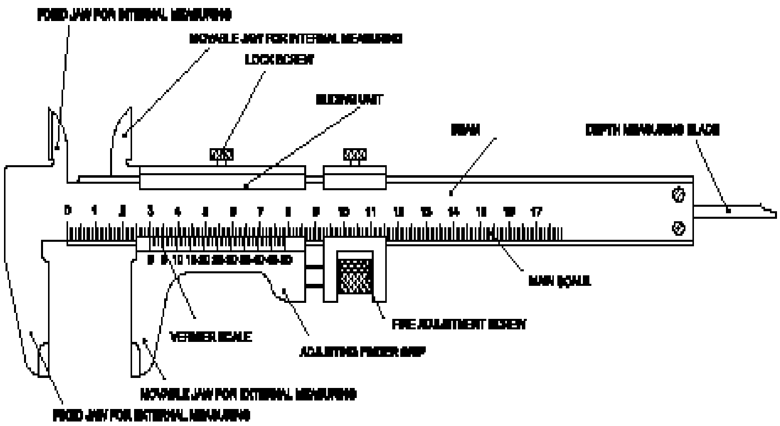


Fig 1.6.9 Vernier caliper

All parts are made out nickel chromium steel, heat treated and ground. They are machined to a high accuracy. They are stabilized to avoid distortion due to temperature variations.

Least count: In the vernier scale illustrated here, 19 mm are divided into 10 equal parts on the vernier scale. The value of 1 vernier scale division will then be $\frac{19}{10} = 1.9\text{mm}$

The difference of the two main scale divisions and 1 vernier scale division gives the least count and it is equal to 2*1m -1.9 mm = 0.1 mm For better accuracy, a 49 mm space is divided into 50 equal parts on the vernier scale so that one vernier scale division value will be $\frac{49}{50} = 0.98\text{mm}$

Here the least count will be 1 main scale division – 1 vernier scale divisions = 1 mm-0.98 mm= 0.02 mm.

Advantages

No need to have separate precision instruments for taking external, internal and depth measurements.

Disadvantages

The accuracy of reading depends on the skill of the operator. It loses its accuracy by constant usage as slackness in the sliding unit develops. It cannot be used to measure components having deviations less than +/-0.02 mm. The possibility of parallax error during noting down, the coinciding line may cause the reading of the measurement to be wrong.

Try Square

The Try Square is a precision instrument which is used to check squareness (angles of 90°) of a surface.

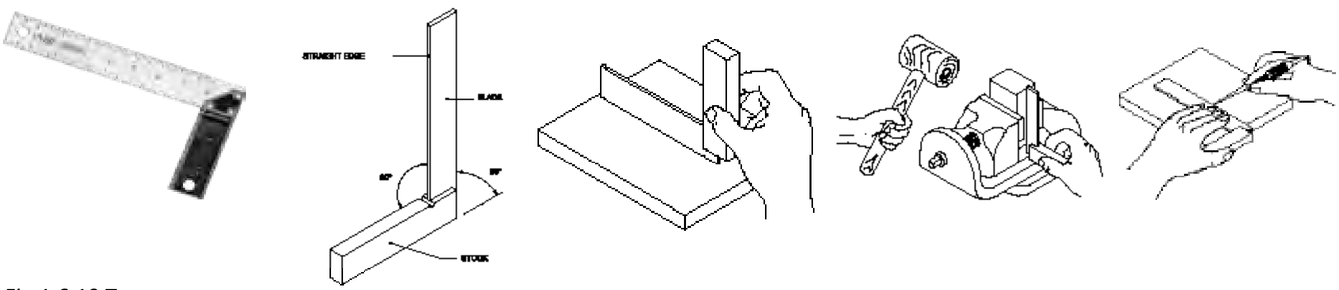


Fig 1.6.10 Try square uses

Tips

For maintaining accuracy, it is important to see to it that the edges and surfaces of instruments are protected from damage and rust.

An experienced person can transfer measurements from a steel rule very accurately. The steel rule graduations are accurately engraved, with the line thickness ranging from 0.12 to 0.18 mm. Do not place a steel rule with cutting tools. Apply a thin layer of oil when not in use. For accurate reading it is necessary to read vertically to avoid parallax errors .

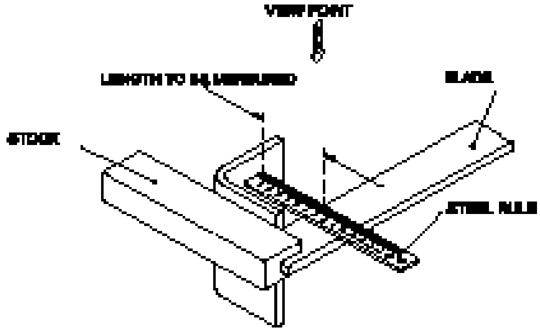


Fig 1.6.11 Try square usage

Marking punches

Punches are used to make certain dimensional features of the layout permanent. There are two types of punches. They are centre punch and dot punch.

Centre punch

The angle of the point is in a centre punch is 90°. The punch mark made by this is wide and not very deep. The punch is used to locate holes. The wide punch mark gives a good seating for starting the drill. The punch marks should not be too close to one another.

Scriber

In layout work, it is necessary to scribe lines to indicate the dimensions of workpieces to be filed or machined. The scriber is a tool used for this purpose. It is made of high carbon steel which is hardened. For drawing clear and sharp lines, a fine point is ground at one end. Scribes are available in different shapes and sizes. The one most commonly used is the plain scriber. While scribing lines, the scriber is used like a pencil so that the lines drawn are close to the straight edge.

Fig 1.6.12 Centre punch

Fig 1.6.13 Scriber

Tips

Scriber points are very sharp, and they are to be handled very carefully. Do not put the scriber in your pocket. Place a cork on the point when not in use to prevent accidents.

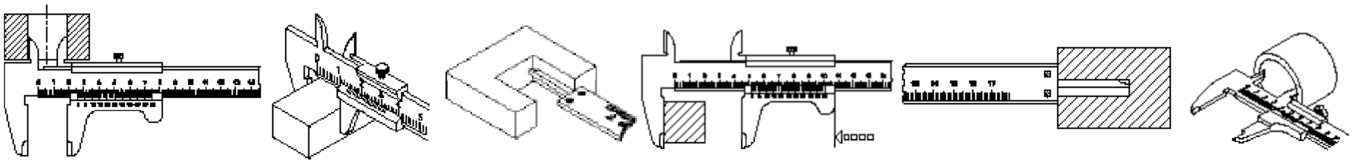
1.6.2 Measuring with Vernier Caliper

At the end of this exercise, you will be able to:

1. measure a pipe's inside diameter with a vernier caliper
2. measure a plate or pipe's wall thickness.

Practical

Required Tools / Instruments:		Required Materials / Components:	
Vernier Caliper	– 1 No.		
Measuring Tape	– 1 No.	2" Ø pipe - 300mm	– 1 No.
Flat File	– 1 No.	10xmmx300x100-plate	– 1 No.



Tips

Clean the vernier caliper before use with cloth and apply a light film of oil.

Check and ensure all burrs are removed from the job before taking the measurement.

Select a suitable size of vernier caliber according to the size of the pipe/plate.

Open the jaws wider than the size of the job.

Rest the job near the centre of the fixed jaw and move the slide jaw with minimum force.

Read and note the measurement. Avoid parallax error, while reading.

Hold the jaws parallel to the axis of the slot to be measured while taking internal measurement.

Tips

Safety: Use appropriate personal protective equipment. Do not give undue pressure while measuring as it will make the jaws spring and give wrong measurement

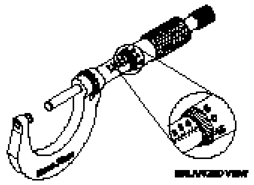
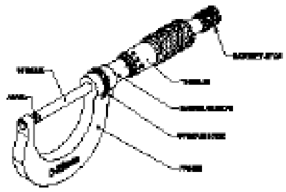
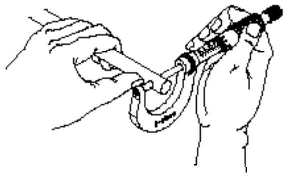
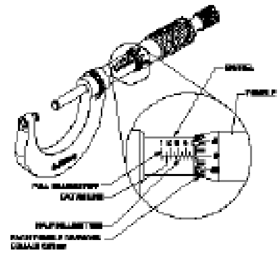
1.6.3 Measuring a Job with Micrometer

At the end of this exercise, you will be able to:

1. measure a pipe's wall thickness with micrometer
2. measure a plate's thickness.

Practical

Required Tools / Instruments:		Required Materials / Components:	
Micrometer	– 1 No.	2" Ø pipe - 250mm long	– 1 No.
Measuring Tape	– 1 No.		
Flat File	– 1 No.		

Clean the measuring faces of the micrometer and the surfaces of the job to be measured.

Check for zero error/accuracy.

In the case of a 0-25mm range outside micrometer, the zero of the thimble should coincide with the datum line, when the ancil and spindle are touching each other.

If they do not coincide, the instrument has an error.

Open the measuring faces so that more than the size of the workpiece is to be measured.

Use both hands for taking measurement, if the workpiece is held on a work bench.

Hold the workpiece in one hand and the micrometer in the other if the pipe size is small.

Bring the spindle slowly to touch the job to be measured.

Use the ratchet stop when the measuring face touches the workpiece.

Make sure that the measurement faces of the micrometer are square with the surface being measured.

Read the measurement.

Tips

After use, clean the micrometer with a cloth and apply a thin film of oil and store it in its box.

Exercise

I. Answer the following questions.

1. Name the measuring tools used in pipe fitup and alignment.

   ----

2. Name the marking tools used in pipe fitup and fabrication.

   ----

3. Name the two types of measuring tape used in pipe fitup.

II. State whether the following statements are True or False.

1. Steel rule is made of spring steel or stainless steel.

   True   Flase

2. The least count and vernier scale accuracy in mm is 0.02

   True ☐   Flase ☐

3. The Try Square is a precision instrument which is used to check squareness of a flange surface.

   True ☐   Flase ☐

Notes

1.6.4 Hand Tools and Uses

At the end of this topic, you will be able to:

1. name the different hand tools and their use.

I. Hand tools:

File: Filing is a method for removing excess material from a workpieces tusing a file which acts as a cutting tool. Files are available many shapes and sizes.

Elements of a file: Tip or point, face or side, edge, heel, handle.

Types of cuts: Basically there are four types of cuts single cut, double cut, Rasp cut and curved cut.

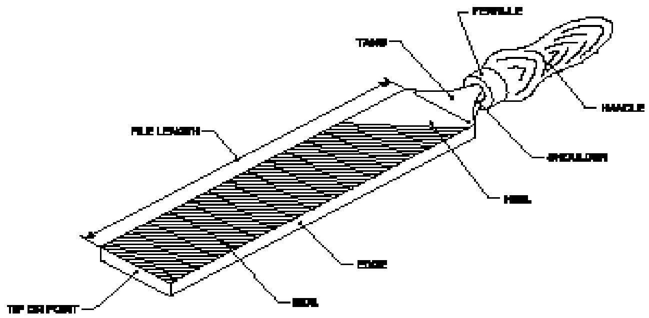
Single/cut file: A single cut file has rows of teeth cut in one direction across its face. The teeth are at an angle of 60° to the centre line. It can chip as wide as the cut of the file. The other cut, made diagonal to this, is known as and is at an angle of 51°. This removes stock faster then the single cut file.

Rasp out file: The rasp cut has individual sharp pointed teeth in line and is useful for filing wood, leather and other soft materials. These files are available only in half round shape.

Curved cut file: These files have deeper cutting action and are useful for filing soft materials like aluminium, tin, copper and plastic. The curved cut files are available only in a flat shape.

Tips

The selection of a file with a particular type of cut is based on the material to be filed. Single cut files are used for filing soft materials. But certain special files, for example, those used for sharpening saws are also of single cut.



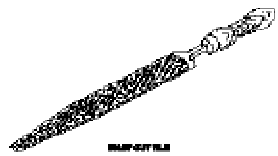


Fig 1.6.15 RASP Cut File

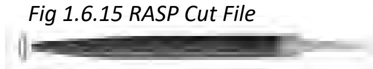


Fig 1.6.14 Elements of File

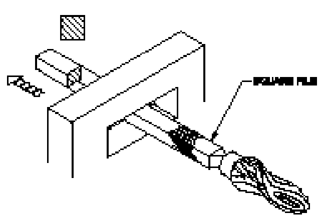
Fig 1.6.16 Curved cut file

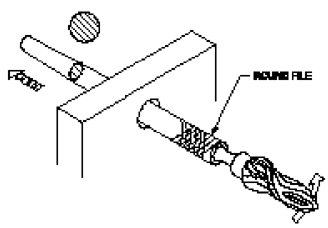
Fig 1.6.17 Different type of file

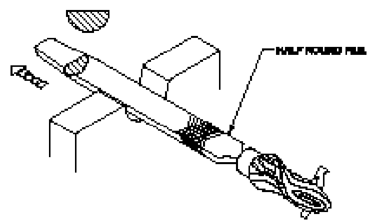
Common files of different shapes–Flat file, hand file, square file, round file, half found file, triangular file and Knife edge file.

Half round File: A half round file is in the shape of a segment of a circle. It is used for filing internal curved surfaces.

Triangular File: A triangular file is of triangular crosssection. It is used for filing corners and angles which are more than 60°.







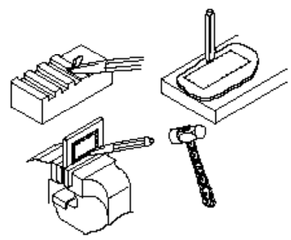


Fig 1.6.18 Square file

Fig 1.6.19 Round file

Fig 1.6.20 Half round file

Fig 1.6.21 Chisel

Chisel: The cold chisel is a hand cutting tool used by fitters for chipping and cutting off operations. Chipping is an operation of removing excess metal with the help of a chisel and hammer. Chipped surfaces are rough. They should be finished by filing.

Parts of a chisel

A chisel has the following parts – head, body, point or cutting edge. Chisels are made from high carbon steel or chrome vanadium steel. The cross-section of chisels is usually hexagonal or octagonal. The cutting edge is hardened and tempered.

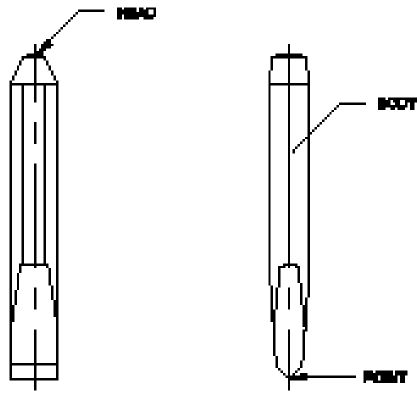


Fig 1.6.22 Parts of chisels

Common types of chisels: There are four common types of chisels. Flat chisel, Cross-cut chisel, Hall round nose chisel, Diamond point chisel.t

Flat chisels: They are used to remove metal from large flat surfaces and chip excess metal of weld joints and castings.

Cross-cut or cape chisels: These are used for cutting keyways, grooves and slots.

Half round nose chisels: They are used for cutting curved grooves (oil grooves).

Hammer: An engineer's hammer is a hand tool used for striking purposes. It includes punching, bending, straightening, chipping, forging, riveting.

Major parts of a hammer

The major parts of a hammer are head and handle.

The head is made of drop forged carbon steel, while the wooden handle must be capable of absorbing shock.

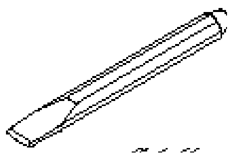


Fig 1.6.23 Flat Chisel

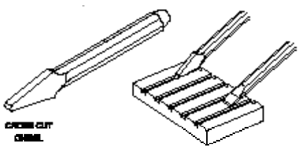


Fig 1.6.24 Cross cut chisel

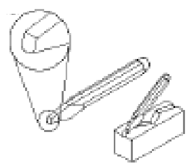


Fig 1.6.25 Half round chisel

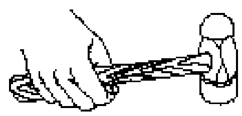


Fig 1.6.26 Hammer

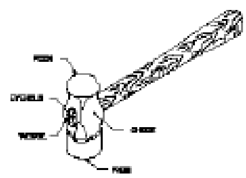


Fig 1.6.27 Major parts of a hammer

The parts of a hammer head are the Face, Cheek, Wedge, Peen, Eyehole. The face is the striking portion. Slight convexity is given to it to avoid digging of the edge. The peen is the other end of the head. It is used for shaping and forming work like riveting and bending. The peen is of different shapes like the ball peen, straight peen. The face and the peen are hardened.

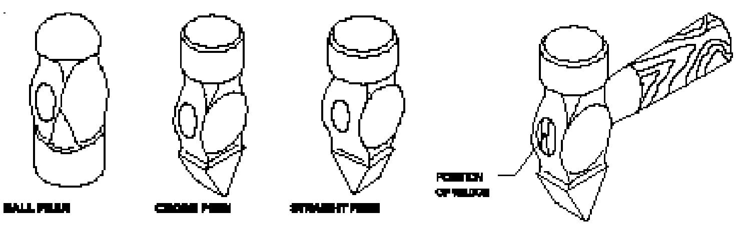


Fig 1.6.28 Different types of a hammer

Fig 1.6.29 Different types of C-Clamps

The cheek is the middle portion of the hammer-head. The weight of the hammer is stamped here. This portion of the hammer-head is left soft. An eyehole is meant for fixing the handle. It is shaped to fit the handle rigidly. The wedges fix the handle in the eye hole.

Ball peen hammer

A ball peen head is used to spread metal in all directions. This hammer has a semi-spherical peen suitable for riveting. It is used for shaping the cylindrical end of a metal rivet to form a rivet head.

Straight peen hammer

A straight peen hammer is used to spread metal in one direction at right angles to the line of striking. This hammer has a blunt wedge-shaped peen in line with the axis of the handle.

C- clamps

Purpose of using clamps: Clamps of different types are used for preventing the movement of work, and for holding the job tight.

Clamping devices

- help to manipulate for easy loading
- provide the required clamping force.
- are capable of locking with minimum movement.
- accommodate a range of sizes of jobs.

Typical C clamping device is employied to a screw and nut to provide the clamping force.

Wooden mallet

Mallets are soft hammers and are made of raw, hard rubber, copper, brass, lead or wood and are used to strike a soft and light blow on the metal.

Types and uses

Standard wooden mallets are used for general purpose work like flattening, bending, etc. Bossing mallets are used for hollowing panel beatings, etc.

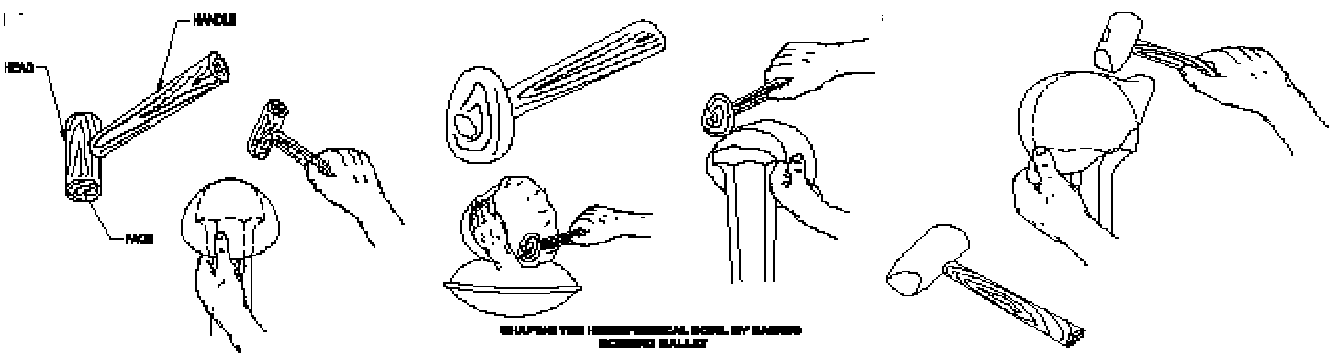


Fig 1.6.30 Standard wooden mallet

Hacksaw frame and blade

The hand hacksaw is used along with a blade to cut metals of different sections. It is also used to cut slots and contours.

Types of hacksaw frames

The two different types of hacksaw frames are soild and adjustable frames.

Soild frame

Only a particular standard length of blade can be fitted to this frame.

Adjustable frame (Flat type)

Different standards of lengths of blades can be fitted to this frame.

Adjustable frame(Tubular type)

This is the most commonly used type. It gives a better grip and control, while sawing. For proper working, it is necessary to have frames of rigid construction.

Hacksaw blades

A hacksaw blade is a thin, narrow steel band with teeth and two pinholes at the ends. It is used along with a hacksaw frame. The blade is made of either low alloy steel (LA) or high speed steel (HS) and is available in standard lengths of 250 mm and 300 mm.

Pitch of the blade

The distance between adjacent teeth is known as the pitch of the blade.

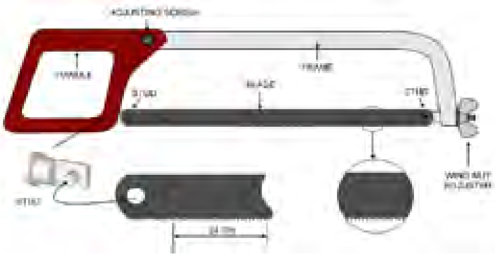


Fig 1.6.31 Hacksaw frame

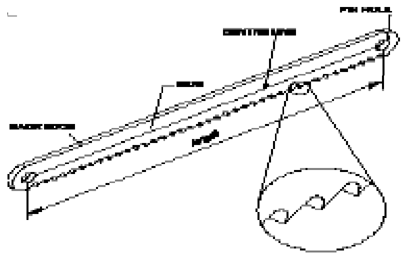


Fig 1.6.32 Hacksaw blades

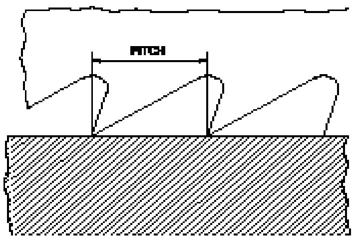


Fig 1.6.33 Pitch of the blade

Pipe bending machines: There are some situations in piping and plumbing jobs, where it is preferable to bend a pipe rather than use a pipe fitting. The portable hand-operated pipe bender consists of the following parts: Tripod stand, Pipe stop lever, Handle or lever, Inside former.

Bench type hand operated pipe bender

It is used for bending galvanized iron and steel pipes. It has the following parts inner former, lever or handle, Adjusting screw with lock nut, pipe guide.

Hydraulic bending machine

This machine can be used bending G.I. and M.S. pipes without sand filling to bend in any direction. It consists of the following the parts. Inner former, back former, hydraulic ram, pressure release valve, operating lever, bleed screws, base plate. Inner formers are interchangeable and are able to bend pipes up to 75 mm diameters.

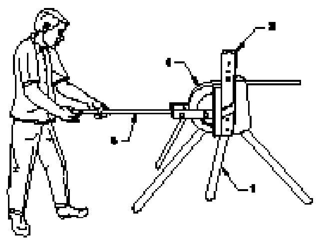


Fig 1.6.34 Pipe bending machine

Fig 1.6.35 Bench type hand operated

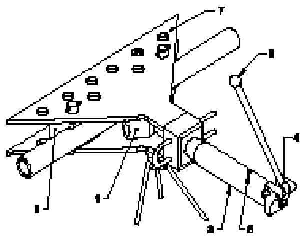


Fig 1.6.36 Hydaulic pipe bender

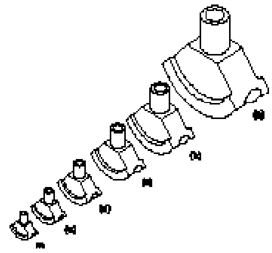


Fig 1.6.37 Pipe bend forming dies

Spanners and uses

Spanners are used for operating threaded fasteners, bolts and nuts. They are made with jaws or opening that fit square on hexagonal nuts and bolts and screw heads. They are made of high tensile or alloy steel. They are drop-forged and heat-treated for strength. Finally, they are given a smooth surface finish for ease of gripping. Spanners vary considerably in shape to provide ease of operation under different conditions.

Fig 1.6.38 Different type of spanners

The basic types of spanners are: open end spanners, tube or tubular box spanners, socket spanners, ring spanners. Use both hands as shown in the figure, when using tubular box spanners. Use two spanners as shown in the figure to stop the head of the bolt rotating as the nut is operated. Socket spanners may be turned by accessories which have square driving ends. To fit exactly, a spanner must be: of the correct size, placed correctly on the nut and in good condition.

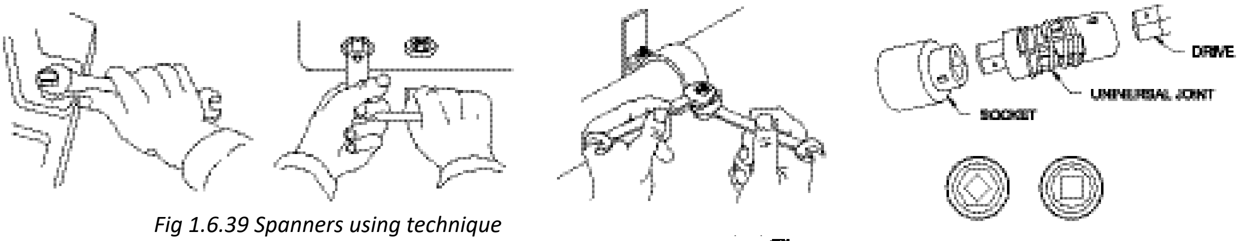


Fig 1.6.39 Spanners using technique

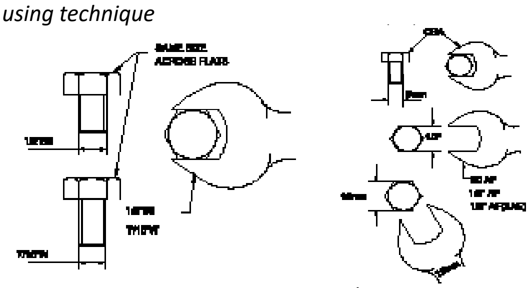


Fig 1.6.40 Spanners using technique

Adjustable spanners

Most common types of adjustable spanners are similar to open end spanners, but they have one movable jaw. The opening between the jaws of a typical 250 mm spanner can be adjusted from zero to 28.5 mm. Adjustable spanners may range in length from 100 mm to 760 mm. The type illustrated has its jaws set an angle of 21.5° to the handle. Adjustable spanners are convenient for use where a full kit of spanners cannot be carried. They are not intended to replace fixed spanners which are more suitable for heavy service. If the movable jaw or knurled screw is cracked or worn out, replace them with spare ones.

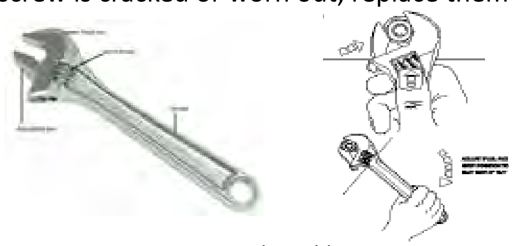


Fig 1.6.41 Adjustable spanners

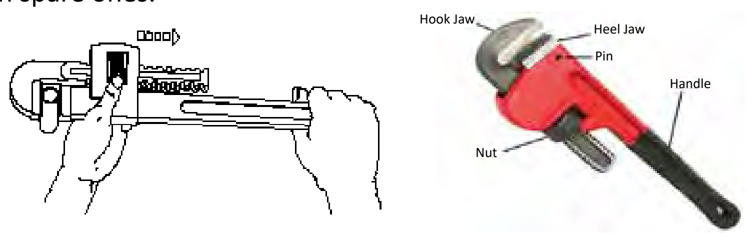


Fig 1.6.42 Wrench spanner

Wrenches

Types of wrenches – stillson pipe wrench, footprint pipe wrench, tension wrench, hexagon socket wrench.

Torque wrench: Torque wrench is used to tighten the bolts / nuts at the recommended torque. The torque wrench will measure the torque (twisting force) applied to the fastener. For example, Cylinder head nuts, bearing cap nuts, ect. (N-M; Kg-m or Ib-ft)

Pliers Features: Pliers have a pair of legs joined by a pivot, hinge or fulcrum pin. Each leg consists of a long handle and a short jaw. Elements of pliers with two joint cutters(Combination pliers) include flat jaw, pipe grip, side Cutters, joint cutters, handles.

Other types of pliers

Flat nose pliers: It has tapered wedge jaws with flat gripping surface which may be either smooth or serrated. It is used for bending and folding narrow strips of thin sheets, wires, etc.

Round nose pliers: This type of pliers is made with tapered round shape. They are used to shape loops in wires and the form curves in light metal strips.

Slip-joint pliers: These pliers are available in various ranges of positions with different shapes of pivot pins so that they have various ranges of jaw opening, and are mainly used for gripping.

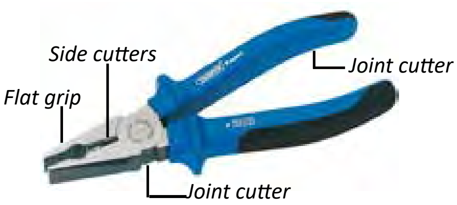


Fig 1.6.43 Elements of pliers

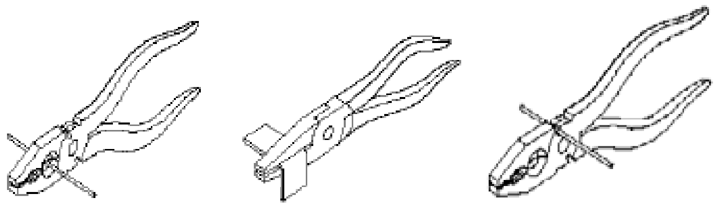


Fig 1.6.44 Different types of pliers

Combination of ring and open end spanner: These tools have a box end on one end and an open end on the other. Both ends are of the same size.

Socket spanners: The socket is one of the fastest and most convenient of all the spanners. Sockets come in two sizes–standard and deep. Standard sockets will handle most of the works, while the extra reach of the deep socket is occasionally needed.

Socket handles: Several different drive handles are used. The socket handle is used whenever possible, as it can be turned rapidly.

Fig 1.6.45 Combination spanner

Fig 1.6.46 Socket spanners

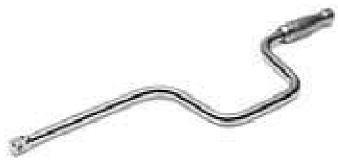


Fig 1.6.47 Socket handle

Types of vices: There are different types of vices used for holding workpieces. They are quick releasing vice, pipe vice, hand vice pin vice and toolsmaker's vice.

Quick releasing vice: A quick releasing vice is similar to an ordinary bench vice, but the opening of the movable jaw is done by using a trigger (lever). If the trigger at the front of the movable jaw is pressed, the nut disengages the screw and the movable jaw can be set in any desired place quickly.

Pipe Vice: A pipe vice is used for holding round sections of metal and pipes. In this vice, the screw is vertical and movable. The jaw works vertically. The pipe vice grips the work at four pionts on its surface.

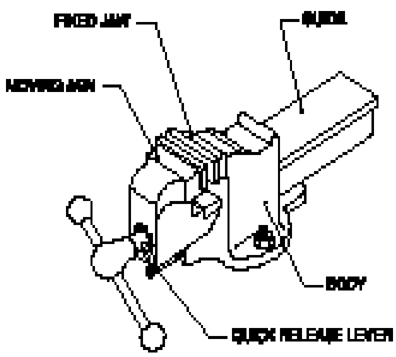


Fig 1.6.48 Quick releasing vice

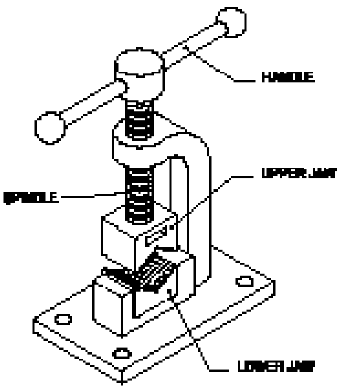


Fig 1.6.49 Pipe vice

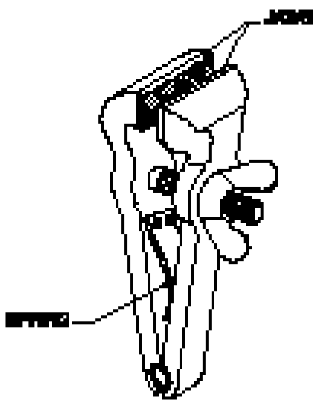


Fig 1.6.50 Hand vice

Hand Vice: Hand vices are used for gripping screws, rivets, keys, small drills and other similar objects which are too small to be conveniently held in the bench vice. A hand vice is made in various shapes and sizes. The length varies from 125 to 150 mm and the jaw width from 40 to 44 mm. The jaws can be opened and closed using the wing nut on the screw that is fastened to one leg and passes through the other.

Toolmaker's vice

The toolsmaker's vice is used for holding small workpieces which require filing or drilling and for marking of small jobs on the surface plate. This vice is made of mild steel. Toolmaker's vice is accurately machined.

Bench vice

These vices are used for holding workpieces. They are available in different types. The vice used for bench work is called as bench vice or engineer's vice. A bench vice is made of cast iron or cast steel and it is used to hold work component / item for sawing, threading and other hand operations. The size of the vice is stated by the width of the jaws.

Parts of a bench vice

The following are the parts of the vice. Fixed jaw, movable jaw, hard jaws, spindle, handle, box-nut and spring. The Vice is generally bolted and secured in a wooden work table, and is useful for operations like filing, chipping, hacksawing, bending sheetmetal, etc. The box-nut and the spring are the internal parts. Do not over-tighten the vice as, the spindle may get damaged.

Flaring, flare fittings and testing the joints

Flaring necessity

When connecting tubing to fittings, it is common practice to flare the end of the tube and to use fittings designed to grip the flare for a vapour tight seal. Special tools are used for making flares.

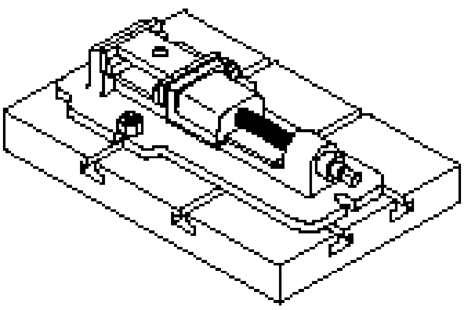


Fig 1.6.51 Tool maker vice

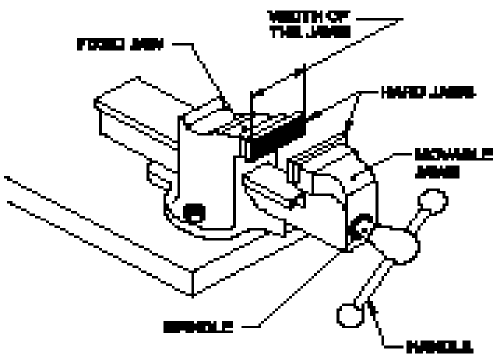


Fig 1.6.52 Bench vice

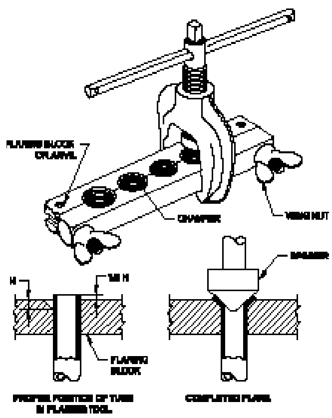


Fig 1.6.53 Flaring tools

Types of flaring

There are two types of flaring – single thickness flare and double thickness flare.

Single thickness flare

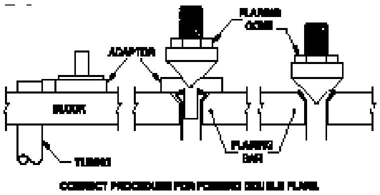
It can be made on smaller size copper tubing.

Double thickness flare

Double thickness flares are recommended for only the larger size tubing 5/16 inch (9mm) OD and over. Such flares are not easily formed on smaller tubing. The double flare makes a stronger joint than a single flare.

Flared tubing fittings

To attach a fitting to soft copper tubing, a flared type connection is generally used.



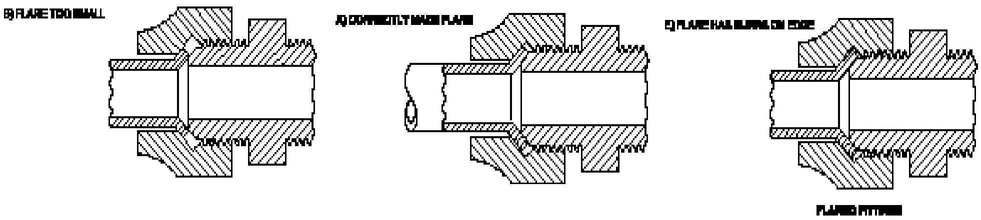


Fig 1.6.65 Correct procedure for forming double flare

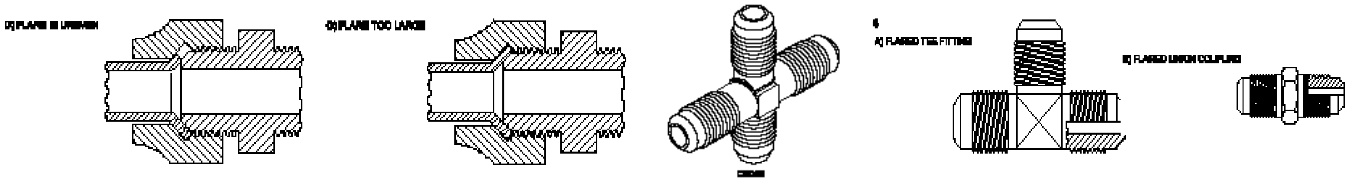


Fig 1.6.66 Different type of flared fittings

Pipe cutter

A pipe cutter is more convenient and neater than a saw when cutting pipes and metal tubing. The sharpened wheel does the cutting. As the tool turns around the pipe, the screw increases the pressure, driving the wheel deeper and deeper through the pipe until it finally cuts rights, through.

Fig 1.6.67 Pipe and Tube Cutter

Standard and special screwdrivers and use

Screwdrivers are used to tighten or loosen screws which are fixed in the machine element.

Classification:

1. Standard type with tips to suit recessed head screw slots.
2. Special type with tips to suit recessed head screws.

Standard screwdrivers

Standard screwdrivers are classified as heavy duty screwdrivers, light duty screwdrivers, stumpv screwdrivers.

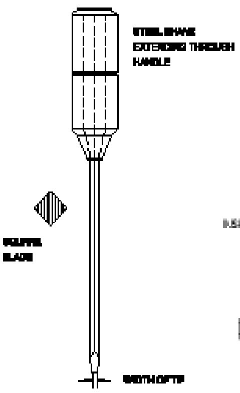


Fig 1.6.69 Heavy duty screw driver

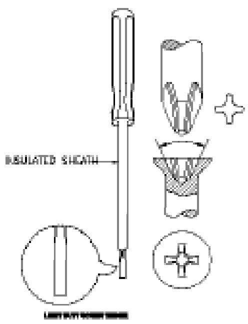


Fig 1.6.70 Light duty screw driver

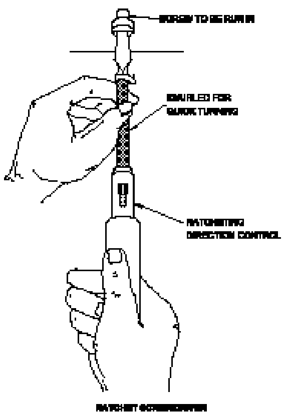


Fig 1.6.71 Philips screw driver

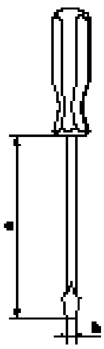


Fig 1.6.72 Ratchet screwdriver

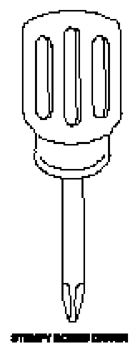


Fig 1.6.73 Special screw driver

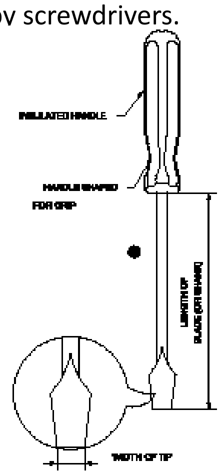


Fig 1.6.68 Screw driver

Hexgon socket screw keys (Allen Keys)

Hexagon socket screw keys/Allen keys are made from hexagonal section bars of chrom vanadium steel. These are hardened and tempered. These are bent to L shape. The size of an Allen key is identified by the size across the flat of the hexagon.

Uses: They are used to tighten or loosen screws having internal hexagon sockets. Allen keys are available in different sets in plastic wallets, comprise a set of 8 (2 to 10mm).

Puller: The puller is a general workshop tool which is used to remove gears, bearings pulleys, flanges, bushes. The puller is made of steel material, generally, with two or three legs and they are adjusted to hold the outside of the gears or bearing sleeves while the central threaded shaft is screwed forward exerting force on the gear/ bearing. This enables to remove the bearing without damaging the shaft. Pullers are classified according to the application and the number of legs. Another classification is based on the power utilised mechanical puller and hydraulic puller.

Two legs puller, is, generally, used for removing the gearss whereas puller, with three legs are for removing pulleys. flanges and bearings. It is also called gear puller.

Special pullers: These are mainly used for specialised application such as crank shaft, bearing removal, brake drum removal, pilot bearing removal.

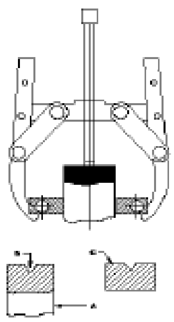
Hydraulic puller: These pullers eliminate time consuming and unsafe hammering, heating or prying. Damage to part is minimised through the use of hydraulic pullers.

Safety: To avoid person injury during system operation, always wear proper PP gear. Never use a tool to strike a puller. Make sure that items that are pulled are well and adequately supported. Do not apply heat to a puller. Before every use lubricate the centre bolt threads with graphite-based lubricant. Use puller only with recommended attachment. Do not overload a pulley which may cause to break.

Shawal: Shawal is used for mixing concrete and also for carrying concrete to mortar pans. Shawals are made of tool steel sheets. The size is designated by its length and width.

Pickax: Pickax is used to excavate hard soil. It is manufactured from tool steel. One end of the pickax is flat, while the other end is sharp. It helps for two different oprations. The size is denoted by its lengths.

Fig 1.6.74 Allen Key Sets



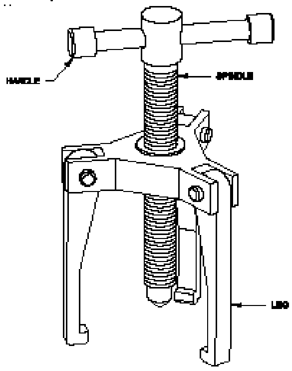


Fig 1.6.75 Puller

Fig 1.6.76 Shawal

Fig 1.6.77 Pickax

Exercise

I. Answer the following questions.

1. List of the hand tools.

   ----

2. How many types of files can be used for pipe edge preparation?

   ----

3. Name any three types of pipe wrenches.

   ----

4. Name the elements of ball peen hammer.

----

5. What are the types of hammers mainly used in pipe fitup application?

----

6. State the purpose of pickax.

----

7. Name any three types of spanners and their uses.

II. State whether the following statements are True or False.

1. File and pipe vice are used in pipe edge perparation.

   True ☐ Flase ☐

2. Chisel and hacksaw are hand cutting tools used by pipe fitter for chipping and cutting off operation.

   True ☐ Flase ☐

3. Mallets are used to strike a soft and light blow on the metal.

   True ☐ Flase ☐

4. Pipe vice is used to hold the round section of metal and pipe.

   True ☐ Flase ☐

Notes

1.6.5 Power Tools and Equipment

At the end of this topic, you will be able to:

1. name the different types of power tools and equipment
2. handle different types of power tools and equipment.

Drilling machine (portable type)

Necessity

Portable hand drills of different types are used for certain jobs which cannot be handled on stationary drilling machines.

Types: There are two types of portable drilling machines – power operated and hand operated.

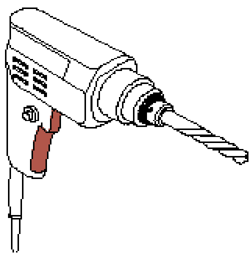
Power Operated drilling machines

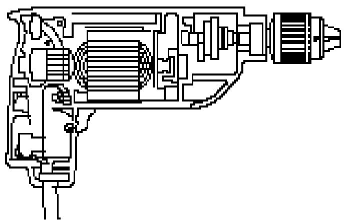
Electric hand drill (light duty): These are available in different forms. The electric hand drill has a small electrical motor for driving the drill. On the end of the spindle, a drill chuck is mounted. Electric hand drills used for light duty will have, usually, a single speed.

Electric hand drill (heavy duty): This drill has an additional feature by which the drill speed can be varied through a system of gears. This is particularly useful for drilling larger diameter holes.

Pneumatic hand drill: This type of drill is operated by compressed air. An air driven motor is housed in the casing, and a handle is fitted along with an air pipe to operate the drill conveniently. This drill is used where electrically operated drills are prohibited, for example, explosives factories, petroleum refineries, etc.

Hand operated drilling machines: Different types of hand operated drilling machines are available. They are used in structural fabrication, sheet metal and carpentry, particularly, where electricity or pneumatic supply is not available. The ratchet drilling machine is commonly used in structural fabrication. Square head, taper shank drills are used on these machines. The bevel gear type drilling machine is used for drilling small diameter holes up to 6mm. The breast drilling machine is used for drilling holes of larger diameter as more pressure can be exerted. Drills between 6 mm to 12 mm can be used on these machines. (Fig. 1.6.78)





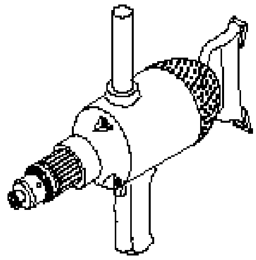


Fig 1.6.78 Electric hand drill

Fig 1.6.79 Hand operated drilling machine

Drill (parts and function):

Drilling is a process of making holes on workpieces. The tool used is drill bits. For drilling, the drill bit is rotated in the clockwise direction with a downward pressure causing the tool to penetrate into the material.

Parts of a drill: The various parts of a drill can be identified from the Fig. 1.6.81.

Point: The cone shaped end which does the cutting is called the point. It consists of a dead centre, lips or cutting edges.

Shank: This is the driving end of the drill which is fitted on the machine. Shanks are of two types. Taper shank is used for larger diameter drills and straight shank is used for smaller diameter drills.

LIP: LIP is the cutting edge which penetrates into metal while drilling.

Tang: This is a part of the taper shank drill which fits into the slot of the drilling machine spindle.

Body: The portion between the point and the shank is the body of the drill. The parts of the body are flute, land/ margin, body clearance and web.

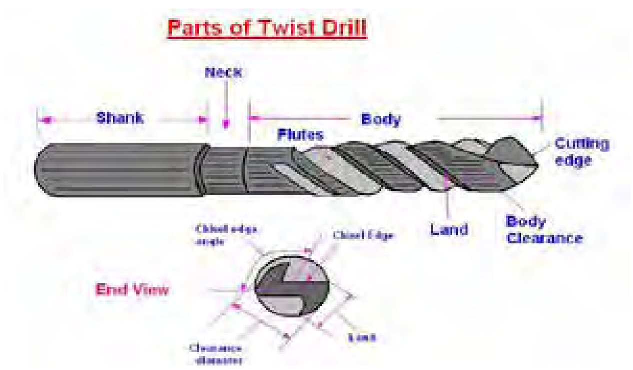


Fig 1.6.80 Typical drill bit

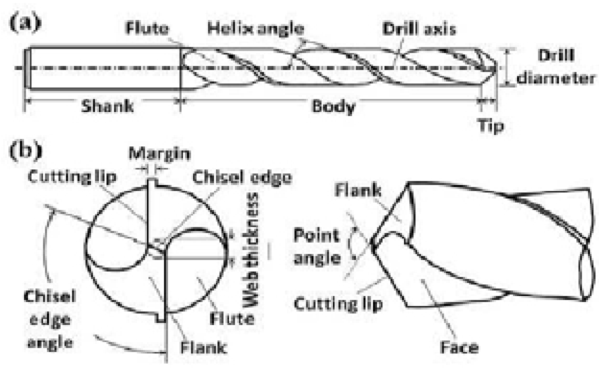


Fig 1.6.81 Parts of a drill

Flutes: Flutes are the spiral grooves which run to the length of the drill. The flutes help to form the cutting edges to cut the chips and, allow them to come out, the coolant to flow to the cutting edge.

Land/margin: The land/margin is the narrow strip which extends to the entire length of the flutes. The diameter of the drill is measured across the land/margin.

Body clearance: Body clearance is the part of the body which is reduced in diameter to cut down the friction between the drill and the hole being drilled.

Web: Web is the metal column which separates the flutes. It gradually increases in thickness towards the shank. A drift is used to remove drills and sockets from the machine spindle. While removing the drill from the sockets/ sleeves, do not allow it to fall on the table or jobs.

Drill angles: Like all cutting tools, the drills are provided with certain angles for efficiency in drilling.

Angles: There are different angles for different purposes. They are – Point angle, helix angle, rake angle, clearance angle and chisel edge angle.

Cleaning Tools - Brushing and abrasive Cleaning tools: It should be used very carefully on soft metals. Heavy deposits that exists even after chemical cleaning can be removed by mechanical cleaning. The General Cleaning Tools are wire brushes, emery paper.

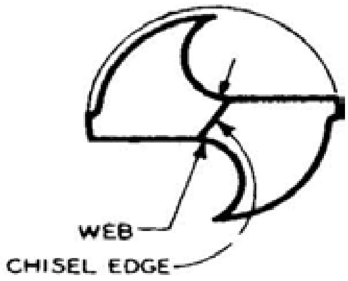


Fig 1.6.82 Web

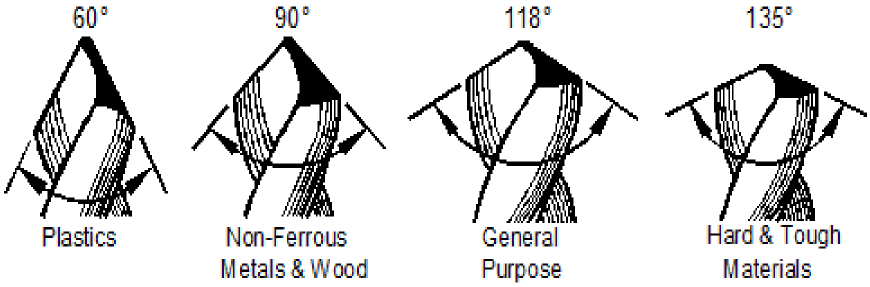


Fig 1.6.83 Drill angles

Wire Brushes: Wire brushes are generally used for cleaning the work surfaces. It is made of steel wires or nylon bristles fitted on a wooden piece. The steel wires are hardened and tempered for long life to ensure good cleaning action.

Emery Paper: This is a type of paper used for cleaning hard and rough surfaces and also used for resistant technology purposes to give a smooth, shiny finish to manufactured products.

Fig 1.6.84 Emery paper

Fig 1.6.85 Wire brushes

Metal-cutting saws of different types are used in industries. The most commonly used are power saw, horizontal band-saw, circular saw, contour band-saw.

Circular saw: This type of cutting machine is used when cutting materials having a large cross-section. The circular saw has a continuous cutting action and is economical in production work where heavy section metals are used.

Power hacksaw: Cut-off saws are used to cut metal stock roughly to the required length. The commonly used cut-off saw in small scale industries is a power saw.

Power hacksaw blades: The saw blades are selected depending on the machine and the type of work on hand. The blades are made of low alloy steel or H.S.Steel and are fully hardened. For different materials, blades of different pitches are used (number of teeth per 25 mm length). As a general rule, the softer the material, the lesser is the number of teeth per length of 25 mm. Teeth with a large pitch can accommodate large chips. Blades are available with varying coarseness between 4 to 14 teeth per 25 mm length. Coarse pitch blades are also used while cutting large sections of stock, as this will help in greater chip clearance and increased penetration. For cutting hard material (tool steel) and thin material, a 14 pitch blade is recommended. For general purpose sawing, a 10 pitch blade will be useful.

Tips

While selecting blades, make sure atleast two teeth of the blade will be in contact with the work at all times.

Clamping arrangement: Power saws are provided with clamping devices similar to those in machine vices, and the work can be gripped by using the crank handle. When a number of pieces of the same size are to be cut, an adjustable stop is used. Long bars are supported, and the level maintained by the use of adjustable floor stands.

Fixing blades: The blades are mounted on frames using screws. The teeth of the blade should point towards correct directions. (Depending on the type of machine, the blade cuts either on the forward or on the return stroke. It is necessary to follow the directions given by the manufacturers as indicated in the frame. Tension the blade using the tensioning device.

Fig 1.6.86 Horizontal band saw

Fig 1.6.87 Power hacksaw

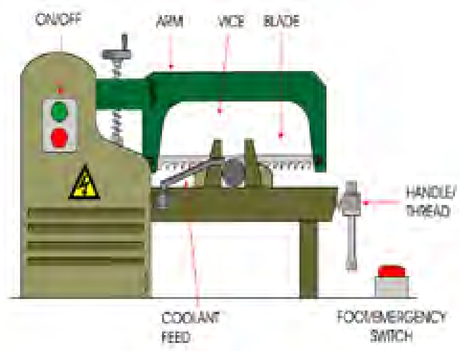


Fig 1.6.88 Power hacksaw with blades

Precautions while machine - sawing

In order to work safely and efficiently, certain precautions are to be observed. While taking measurements of the work for setting, always stop the machine. Projecting ends of the work should be well guarded to ensure safety of all. Ensure that the work does not protrude into the gang-ways. When sawing thin pieces, hold the material flat in the vice to prevent the saw teeth from breaking. Ensure a cutting fluid is always used. Avoid giving excessive cutting pressure, because this can cause breakage to the blade, and cut the work out of square. When several pieces of the same length are to be cut, use a stop gauge. When holding short workpieces in a vice, be sure to place a short piece of the same thickness in the opposite end. This will prevent the vice from twisting, when it is tightened.

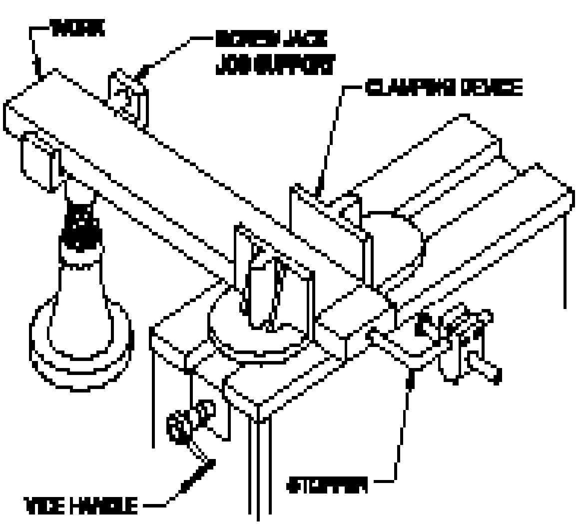


Fig 1.6.87 Clamping arrangement

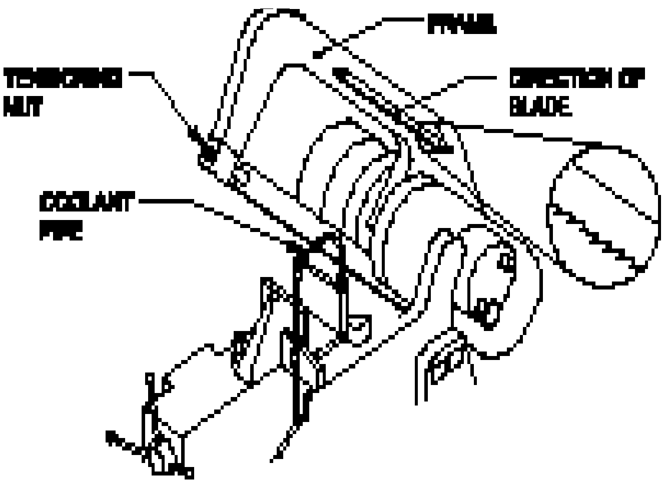


Fig 1.6.88 Fixing blades

Table 1

Table for tap drill size					
ISO Metric(60^{0})				**B.S.W.(55^{0})**	
Nominal diameter mm	**Pitch**	**Tap drill sizes**	**Nominal diameter (inch)**	**Threads per inch (mm)**	**Tap drill sizes**
3	0.5	2.50	1/8	40	2.5
4	0.7	3.30	5/32	32	3.2
5	0.8	4.20	3/16	24	4.0
6	1.0	5.00	1/14	20	5.0
8	1.25	6.80	5/16	18	6.5
10	1.50	8.0	3/8	16	8.0

Exercise

I. Answer the following questions.

1. Name the power tools that are used in pipe fitup application.

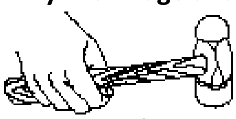
   ----

2. Name the different types of drills that are used for piping assembly fitup.

   ----

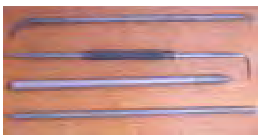
3. Name the power tools which are used in pipe cutting operation.

II. Identify the image and note it down in the Table 2.



1

2



3

4

5

6

7

Sl.No	Name of image	use	
1			
2			
3			
4			
5			
6			
7			

Notes

Unit 1.7 Pipe Fitting Operation

Unit Objectives

At the end of this unit, you will be able to:

1. select appropriate equipment and accessories used in pipe fitup
2. select correct marking tools and materials
3. fabricate, install, repair and maintain low and high pressure piping system
4. produce pipe bends using the appropriate tools and equipment
5. fabricate piping spools with a range of different fittings.

1.7.1. Equipment and Materials Used in Piping Fabrication

At the end of this topic, you will be able to:

1. identify types of equipment used in piping spools fabrication work
2. list codes and standards as applicable
3. specify the list of materials used in pipe fitup
4. define technical terms in process piping (oil & gas).

Equipment and accessories used in piping spools fabrication work

Set of PPE (personal protective equipment)

1. Pipe cutting and beveling machine (Cold cutting)
2. Orbital pipe cutting and beveling equipment (Hot cutting)
3. Grinding machine – AG4, AG7
4. Lifting crane, forklift and accessories
5. Chain block
6. Oxyacetylene cutting equipment and saw cutting machine
7. High speed cutter
8. Marking Tools

Personal Protective Equipment (PPE)

Hard hat (Helmet)

A hard hat is a type of helmet predominantly used in the workplace environments such as industrial fabrication and construction sites to protect the head from injury due to falling objects, impact with other objects.

Fig. 1.7.1 Hard Hat

Fig. 1.7.2 Safety Harness

Fig. 1.7.3 Hand Gloves

Fig. 1.7.4 Safety Shoes

Safety goggles

Safety goggles are a type of personal protective equipment (PPE) that is worn on the eye for protection.

Safety harness: A fall Protection accessory that protects workers in case of falling while working at heights.

Hand Gloves: Hand gloves are personal protective equipment worn to cover and protect the hands from the wrist to the fingers.

Safety shoes: A steel toe boot is a durable boot or shoe that has a protective reinforcement in the toe. It protects the foot from injury.

Reflective jacket: A reflective fabric will keep workers visible at all times.

Dust mask: A flexible pad worn over the nose and mouth to protect against dust in the construction site.

Ear plug: A earplug is a device meant to be inserted in the ear canal to protect the ears from loud noises.

Fig. 1.7.5 Safety goggles Day and Night

Fig. 1.7.6 Reflective Jacket

Fig. 1.7.7 Dust Mask

Fig. 1.7.8 Ear Plug

Pipe cutting and beveling machine:

Pipe cutting is a mechanized or normal cutting process that removes material from pipe to create desired profile. Pipe beveling is the process where an angle for fitup and welding is prepared such as 30°/37.5°.

Orbital pipe cutting and beveling equipment: A pipe cutting and beveling machine used for the cutting and beveling of pipe ends / edges.

Oxy acetylene cutting equipment: Oxy fuel cutting processes that use fuel gases (Acetylene) and oxygen to cut pipes.

Fig. 1.7.9 Beveling and cutting equipments

Fig. 1.7.10 Oxy-Acetylene cutting equipment

High speed cutter / grinding machine: A machine designed for cutting and beveling of pipe ends by mechanical method.

Fig. 1.7.11 High speed cutter/grinding machine

Mobile crane: Mobile crane is a controlled crane mounted on crawlers or with rubber-tyre telescope boom mounted on truck. They are designed to easily transport to a site and use for different type of loading, lifting and set up piping assembly.

Fork lift: Fork lift is one of the most important and widely used equipment in pipe material handling, piping spool fabrication workshop yards. The lift truck is a powered industrial vehicle used to lift and transport piping materials.

Chain block: Chain block is a mechanism used to lift and lower heavy loads using a chain block with two wheels in which chain is wound around. When the chain is pulled, it winds around the wheels and begins to lift piping spools /fittings.

Hoisting equipments and their application (chain hoists): Lifting and moving of loads by hoisting equipment is a rigging operation. In rigging, many types of hoisting equipment like hoists, derricks and cranes are employed. Both hand and electrically operated hoisting equipment are available and used widely in piping / pipeline construction works. All lifting equipment shall be calibrated to the maximum load carrying capacity.

Chain hoist: The chain hoist is a most widely used device for lifting loads. Chain hoists are dependable and usually portable. Three basic types of chain hoists are the differential, screw-geared, spur-geared.

Fig. 1.7.12 Mobile crane

Fig. 1.7.13 Fork lift

Fig. 1.7.14 Chain Block

Fig. 1.7.15 Hoisting Equipments

Spur-geared hoist: The spur-geared hoist is the most efficient type of hoist which uses an endless chain to drive a pocket sheave. The pocket sheave drives a gear reduction unit that is fitted with the second or load chain. One end of the load chain is fitted with a hook.

The come along chain hoist is another type of chain hoist. It uses a ratchet operated by a lever for lifting. The come along chain hoist is used to lift loads to short distances. But it is used more often to stretch wires and cables. It is also known as pull lift. Wire rope hoistings are also used for hoisting the load. Generally, manila ropes are used to hoist the load.

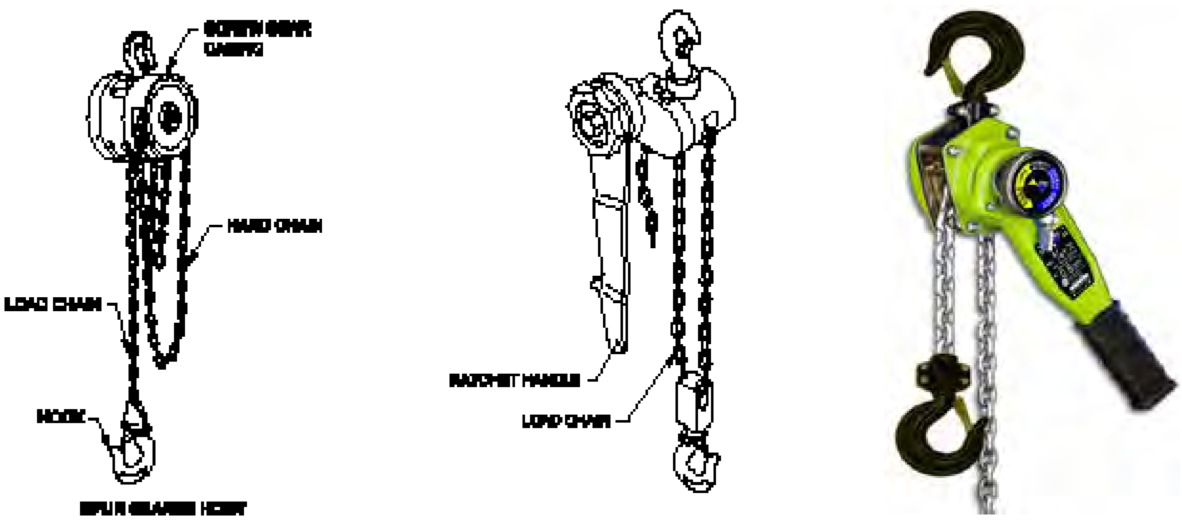


Fig. 1.7.16 Different type of chainhoist

Exercise

I. Answer the following questions.

1. What are the equipment required for pipe fitup and assembly?

2. What is the purpose of using chain block?

3. Name the important PPEs?

II. State whether the following statements are True or False.

1. Tube is always used to measure (OD) outside diameter.
   True ☐ False ☐
2. Stainless steel is the alloy of chromium and nickel.
   True ☐ False ☐
3. Fuel gases acetylene and oxygen are used in oxy-fuel cutting processes.
   True ☐ False ☐

Notes

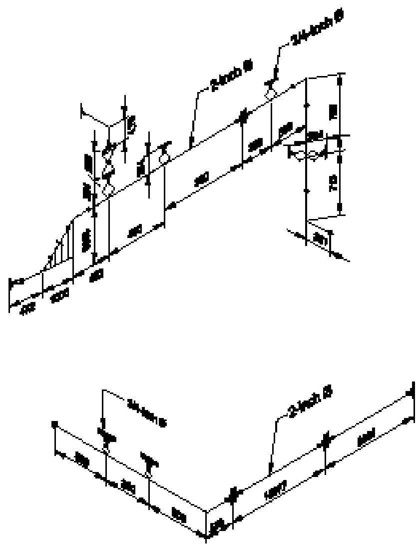
1.7.2 Planning Pipe Fitting Activities before Starting Fitup

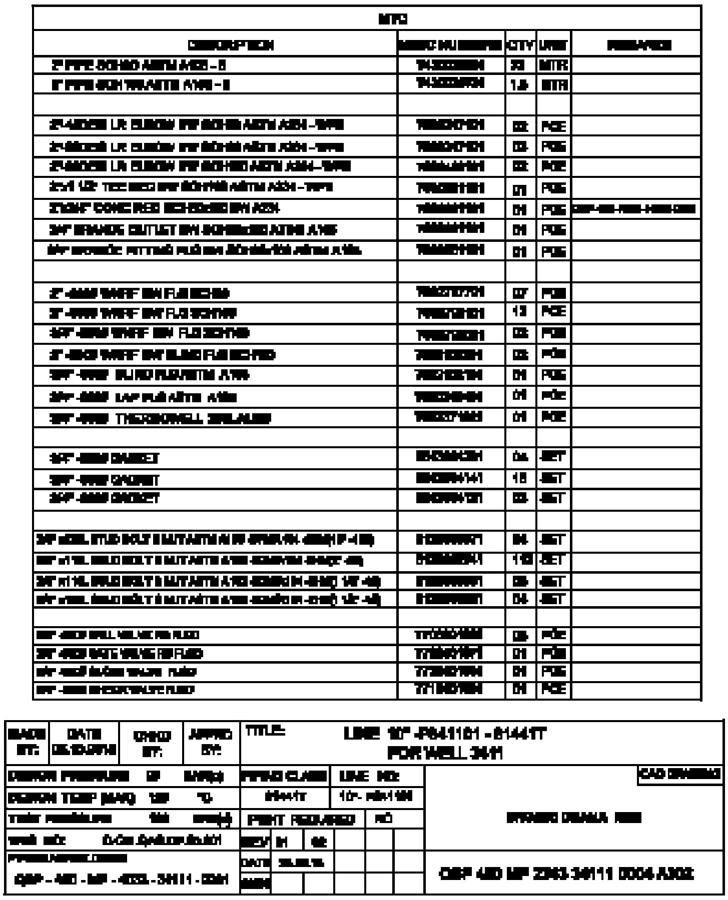
At the end of this topic, you shall be able to:

1. interpret the drawing carefully and prepare material MTO
2. perform material transportaion, storage and handling in store / site
3. carryout material receiving, checking and issue from store
4. carryout material issuing for fabrication and construction purpose.

Material reveiving and checking in store / site

The first step to ensure the quality of the piping product is to make sure that the incoming material being used, meets the specified quality standards requirement. Ensure that this happens as per company approved procedure. It should also be ensured that secure storage areas are provided for pipe materials, fittings and equipment irrespective of their point of origin. The site store keeper should be responsible for the receipt storage, issuing of materials at store / site.





Protective Coatings: Protective painting and coating systems, external surface of carbon steel structures piping and equipment on shore piping shall be protected with suitable coating systems.

Painting and coating related terms

Anticorrosive paint	–	A paint formulated to prevent corrossion of steel substrates/ pipe surface.
Primer	–	Paint intended for protection of metals against corrosion or for preparing a surface for subsequent top coats, the primer must have sufficient wetting properties to saturate the surface and maintain the adhesion.
Thinner	–	Any volatile liquid used for reducing the viscosity of coatings, may consist of a simple solvent.
Epoxy	–	A resin based on polymerised bisphenol containing epoxy groups.
Air less spraying	–	Method of paint application which uses hydraulic pressure to atomise the paint. Airless spraying is a very fast and efficient method of painting application.

Different types of protective coatings applied in piping system include:

- Liquid Epoxy – External and Internal coating
- Zinc rich epoxy – Coating for pipes
- Poly urethane – External coating for pipes
- Fusion bonded epoxy – External and internal
- Galvanizing – For pipes and supports
- Mastic coating for pipes – External and internal surface coating
- Glass Flake coating – For tanks
- PE Coating – High density Polyethylene coating.

Purpose of painting and coating include: protection, decoration, information

Protection: Paint is used to protect objects / pipes from adverse effects of weather Epoxy layer protects the pipe against corrosion and damages.

Decoration: Paint is used to decorate all sorts of objects.

Information: Paint is used to give information by means of painted signs / colour coding.

Material transportation, storage and handling

1. It shall be ensured that adequate protection against damage is provided for all components during transportation, loading, storage activities by providing adequate timber bearers during the transport and the wrapping of lifting points.
2. Pipes and fitting, flanges or component parts should be stored above ground on pallets and kept free from dirt, grease, paint sprays.
3. Pipe and fitting open ends should be protected by the use of end caps.
4. Particular care should be taken in the storage and handling of coated, painted and galvanized piping materials.
5. Different grades of materials including cut segments or shapes should be clearly marked using identification coding system. Stainless steel and duplex stainless steel should be stored in different locations to avoid contamination (or) mixing.

Fig. 1.7.17 Typical Piping Material storage (Flanges, Pipes, Fittings)

Corrosion: Corrosion is usually described by its results. Familiar terms include rust, scaling, pitting etc., The corrosion process involves the deterioration of a pipe or its properties because of reaction with environment.

Handling and storage of coated pipes and associated assembly

When handling coated pipes, special attention to be taken, as follows:

1. To prevent damage to the coatings and pipes.
2. Pipe bevel ends should be protected with suitable protector.
3. Pipe must be handled with suitable lifting gear. Only soft, non–metallic slings should be used.

Storage of pipes

1. Plan and arrange the safe storage of pipes.
2. Protective plastic stoppers and metallic bevel protection must be kept in the correct places.
3. A sufficient number of wooden base and separators must be used when storing pipes indoors and outdoors.

Lifting of coated pipe and associated components

1. Pipe must always be horizontally positioned when lifting to prevent damage to the coating.
2. Coated pipe should not be lifted with chains in direct contact.
3. Do not damage pipe coating ends and welding bevels.

Fig. 1.7.18 Image for Pipe storage and handling

Tips

Painting and coating

Pipe ends (cut back) should not applied in the range of 50 - 75mm in order to facilitate fitup and welding.

Support wedges

Wedges are nailed onto the base and separators to prevent pipes from moving and avoid abrasion during unnecessary moving of pipes.

Exercise

I. Answer the following questions.

1. How are pipe ends and flanges protected?

   ----

2. How are SS and duplex piping materials stored at the construction site?

   ----

3. Define corrosion.

   ----

4. Explain the purpose of painting and coating.

   ----

5. Name the different types of coating and painting system.

II. State whether the following statements are True or False.

1. The corrosion process involve the deterioration and loss of material and its critical properties due to chemical and electro-chemical reaction.

   True ☐ False ☐

2. Pipe ends are (cut back) 50-75mm left without painted and coated for good fitup and welding.

   True ☐ False ☐

3. Pipe should always be lifted in the horizontal position.

   True ☐ False ☐

4. Pipe ends and spools ends and flange surface should always be protected from damage.

   True ☐ False ☐

Notes

1.7.3 Cutting Fluids Used on Ferrous and Non-ferrous Metals

At the end of this topic, you should be able to:

1. list the different cutting fluids used for ferrous metals
2. list the different cutting fluids used for non-ferrous metals
3. state the function of cutting fluids.

Cuttings Fluids: Cutting Fluids and compounds are the substances used for efficient cutting while the cutting operation takes place. The function of cutting fluids include:

1. To reduce the friction between the chip and the tool face by lubricating.
2. To prevent rusting of the work and machine.
3. Heat is dissipated to some extent.

Advantages of cutting fluids: As the cutting fluid cools the tools, the tool retains its hardness for a longer perid. so the tool's life lasts longer. As the chips are flushed away, the cutting zone will be neat and clean.

Properties of good cutting fluid

Good cutting fluid should be sufficiently viscous. It should have low evaporation rate. It should be stable and should not foam or fume. It should not create any health problem to the operator.

Type of Cutting Fluids

The following are the common cutting fluids:

1. Straight mineral oil
2. Chemical solution (synthetic fluids)
3. Blended oil
4. Fatty oils
5. Soluble oil (Emulsified oil).

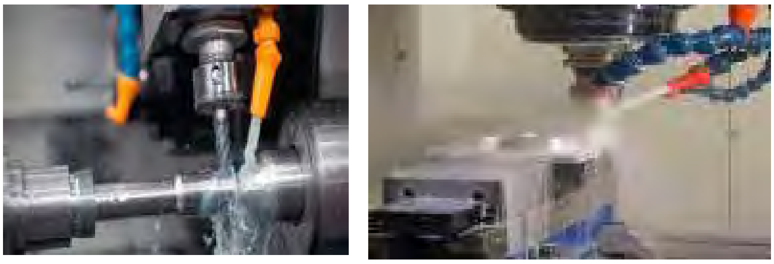


Fig. 1.7.19 Metal cutting fluids

Straight mineral oil: Straight mineral oil is the coolant which can be used undiluted. For example, kerosene, which is straight mineral oil widely used as a coolant for machining aluminium and its alloys.

Chemical solution (synthetic oil): These consist of carefully chosen chemicals as dilute solution with water. They possess good flushing and cooling action, and are non-corrosive and non-clogging. Hence, they are widely used for grinding and sawing. They do not cause infection and skin trouble. They use artificially coloured.

Fatty oil: Lard oil or vegetable oil are fatty oils. They are used on heavy duty machines with less cutting speed. They are also used on bench-works for cutting threads by taps and dies.

Soluble oils (emulsified oil): Water is the cheapest coolant, but it is not suitable because it causes rust on ferrous metals. An oil called soluble oil is added to water which gets a non-corrosive effect with water in the ratio of about 1 : 20. It dissolves in water giving a white milky solution. Soluble oil is an oil blend mixed with an emulsifier. Other ingredients are mixed with the oil to give better protection against corrosion and help in the prevention of skin irritations. Soluble oil is generally used as a cutting fluid for centre lathes, drilling, milling and sawing.

Exercise

I. Answer the following questions.

1. Name the different types of cutting fluids used for ferrous metals.

   ----

2. Name the different types of cutting fluids used for non-ferrous metals.

----

3. State the function of cutting fluids.

----

4. What are the key properties of cutting fluids?

----

5. What is the mixing ratio of water in soluble oils?

II. State whether the following statements are True or False.

1. Kerosene can be used as a coolant for machining aluminium and its alloys.

   True ☐ False ☐

2. Cutting fluids are to reduce the friction between chip and the tool face.

   True ☐ False ☐

3. Good cutting fluids have sufficient viscosity.

   True ☐ False ☐

4. Blended or compounded oil is used in automatic cutting lathes.

   True ☐ False ☐

5. Fatty oil is also called vegetable oil.

   True ☐ False ☐

Notes

1.7.4 Different Typess of Thread and its Plumbing Applications

At the end of this topic, you should be able to:

1. define different types of thread on pipe and its application in plumbing work
2. produce different types of threads on pipe with different methods of production
3. name the types of equipment used for threading of pipes
4. recognise on different instruments used in plumbing.

Pipe thread types

There are six types of threads commonly used on pipe / tube Fittings. (ASMEB 16.11)

- UN / UNF – Unified Fine
- NPT / NPTE – (National Pipe Thread)
- BSPP – (British standard pipe parallel thread)
- BSPT – (British standard pipe taper thread)

Manufacturers follow pipe thread industry standards. The two main pipe thread standards are

1. NPT – National pipe thread
2. BSP – British National Pipe Thread

Plumbing plan – blue print reading: Plumbing plan describes the piping systems and plumbing fixtures. The term blueprint will be used when referring to drawings. Ability to interpret drawings and specifications for a building is absolutely necessary if fitters are to do their work correctly. In most cases, the location of the plumbing fixtures and the basic layout of the piping system will be shown on the drawing. It is the fitter's responsibility to interpet the drawings and install the plumbing system according to the plan.

Plumbing symbols: Plumbing symbols are used on the working drawings or sketches. The fittings are shown by symbols. The symbols are used for representing elbow, valves, unions, reducer, etc. These symbols should be recognised to locate fluid supply systems on drawings. A model assembly of pipe fitting arrangement is shown in Fig 1.7.20. Observe the symbols and interpret the drawing.

Fig 2

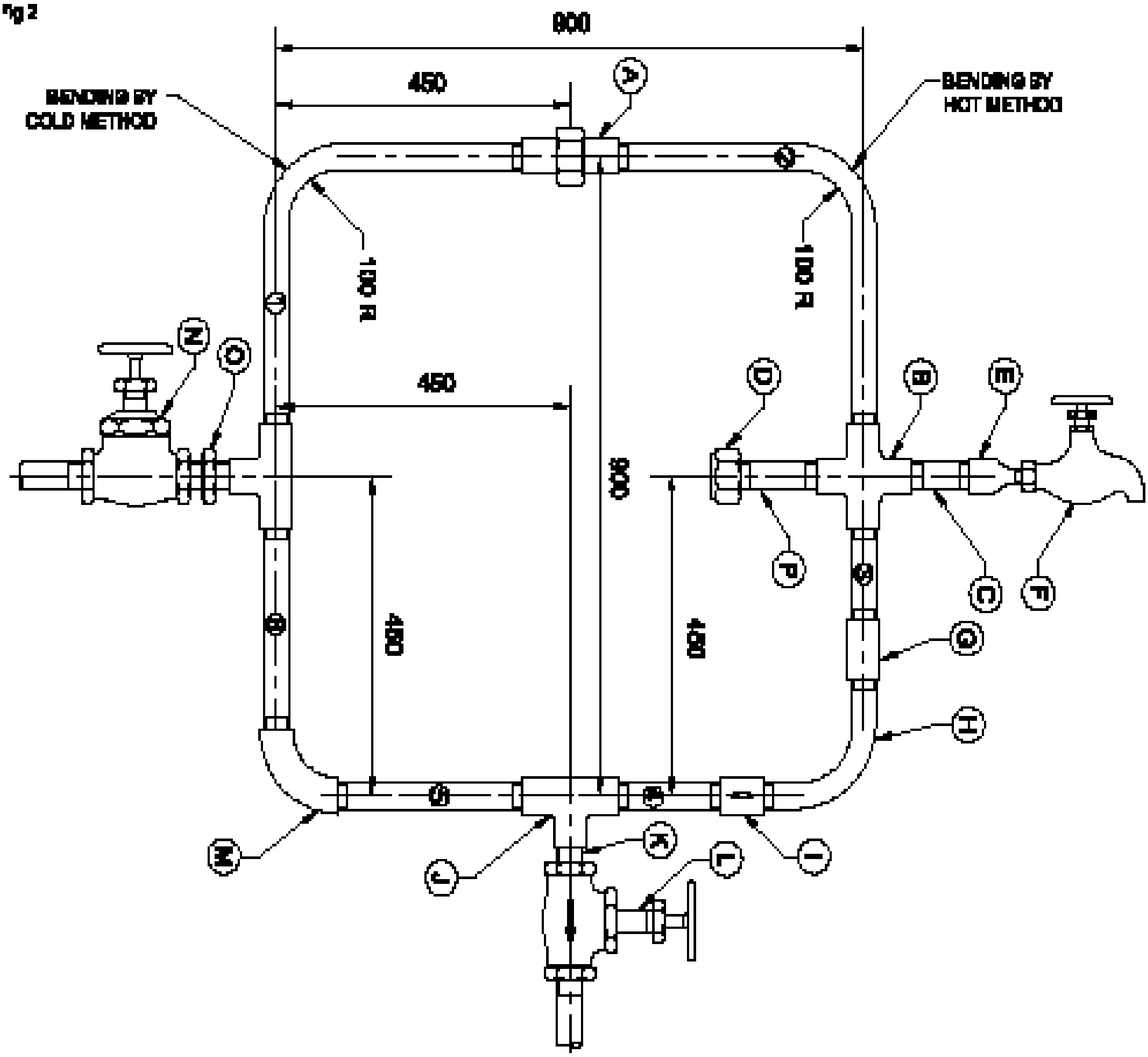


Fig. 1.7.20 Plumbing plan Drawing

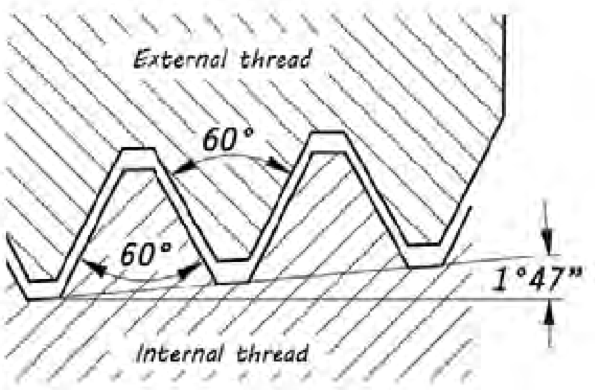
1	[illegible]	[illegible] NIPPLE	G.I		P	
1	[illegible]	HEXAGONAL NIPPLE	G.I		Q	
1	25mm	GATE VALVE	COPPER ALLOY		N	
1	25mm	ELBOW	G.I		M	
1	25mm	GLOBE VALVE	COPPER ALLOY		L	
1	[illegible]	BARREL NIPPLE	G.I		K	
2	25mm	TEE	G.I		J	
1	25mm	[illegible] COUPLING	G.I		I	
1	25mm	BEND 90°	G.I		H	
1	25mm	PLAIN COUPLING	G.I		G	
1	1/2 inch	GAS COCK	BRASS		F	
1	[illegible]	REDUCER	G.I		E	
1	25mm	CAP	G.I		D	
1	[illegible]	BARREL NIPPLE	G.I		C	
1	25mm	CROSS	G.I		B	
1	25mm	UNION (WITH WASHER)	G.I		A	
1	Ø 25 x 4.05 - [illegible]	PIPE (CLASS B)	G.I		6	
1	Ø 25 x 4.05 - 410	PIPE (CLASS B)	G.I		5	
1	Ø 25 x 4.05 - [illegible]	PIPE (CLASS B)	G.I		4	
1	Ø 25 x 4.05 - 300	PIPE (CLASS B)	G.I		3	
2	Ø 25 x 4.5 - 150	PIPE (CLASS B)	G.I		1 & 2	[illegible]
NO.OFF	STOCK SIZE	DESCRIPTION	MATERIAL	REMARKS	PART NO.	EX. NO.

NPT thread (American National Pipe Thread): National pipe thread tapered is the best known and most widely used connection where the pipe threads provide both the mechanical joint and hydraulic seal. NPT has a tapered male and female thread which seals with thread tape or adhesive compound.

British Standard Pipe Thread (BSPT): The joint is made self sealing by thread cutting on at least one of the threads on a tape (usually the male thread). This is known as the British standard pipe thread and has been adopted internationally for interconnecting and sealing pipe ends.

Sealing a tapered thread

For pipe fitters, it is more convenient to know how many turns to make by hand and how many with a wrench. A simple rule of thumb for installing tapered pipe threads is finger tight plus remaining turns with a wrench when standard torque specification cannot be generically applied.



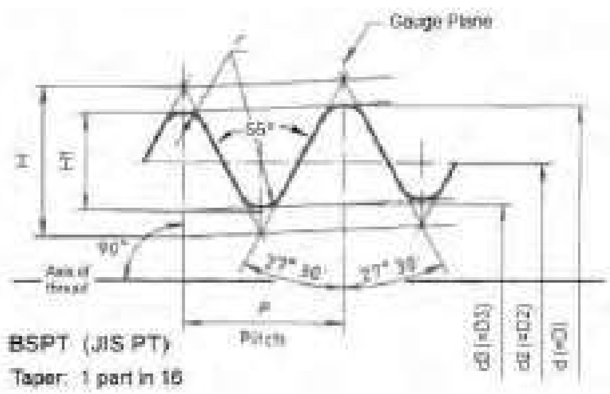


Fig. 1.7.21 NPT and BSPT Thread

Table 2

	British BSP		American NPT		
Nominal Size	Actual OD	Threads per inch	Actual OD	Threads per inch	Turns for a hand tight joint
1/8”	0.383”	28	0.405”	27	3.3 turns
1/4”	0.518”	19	0.540”	18	3.1 turns
3/8”	0.656”	19	0.675”	18	3.3 turns
1/2”	0.825”	14	0.840”	14	3.4 turns
3/4”	1.041”	14	1.050”	14	3.7 turns
1”	1.309”	11	1.315”	11.5	3.7 turns
11/4”	1.650”	11	1.660”	11.5	3.8 turns
11/2”	1.882”	11	1.900”	11.5	3.8 turns
2”	2.347”	11	2.375”	11.5	3.9 turns

Pipe threading equipment

Manual equipment used for threading pipe, External pipe threading machine, Internal pipe threading machine.

Manual pipe threading equipment: Handheld threading equipment is made of a stock to which the handles are attached and in which cutting die is inserted. There are two sets of set screws on the stock–one set for holding the dies in place and the other set for adjusting the dies. On the stock, there is a deep mark to correspond with the standard thread mark on the dies. On the opposite side of the stock, there is a place for pipe fitter / turner, which helps to guide the cutting dies onto the pipe that is to be threaded.

Portable hand held threading machine: Portable handheld threading machines are light weight and are ideal for plumbers. They can thread pipe from 1/8” to 2” in diameter.

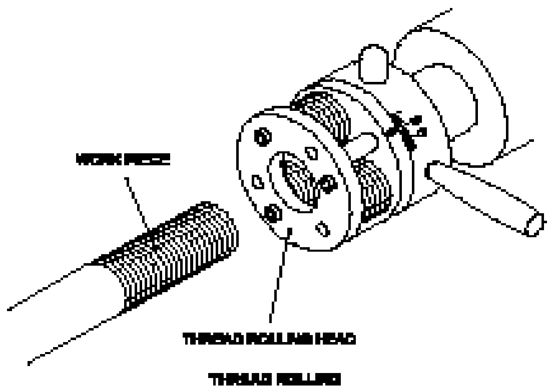
Methods of producing External threads: External threads are generally manufactured by using a single point tool with self opening die heads and by thread rolling heads.

Self-opening die heads: Self-opening die heads are most commonly used in the thread manufacturing process. They are made in a wide range of sizes for producing threads up to about 100 mm diameter.

Fig. 1.7.22 Different type of theading machine

In addition to dies / chasers for standard threads, many dies / chasers for special threads are also available. The die head is fed to the work by the operator which then allows it to feed itself along the work, and follows up with the turret. The turret stop is set slightly short to the thread length. When the die head movement is stopped by the turret stop, the front portion of the die head continues to feed forward under the self-feeding action until it is pulled clear of the detent pin. Long accurate threads need a positive method of feeding the die head over the work. On capstan lathes, this is achieved with a hexagon turret, lead-on attachment. If the machine is equipped with a cross-slide and the thread chasing attachment, the cross-slide is linked to the hexagon turret to provide positive lead.

The markings on the die piece indicate the die type thread diameter - die number, thread relieved on the leading side and slots to locate the die in the die head.



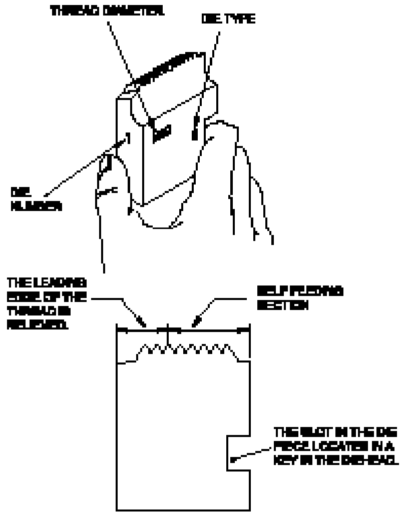


Fig. 1.7.23 Thread rolling heads and c

Threading oils: Threading oils are used to cool and lubricate the cutting die and workpiece. The use of threading oils assists the threading process for the following reasons:

1. keeping the threading dies and the workpiece at a stable temperature.
2. Increasing the life of the cutting dies by lubricating the working edge.
3. Reducing the threading torque and speeding metal removal.
4. Preventing rust on the threading dies and on the machined threads.

Sealing tape: BSPT fittings and NPT threaded pipe and ends must be made leak-free with the aid of thread seal tape. The most common pipe thread tape is polytetrafluoroethylene (PTFE) tape. Pipe thread tape prevents seepage and reduc thread damage.

Threading sealants: There are different types of sealant for different applications depending on the type of pipe and service conditions.

Fig. 1.7.24 Sealing Tape

Fig. 1.7.25 Threading sealants

Internal threads are cut using 2 types of tools single point thread cutting tool and solid tap.

Internal threading by using a single point thread cutting tool: Threading with a single point tool is usually carried out on large workpieces or when special threads are required. The tool may be mounted either on the hexagon turret or on the square turret fitted to the cross-slide. A threading drive accessory is fitted to the lathe, which enables the tool to be fed along the work at the appropriate rate for the desired pitch. Several cuts are normally made, each slightly deeper than the previous cut, until the thread depth appropriate to the selected pitch is obtained. The threading tool is normally held in a bar mounted in a slide tool-holder.

Solid taps:

Solid taps are used for small diameter threads. They are usually spiral fluted. The tap is fitted to the hexagon turret in a special tap-holder. The holder is designed to release the tap automatically at the end of the cut, permitting the tap to rotate along with the workpiece.

The procedure for cutting the thread is as follows: Move the turret to the workpiece and start the tap in the hole by exerting pressure on the turret drive hand wheel. Keep slight forward pressure on the turret drive to prevent the tap from pulling the turret along as the thread cutting operation progresses. This precaution will prevent distortion of the thread and excessive forward drive pressure will also distort the thread.

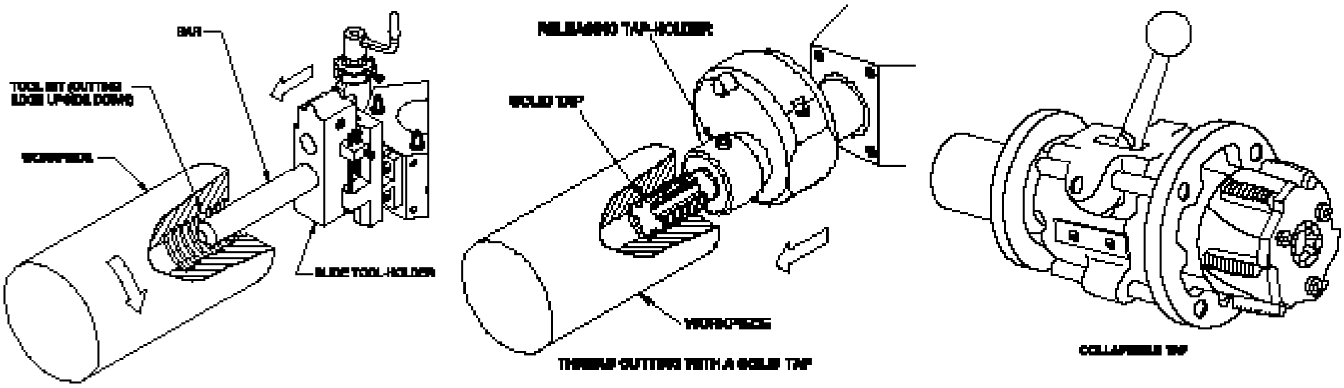


Fig. 1.7.26 Threading and taping

Forward motion of the tap should be stopped first before it reaches the end of the hole being threaded. When using the hexagon turret, this distance is set with the turret stop. When the stop is reached by the advancing turret, the automatic release operates, releasing the tap and allowing it to revolve with the workpiece.

Reverse the headstock spindle rotation to drive the tap back out of the threaded hole.

Screw thread measurement (gauges): The selection of measuring instruments used for checking the threads depends very much on the accuracy requirement and the feature of the thread to be checked. The accuracy requirement varies from a bolt used in structural work to threads of a fine measuring instruments. The surface of a screw has a complex shape. The following elements of a screw thread are to be considered in thread measurement–major diameter, minor diameter/root diameter, pitch, effective, diameter, thread angle, form of root and crest. They contribute to the strength and interchangeability of the threads. The most important elements to be checked are the pitch of the thread, the angle and, the effective diameter.

Screw pitch gauge: This gauge is mainly used to check the pitch of external and internal threads. This consists of a number of blades with accurate notches made to the profile and pitch of the thread. The decision about the correctness of the pitch is taken by comparing them by placing the appropriate blade on the screw. Each blade has an indication about the size of the screw and the pitch.

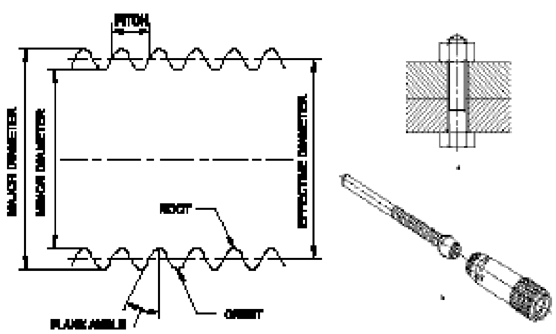


Fig. 1.7.27 Screw thread method

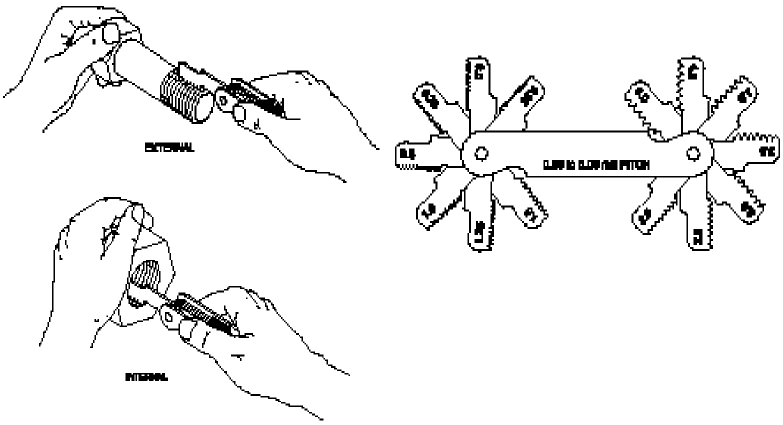


Fig. 1.7.28 Screw pitch gauge

Thread gauges:

The screw thread plug gauge is used to check the internal thread. It checks whether a thread dimension is within its tolerance. The 'Go' side of the gauge checks the following the profile angle (β), the pitch (P), the major diameter (D), the effective diameter (D_2), the minor diameter (D_1).

Thread ring gauge: This is used to check the external thread for its accuracy. Go No Go gauges are used to check whether the thread is within tolerance.

(**Screw thread caliper gauge):** This is used for checking external threads. This gauge is a highly efficient type. This finds greater usage than the ring gauge for checking external threads. In this, the external threads are gauged with a caliper type gauge with two sets of anvils representing the Go and No Go conditions. The Go anvils have full thread form and are set to ensure no element of the thread is oversize. The No Go anvils have truncated thread form to ensure that the contact is made only on the flanks of the thread and checks that the effective diameter of the workpiece thread is not undersize. The gauges are adjustable and are set by means of master setting plugs. The gauges can be used for right or left hand threads.

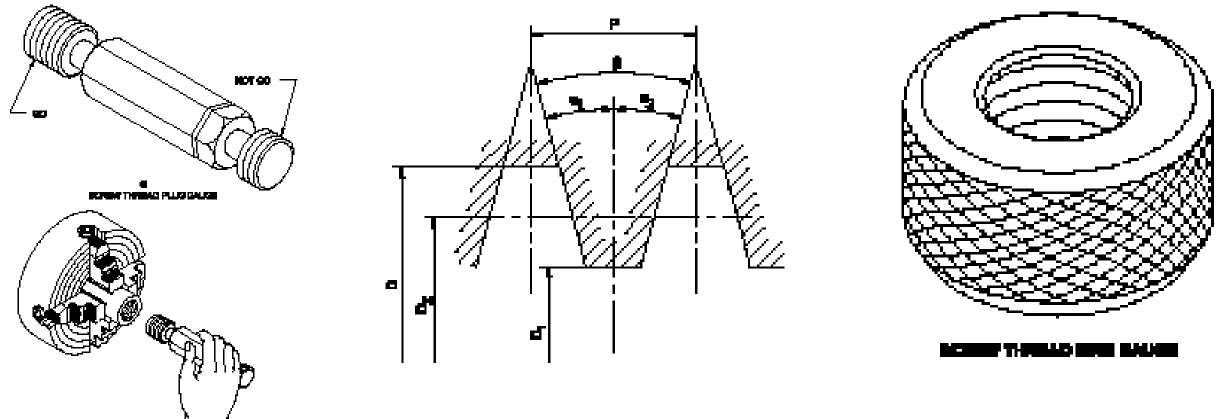


Fig. 1.7.29 Different Thread gauge

General safety precautions for pipe threading

1. When operating pipe threading equipment, the operator should be properly trained and monitored and observed by supervisor.
2. Do not allow untrained persons to operate threading equipment.
3. Wear IS / ANSI approved safety goggles and heavy duty work gloves during threading operation.
4. Keep hands, fingers, feet away from the threading machine during operation.
5. Keep working area clean, tidy and free from unrelated materials.

Assembling the threaded pipe joints

Tools and equipment required to complete a threaded pipe joints include pipe vice, pipe cutter, threading die, reamer, set of pipe wrenches, cutting fluid and sealing tape.

Fig. 1.7.30 Threaded Pipe Joint assembly

Assembling the threaded pipe joints: The threaded pieces are joined together using couplings or fittings and suitable sealing materials must be used on the threads at each joint. This can be either teflon tape or a pipe thread sealing compound. With the sealing material in place, hand tighten the pipe and fittings. Then, using pipe wrenches, one on the pipe and one on the fittings, tighten one and a half more turns.

Pressure testing of threaded piping system: Pressure testing of threaded piping system should normally be carried out by using compressed dry air, and then only under carefully controlled conditions. A pneumatic leak test with a soap bubble test at all joints should be performed.

Tips

1. Prior to execution of the test the supervisor / pipe fitter should ensure that all test gauges are calibrated in accordance with proper procedure and National / International Standards.
2. The maximum test pressure shall not exceed 1.5 times of the maximum system operating pressure.

1.7.5 External Pipe Threading and Assembly

At the end of this exercise, you will be able to:

1. perform measuring, marking and cleaning
2. carryout hacksaw cutting and deburring
3. perform external threading by manual (NPT) type
4. assemble the threaded pipe with fittings.

Practical

Requirements		
Tool/Instruments		**Materials / Components**
Measuring tape Pipe vice, Pipe cutter		Sealing Tape Sealing compound
Tri square, Reamer Set of pipe wrenches **Equipment/Machines**		Require pipe size –1” – 1 meter length 1” – Tee, coupling 1” – Elbow 90°, 45° – EA
Personal protective equipment	1 - set	1” – CAP – 1 1” – union
Manual threading equipment	- 1No.	1” – Cross 1” square Edge plug

Select the required piping materials as per drawing.

- Check the diameter and thickness of the pipe with the help of vernier caliper.
- Carryout marking with the help of scriber.
- Hold the pipe with the pipe vice and cut manually with the help of hacksaw and frame.
- Check the dimension of the cut lengths.
- Choose an appropriate die set for external threading.
- Hold the pipe with pipe vice and start threading (NPT type) is the proper sequence
- At the time of threading thread the protective gap at both the ends.
- Check the threads using calibrated thread gauges (ring gauge).
- Place a temporary thread protective gap at both the ends.
- Apply thread sealing tape/sealing compound.
- Hand tighten the pipe and fittings using pipe wrenches.

Fig. 1.7.31 GI – piping threading and assembling

Safety : Use appropriate personal protective equipment (PPE's)

Exercise

I. Answer the following questions.

1. How many type of threads are used on pipe / tube Fittings?
2. Name the two main pipe thread standards that are most commonly used.
3. Name the three types of pipe threading equipment.
4. Name the pipe thread tapes and sealents used to reduce seepage.
5. Name any two thread measuring gauges.
6. List tools required to complete thread joints.

II. State whether the following statements are True or False.

1. NPT stands for National Pipe Threading and is the most widely used type in plumbing.
   True ☐ False ☐
2. Threaded piping is commonly used in low pressure piping system and non-critical applications.
   True ☐ False ☐
3. Portable handheld threading machines are ideal for plumbers and they can thread up to 2" Inch, diamter Pipe.
   True ☐ False ☐
4. Threading oils are used to cool and lubricate the cutting and work piece and increase life of the Cutting Tool.
   True ☐ False ☐
5. Threading machine allow the threading process to produce uniform pipe threads.
   True ☐ False ☐

Notes

1.7.6 Fitup, Assembling and Alignment of Piping Work

At the end of this topic, you shall be able to:

1. explain marking, measuring, cutting and edge preparation
2. define pipe fittings and flanges, piping class
3. recognise up pipe and alignment sequence
4. produce pipe work assemblies and subassemblies using approved piping drawing
5. check dimension with approved drawing.

Measuring, marking, cutting edge preparation and cleaning

Introduction to pipespools fabrication

The word pipe - spool is a unit of prefabricated piping consisting of pipe, fittings, flanges and other components integral to the assembly. This piping is assembled and welded in the shop and transported to the construction site for installation.

All pipe spools fabrication, installation / assembly shall be performed with reference to approved construction drawings. All procedures and inspection and test Plans (ITPs) requirements shall be followed and met. Pipe spools may be fabricated in shop or site or in the actual installation field. It is recommended to perform pipe spool prefabrication due to many advantages as discussed below.

The shop fabricated spool will include all branch connections for field piping, up to the first field butt weld, first field socket weld, first screwed connection or first flanged joint including the first flange.

Pipespools in all sizes of butt welded and socket welded construction will be prefabricated in the shop.

Quality of the work is easier to manage and maintain in a controlled environment. High accuracies on specified tolerances will avoid rework at the site.

Weather independent fabrication will minimize production delays. Better control on welding parameters in controlled environments will result in lesser probability of rework at the site.

Prefabricated Spools are the perfect answer to severe skill and labour shortage. Users do not have to mobilize significant workforce for fabrication of spools on site and Mass production will result in lower manufacturing costs compared with site fabrication.

Prefabricated spools will take lesser fabrication / assembly time, thereby avoiding time and cost overruns.

Checking calibration status of measuring equipment: All pipe spools assembly / installation shall be performed and checked with calibrated monitoring and measuring equipment. All monitoring and measuring equipment will have calibration certificate / calibration sticker. Calibration certificate / sticker shall be verified for calibration date and calibration expiry date. If calibration has expired, those equipment shall not be used, till recalibrated and validated.

Measuring, marking, cutting and edge preparation:

Cleaning: The pipe and fitting surface shall be cleaned using a stainless steel wire brush for a distance of 25mm up the bore and on the outer surface. The ends shall be completely dry before the fitup.

Measuring and marking: Measuring and marking shall be done accoriding to drawing requirement and the same - shall be checked prior to cutting.

Cutting: The cutting shall be generally done as follows:

1. carbon steel pipes by gas cutting saw cutting and grinding
2. alloy steel pipes by grinding or flame cutting or saw cutting
3. stainless steel pipes by grinding or plasma cutting
4. based on spool breakdown of piping isometric, pipe length shall be cut with extra length pipe for field adjustment
5. before cutting the pipe, heat number will be transferred to the cut pieces by low stress dye stamping, paint marking or tagging
6. end / edge preparation shall be done by grinding or machining cutting method in according to drawing and approved welding procedure specification.

Fig. 1.7.32 Image for Measuring and Marking

Fig. 1.7.33 Image for Cutting and Edge Preparation

Pipe bending

In general, pipe bends manufactured at factory / vendor premises shall be used as bending is performed under controlled conditions and supplied after appropriate heat treatment. Field pipe bending shall be avoided. Pipe bending shall be carried out in pipe bending machines or presses using formers as required by project specification, approved procedure. Cold bends to a centerline radius greater than five (5) times the nominal pipe diameter may be manufactured / fabricated. Cold bends to a radius less than five (5) times the nominal pipe diameter is generally not allowed.

Pipe fitup and alignment

1. Pipe end shall be beveled and cleaned prior to fitup and placed on pipe stand / pipe support and eusured that supports are secured properly.
2. Welding / fusion faces may be prepared by chipping, machining or grinding. They shall be smooth and free from defects such as gas-cut notches / undercuts, gas-cut slags, scales / oxides. Joining faces together with the adjacent material shall be thoroughly cleaned of oil, grease, paint and shall be free from all rust, scale, etc for a distance of about 25 mm from the edge of the weld.
3. Pipe fitter should check the pipe ends inside and outside for damages, dents, contamination, etc.
4. Pipe to pipe beveled ends should be set up and correctly spaced according to drawing and approved welding procedure specification (WPS).
5. External alignment (tools) clamp should be used for alignment and to reduce misalignment by the use of clamp and rotation of pipe to the best fit.
6. For pipes of same nominal wall thickness, offset misalignment shall not exceede 1.6mm.
7. In general, shop welds are identified as W1, W2, etc., and construction / installation field welds are identified as "FW". All weld numbers and welder's identification numbers shall be marked / painted close to the weld, to enable traceability of each weld and welder.

Fig. 1.7.34 Pipe Fitup and Alignment

8. All attachments to piping – saddles, pads, etc., are to be made of same material as that of the pipe.
9. Tack welds shall be removed so that they do not form part of the finished weld unless they are produced by fully qualified and tested welders to the same procedure as the finished weld, in which case they may be absorbed into the finished weld.
10. During welding, flange faces shall be protected to keep free from weld spatter and arc strike.

Pipe to pipe fitup and alignment

1. Align the pipe or pipe as closely as possible and hold it the correct position.
2. For butt-welding of all piping components (pipe ends, fittings and welding neck flanges), a uniform root gap shall be provided as specified in the relevant welding procedure specification.
3. If the pipe contains a longitudinal weld, this weld shall not be located at the bottom of the pipe after installation. It should be located at least 45° from the bottom of the pipe.
4. Longitudinal seams in seam welded pipe shall be located to clear openings and external attachments possible. Longitudinal seams in adjoining courses shall be preferably at 180 degree. The minimum separation between long seams are to be in accordance with construction specification.
5. If required as per drawing, pipes are to be installed with necessary slopes duly ensuring that pipe slopes are maintained in the required direction.
6. Join together with proper root gap and align for straightness without hi-low at the joint.
7. Tack on one side (apply bridge tack method). Tack welding should be done by qualified welder only. On the side opposite to the tack, again align pipe for straightness then open the clamp / joint slightly to allow for shrinkage, then tack.
8. Roll pipe one quarter turn, check for straightness. Open one side slightly and tack.
9. Tack opposite side. Apply bridge tack method with similar grade of pipe by employing qualified welder.
10. Tacks should be in the range of 1/2 to 3/4 of an inch.
11. Squarness should be checked for alignment.

Pipe to elbow fitup and alignment: The proper fitup of a small diameter elbow is not as critical as two pipe section which must be straight, due to the small size and ease of allowance for the pipe which must butt onto the other end of the elbow. The difficulty in fitting up the pipe on the other end of the elbow seams to increase proportionately with the increase in diameter.

1. Align pipe and elbow with proper root gap.
2. Check hi-low at joint area and ensure that it does not exceed 1.6mm.
3. Tack on top side (apply bridge tack method by employing qualified welder).
4. Again align, then open up bottom slightly to allow for shrinkage.

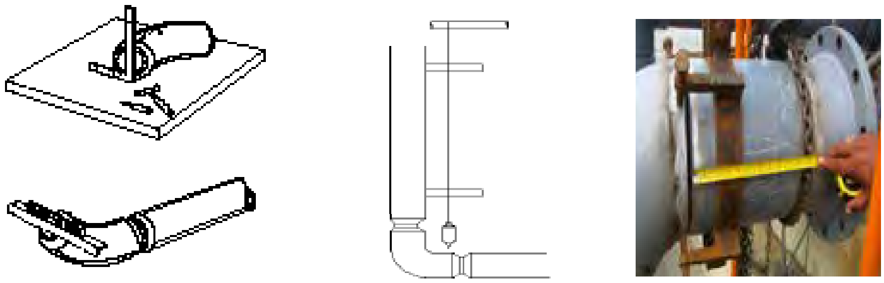


Fig. 1.7.35 Pipe to Elbow Fitup and Alignment

5. Check root gap and tack weld at the bottom.
6. Check orientation and squareness prior to welding.

Flange fit-up orientation: Flanges can be installed with bolt holes oriented in "on Centre" or "off centre". Unless otherwise specified, all flanges shall be fit and aligned in "off centre". Off centre holes shall straddle the centrelines / axis.

Pipe to flange fit up orientation

For fitup flange to pipe, three things have to be watched at the time of fitup.

1. Any damage to the gasket seating surface, would prevent gasket seating. The flange should be replaced, if damage is severe.
2. Root gap, hi-low orientation and level of holes should be checked prior to tack weld.

Fig. 1.7.36 Pipe to Elbow Fitup and Alignment

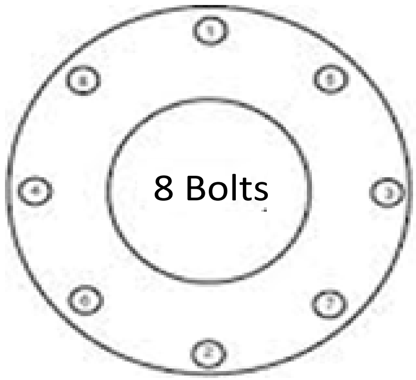


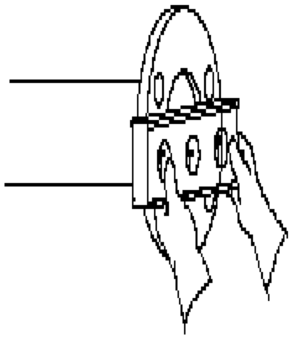
Fig. 1.7.37 Flange orientation – On centre.

3. Tack weld on top side (apply bridge tack method by employing qualified welder).
4. Align bottom, with required root gap, then open slightly to allow for shrinkage. A square or a vertical spirit level should be used to check squareness.
5. Tack weld on bottom side (apply bridge tack method by employing, qualified welder).
6. Using a square on the sides, check squareness of flange, then tack weld both sides duly ensuring proper root gap, alignment, squareness and orientation.

Small diameter pipe jig: Jig made of channel is helpful in aligning small diameter pipe and elbows. Layout a 90° notch on both sides and channel and cut out to form a 'V' heat and bend to a 90° angle and weld.

Pipe to tee fitup and alignment

1. Align pipe end with equal tee or unequal tee.
2. Check hi-low at joint area.
3. Tack on top side joint (Apply bridge tack method by employing qualified welder).



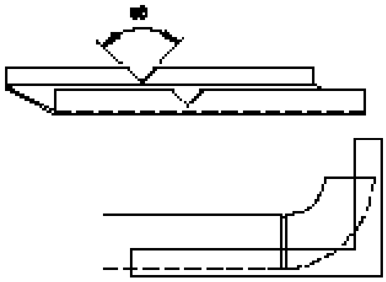



Fig. 1.7.38 Pipe to Flange Fit up and Alignment *Fig. 1.7.39 Pipe jig and fixture*

4. Again align, the open up bottom slightly to allow for shrinkage.
5. Check root gap and tack weld at bottom side of the joint (Apply bridge tack method by employing qualified welder).
6. Check orientation and squareness prior to welding.

Dimensional and alignment checks for piping assembly: All Fabricated piping spools shall be checked with issued fabrication / construction drawing (IFC) for the following:

1. Fitup tolerance for length, depth, orientation and straightness of piping members.
2. Piping elevation and degree of levelness and the date of inspection shall be marked near to the joint with metal paint marker.
3. Flange alignment and hole orientation should be checked.
4. All butt welds should be spaced at a minumun of 50 mm or four times the wall thickness or whichever greater.
5. Care should be taken to ensure that the longitudinal welds clear form the branch connection.
6. Line number, component heat number, joint number, date of fitup, etc., shall be marked near to the joint with metal / paint marker pen
7. Spool number shall be marked with paint marker and aluminum tag will be tied with the spool.
8. Fitup and visual acceptance status, signature and date of instpection shall be marked near the joint with metal paint marker.

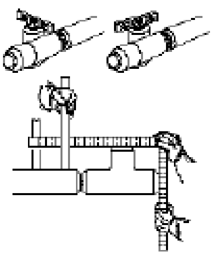



Fig. 1.7.40 Pipe to Tee Fitup and Alignment *Fig. 1.7.41 Stainless Steel and Duplex Stainless Steel Pipe spools*

Stainless steel and duplex stainless steel pipe fitup and alignment

In addition to the above:

1. stainless steel pipe fitup should be done in the shop with an isolated / segregated area from carbon steel and alloy steel piping materials.
2. No tools and tackles, equipment shall be used for SS, DSS which has been used for CS. All tools and equipment dedicated to SS, DSS work should be clearly marked for stainless steel only.

3. eor stainless steel, duplex steel materials, stainless tools will be used for grinding, brushing and clamping, alignment pipe to pipe, pipe to elbow, pipe to flanges, etc.

Fabricated spools protection: Pipe fitter must provide adequate protection for piping, flange faces, threaded connections, etc. to prevent damage during handling and storage. Pipe fitter shall ensure that flange faces are protected from corrosion or rust. Pipe ends and flange faces shall be properly protected against the ingress of dirt, mechanical damage and atmospheric corrosion. The term pipe end shall include any weld preparation. The pipe protection applied shall not be capable of passing into the bore of the pipe.

Threaded connections shall be fitted with a line class plug or covered with a plastic sheet securely wired or taped to the spool. Socket weld connections shall be fitted with taped polyethylene plugs or plastic sheet securely tied with wire or taped to the spool. All flange raised facess of completed piping spools should be fitted with plywood blinds for protection and spool ends shall be fitted with proper caps.

Dimensional Tolerances

1. ± 3mm maximum from the indicated dimension for face to face, centre to face, location of attachment, etc.
2. ± 3mm maximum lateral deviation of branches or connections.
3. ± 1.5mm maximum rotation of flanges from indicated position measured.
4. ± 0.8mm out of alignment of flanges from the indicated position measured across any diameter.
5. Tolerances on dimensions which do not include pipe segments are to be based on ANSI specifications for fittings and / or flanges.Unless otherwise specified, in drawing or procedure or specification, the spools / piping shall be fabricated within the dimensional tolerances specified.

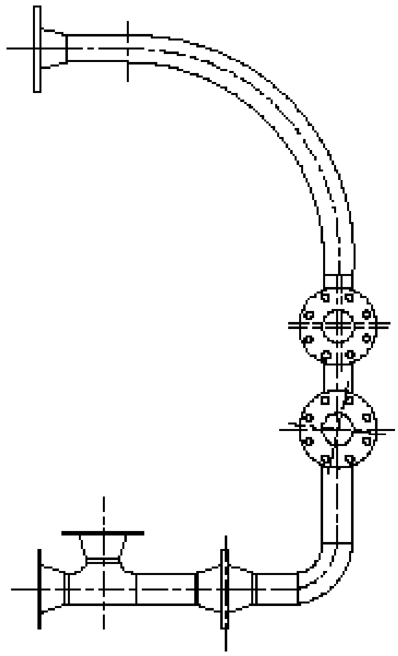


Fig. 1.7.42 Dimensional and alignment checks for piping assembly

1.7.7 Pipe Spool Fabrication

At the end of this exercise, you will be able to:

1. list the type of tools and equipment in common use in the pipe fitting application
2. identify and list the piping materials and fittings required for piping spools, fitting, assembly
3. carryout pipe fitup alignment and dimensional check.

Practical

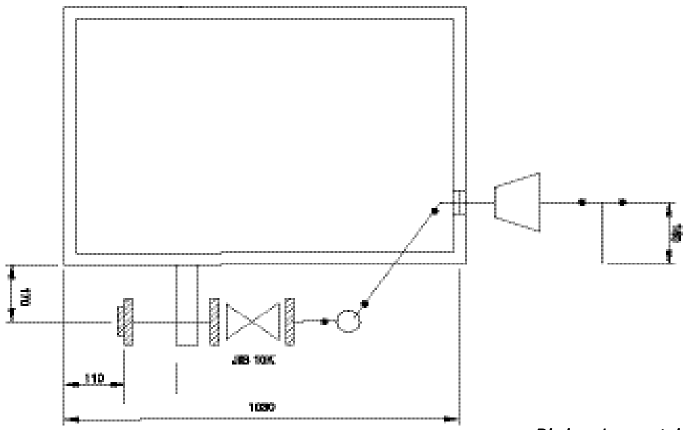
Requirement	
Tool/Instruments	**Materials / Components**
Measuring Tape – 1 No.	1. ASTM 106 Gr B Carbon steel 2”ϕ pipe - 2 mtrs
Tri square – 1 No.	2. ASTM A 106 GrB – 3 ”ϕ pipe - 1 mtr
Spirit level – 1 No.	3. ASTM A 105 N 2” – WNRF/SORF/Flange - 0.5 mtr
Bevel protractor – 1 No.	4. 2” – WNRF / SORF / Flange - 2 Nos
C - Clamps, wire brush – 1 No.	5. 150 class - 3 Nos
External alignment clamp – 1 No.	6. 2” – Elbow – CS – 90° - 1 No.
Lever bar, file - flat – 1 No.	7. 2” – Elbow – CS – 45° - 1 No.
Ball peen hammer – 1 No.	8. 2” x 3” – Reducer ECC - 1 No.
Spark lighter – 1 No.	9. Bolt & nut M12 x 45mm - 8 set
Bench vice – 1 No.	10.Gasket (Spiral wound Gasket-SWG) - 50mm
Equipment / Machines	11.Gate valve 2” ϕ - 1 No.
Personal protective equipment (PPE)	12.Fire extinghuser - 1 No.
Grinding machine – AG4 – 1 No.	13. First-aid kit - 1 No.
Beveling machine/cold cutting – 1 No.	
oxy acetyline cutting equipment – 1 No.	
With the relevant accessories	

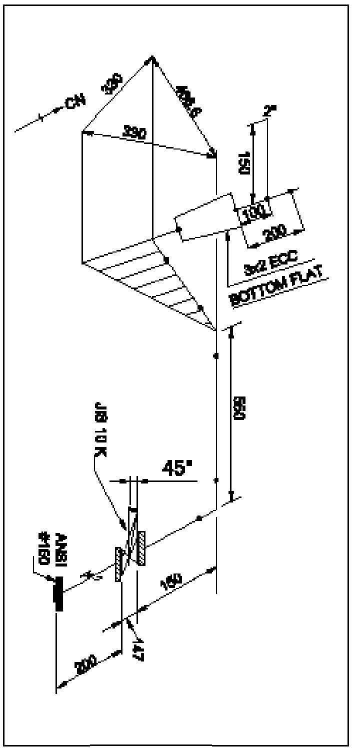
Tips

1. All dimentions are in mm.
2. With the materials given, trainee is required to fabricate the piping according to given dimensions.
3. Pipe fabrication and installation shall be in accordance with the relevent Indian standard / ASME standard / customer specification as applicable.

Pipe to flange, pipe fittings to pipe fitup and alignment

1. Flange must be centered with respect to the axis of the pipe and the face of the flange must be perpendicular to the axis.
2. Check the internal surfaces of the flange and the pipe.
3. Place a spirit level against the face of the flange.
4. Deposit first tack welded by the qualified tack welder.





Piping Isometric drawing

1.7.8 Pipe to Pipe Single 'V' Butt Joint Fitup

At the end of this exercise, you should be able to:

1. perform measuring, marking
2. carryout hacksaw cutting and cleaning (deburring)
3. perform edge preparation by grinding, filing as required.

Practical

Requirement	
Tool/Instruments	**Materials/ Components**
Measuring Tape – 1 No.	1. 2" ϕ SCh – 40 cs pipe 500 MM long – 1 No.
Vernier caliper – 1 No.	2. Grinding Disc – 4" ϕ – 1 No.
Steel rule – 1 No.	3. Face shield – 1 No.
Bevel protractor, try square – 1 No.	4. Welding electrode 3.2 – 1 No.
Ball peen hammer – 1 No.	5. Welding hand shield – 1 No.
Scriber – 1 No.	
Flat file – 1 No.	
Hacksaw frame with blade – 1 No.	
Spirit level – 1 No.	
Equipment / Machines	
Personal protective equipment – 1 Set	
AG–4– Grinding machine – 1 No	
200 Amps capacity – welding machine – 1 No with complete accessories	

- Use appropriate PPEs.
- Select the pipe materials as per requirement.
- Remove rust, mill scale and other contamination on either side of the pipe edges.
- Verify the squareness and perform grinding / filing, if needed to ensure squareness.
- Use spacer wire between pipes in order to maintain root gap.
- Align the pipe to pipe without any misalignment / hi-low.
- Position similar grade of bullet pieces within the groove space.
- Check the Diameter and thickness of the pipe using vernier caliper.
- Measuring and marking is to be done as per drawing by using measuring tape and scriber.
- Cut the pipe manually with the help of hacksaw and frame.
- Hold the pipe with bench vice and grind the edges 30° to 35° bevel angle, maintaining 1.5mm root face.
- Set the 2 pipes to form a single 'V' butt joint.
- Use a fixture or V-profile of an angle to align the pipes.
- Switch 'On' the welding equipment and select 3.15mm ϕ electrode for tacking and set current 100 Amps.
- Perform 4 tacks at equal intervals adjusting 2mm root gap.

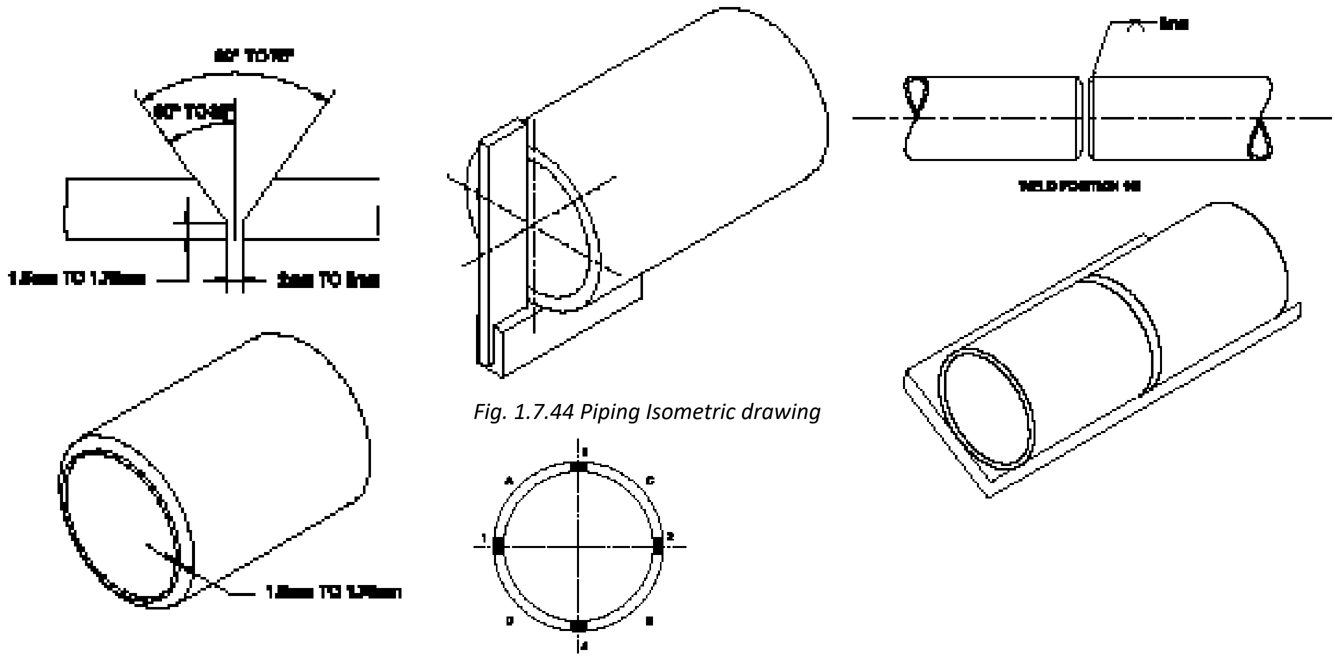


Fig. 1.7.44 Piping Isometric drawing

Safety: Wear appropriate PPE's (Personal protective equipment)

1.7.9 Pipe to Fittings Single 'V' Butt Joint Fitup

At the end of this exercise, you should be able to:

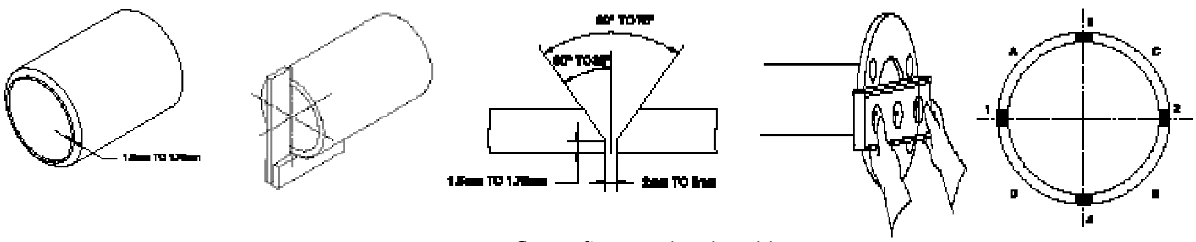
1. perform measuring, marking, cleaning
2. carryout pipe to fittings fitup and alignment
3. check root gap and perform tack weld as required.

Practical

Requirement	
Tool/Instruments Measuring Tape – 1 No. Vernier caliper – 1 No. Try square – 1 No. Spirit level – 1 No. Scriber – 1 No. Flat file – 1 No. Ball peen hammer – 1 No. Hacksaw frame with blade – 1 No. **Equipment / Machines** Personal protective equipment – 1 Set AG–4–Grinding machine – 1 No. 200 Amps capacity – welding machine – 1 No. with complete accessories	**Materials / Components** 1. 2" ϕ SCH – 40 cs pipe 500 MM long – 1 No. 2. 2" ϕ Class # 150 WNRF – 1 No. 3. Grinding Disc – 4" ϕ – 1 No. 4. Welding electrode 3.2 – 1 No. 5. Welding hand shield – 1 No.

- Use appropriate PPEs.
- Select the materials as per requirements (drawing).
- Check the diameter ϕ and thickenss of the pipe using vernier caliper.
- Check the size, ratings of the flanges.
- Measuring and marking is to be done as per drawing using measuring tape and scriber.
- Hold the pipe with bench vice and grind edges 30° to 35° bevel angle maintaining 1.5mm root face.
- Set the pipe with flange to form as a single 'V' butt joint.
- Use a fixture/vice and carryout pipe to flange alignment.
- Check the flange alignment/ off centre using spirit level and Try Square.
- Drilled hole shall straddle the pipe vertical axis centreline.
- Check the squareness of flange and carryout tack weld.
- Place a temporary protective cover on flange faces.





Pipe to flange fit up and tack weld

Safety:

Wear appropriate PPEs (personal protective equipments).

Never saw the welding with bare eyes.

Do not handle, touch hot job/stub end with bare hands.

Exercise

I. Answer the following questions.

1. What are the tools required for pipe fitup and alignment?

   ----

2. What are the cutting process to be used for SS, DSS pipe cutting?

   ----

3. Describe pipe to pipe fitup and alignment sequence.

   ----

4. Explain pipe to flange fitup and alignment sequence.

   ----

5. What are the parameters to be checked for piping assembly?

----

6. How will you protect piping spool end and flange surface?

II. State whether the following statements are True or False.

1. Pipe and fittings should be cleaned externally and internally for a distance of 25 - 50 mm, prior to welding.

   True ☐ False ☐

2. Stainless steel pipes should be cut by plasma cutting.

   True ☐ False ☐

3. For pipes of same nominal wall thickness, offset (hi-low) should not exceed 1.6 mm.

   True ☐ False ☐

Notes

1.7.10 Assembling, Dismantling of Piping Spools and subassemblies

At the end of this topic, you should be able to:

1. perform flanged piping spools assembling and dismantling
2. carryout safe handling of piping spools and their components
3. generate stagewise inspection record
4. return all tools and equipment to the store on completion of the pipe fitting activities.

Flanged piping spools assembling and dismantling

Cleaning: Before erection, all prefabricated piping spools pieces should be cleaned inside. The cleaning process should include removal of all foreign matter such as scale, sand, weld spatter and slag, etc., by wire brushes. Cleaning tools and blowing with dry compressed air may be done. Special cleaning requirements for some services like SS - piping requiring pickling should be used to remove oxidation and discolouring due to welding.

Fig. 1.7.46 Flanged pipe spools

Assembling: While fitting up mating flanges, care should be taken to assemble and align the flanged piping spools and check the flanges for trueness / flatness. Faces of the flanges can be pulled together, without inducing any stresses in the pipe and the sub assemblies. Extra care should be taken for flanged piping spools assembly and temporary protective cover should be provided on flange faces.

Flange bolt-up: In a flanged connection, all components must be correct to achieve a seal. The most common cause of leaky gasketed joints is improper installation procedures. Before beginning a bolting process, the following preliminary steps will help to prevent problems:

- Clean the flange faces and check for scars. The faces must be clean and free of defects (burrs, pits, dents, etc.).
- Visually inspect all bolts and nuts for damage or corroded threads. Replace or repair bolts or nuts, as necessary.
- Remove burrs from all threads.
- Lubricate the threads of the bolt or stud, and the surface of the nut face adjacent to the flange or washer. Hardened washers are recommended in most applications.
- Install new gasket and be sure that the gasket is properly centered. Do not reuse old gaskets not use multiple gaskets.
- Adjust the position of the nuts to ensure that 2-3 threads are visible above the top of the nut.
- Improperly bolted flange includes - bolts that are too short, and the nuts are not completely engaged on the bolts. This means that the joint may not be as strong as it should be. Flanges are designed so that the entire nut-bolt combination holds the forces on the flange. If the nut is only partially screwed onto the bolt, the connection may not be strong enough. This shall be avoided. Ateast one thread shall protrude the nut face.
- Flange leakage test including helium test, snoop test shall be performed as per approved procedure.

Fig. 1.7.47 Insufficient stud bolt length

Expansion joints installation

In general, expansion joints are not allowed in oil and gas piping. Instead, expansion loops are installed. If expansion joints are to be installed, the following instruction shall be followed:

- Check the expansion joint specification and manufacturer recommendations for special instructions.
- Verify to essure expansion joint matches the specified size, material, and capabilities for the application.
- Examine expansion joints including exterior, interior, and flange faces for cuts and gauges. Inspect for damage during shipment–dents, broken hardware.
- Use only designated lifting lugs.
- Review anchors, supports, and alignment guides to assure they meet system requirements. Assure anchors and guides can withstand expansion joint pressure thrusts and spring action rates.

- **Mating flanges:** Install the expansion joint flange against the mating pipe flanges and install bolts so that the bolt head is against the expansion joint flange. Bolts should be installed from the bellows side (so that the bolt heads are adjacent to the bellows) to ensure that the bolts do not interfere with the bellows during periods of compression. Flange-to-flange dimensions of the expansion joint must match the required opening.
- Examine pipe flange faces for roughness and damage. Make sure mating flanges are clean and are matched to the type supplied with the expansion joint. Gaskets of appropriate material, size and temperature ratings must be used in all flange-to-flange type installations.
- Position pipe flange faces to ensure axes are aligned to within 1/8 inch without using excessive force.
- Carefully install the expansion joint to ensure no damage occurs and align bolt holes.
- Install joint with arrow pointing in the direction of flow.
- Support the expansion joint until bolted in place.
- Insert bolts with washers through retaining rings on the arched side of the expansion joint and then through the mating flanges in a cross pattern.
- Attach and tighten nuts (with washers) until it is hand tight.
- Torque each bolt to full torque with the cross-bolt pattern until the outside edge of the expansion joint flange bulges slightly.
- **Bolt torque:** Tighten bolts by alternating around the flange in stages. Never tighten an expansion joint to the point that there is metal-to-metal contact between the expansion joint flange and the mating flange.
- Corrugated expansion joints shall be installed with the length extended or compressed for the ambient temperature condition at erection, depending on anticipated direction and magnitude of movement after the line reaches the operating temperature.
- Make a final check to see that shipping ties have been removed.
- Remove all shipping devices after the installation is complete and before pressure test of the fully installed system.
- Remove any foreign material that may have become lodged between the convolutions.

Installation of gaskets: Various types gaskets are available from different manufacturers. Appropriate gaskets shall be installed based on the purpose and service conditions. Fitter shall not make their own choice. Fitter shall refer to the drawings or consult the supervisor for installing the right gaskets. Joint integrity and tightness depend on gasket installation workmanship. Unless otherwise specific instruction is available, the following installation instructions shall be followed during gasket installation.

- Examine the flange surfaces, fasteners (bolts or studs), nuts and washers to ensure they do not have any defects or damages.
- Ensure the gasket is of the correct size. The inner diameter of the gasket should not be smaller than the inner diameter of the flange.

Fig. 1.7.48 Checking flange faces

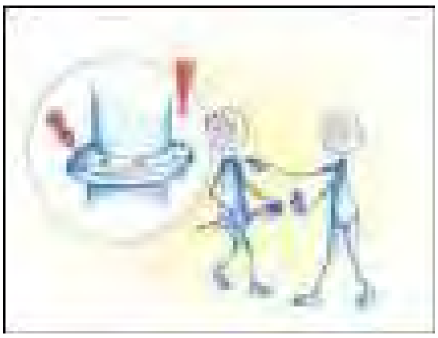


Fig. 1.7.49 Aligning bolt holes

Fig. 1.7.50 Installing gasket

- All types of gaskets should be handled with care. Carry gaskets carefully, ideally in some form of protective cover.
- Protect the surfaces and never bend or write on the gasket.
- Be sure to install the bolts that are designed for the flange are suitable for the given operating temperatures.
- Ensure that there is no corrosion on the bolts as this can affect the function of the bolt.
- Align the flange faces and bolt holes.
- Verify to ensure the gasket is of the specified size and material and ensure that it is free of defects.
- Carefully insert the gasket between the dry flanges.
- Make sure the gasket is centered between the flanges. This is extremely vital, especially, where raised faces are involved.
- Do not use joint compounds or release agents on the gasket or seating surfaces unless specified by the gasket manufacturer as this can lead to reduced surface friction.
- Bring the flanges together ensuring that the gasket is not pinched or damaged.
- Do not contaminate the gasket or the flange surfaces with lubricants.
- Gaskets shall never be reused, as it will not have enough resilience.

Bolt tightening sequence

- The pressure over the gasket shall be uniformly distributed in order to achieve satisfactory sealing. Always use the proper tools such as a calibrated torque wrench.
- Tighten all nuts, initially, by hand.
- Tighten two bolts diametrically opposite to each other to 30% of the required bolt stress.
- Tighten another pair of bolts approximately 90° further round the circumference. Continue until all bolts have been tightened to 30% of the required bolt stress.
- Torque each nut to approximately 60% of the required torque is same sequence is diametrically opposite sequence as the above step.
- Torque each nut to approximately 80% of the required torque is same sequence is diametrically opposite sequence as above.
- Torque each nut to full (100%) torque. Apply at least one final torque to all nuts in the clockwise direction until all torque is uniform.

Dismantling: After the completion of pressure testing, pressure should be reduced and released by opening the vents, till all draining is completed. After draining the piping system, the piping assembly should be dried by dry air and test blinds should be dismantled and the equipment is to be isolated.

Tips

Control valves and instrument should be dismantled. Prior to hydrotest and reinstated after hydrotest.

Check valves in lines 1.5 inch and below flapper or seat should be removed during pressure testing.

Pressure gauges which are part of the finished piping system should be removed.

Temporary protective covers should be retained on all open ends and flange faces until the piping is finally connected to avoid any foreign material.

Bolting should be protected by non-corrosive oil or grease to prevent rusting.

Safe handling of piping components and sub assemblies

1. There are many components that go into producing piping spools subassembly, and equipments. Many of them have critical machined surfaces such as flange faces.
2. Pipe and completed spools should be stored above the ground on wooden pallets.
3. Company / institute is responsible to protect all open ends of pipes and flanges with the use of suitable end caps.
4. Company / Institute should provide adequate and safe lifting slings or similar equipment during handling or lifting operations. When piping spools are lifted by their ends, soft faced hooks should be used.
5. All completed spools should be transported by a method which does not induce significant deformation or stress.
6. Pipe fitter should be familiar with the piping colour coding system.

Piping assembly installation and inspection

1. Pipe fitter may not perform all necessary checks for acceptance purpose. But, pipe fitter shall know all inspection and test requirements and ensure that the respective piping work has been completed as per AFC drawing, approved procedures and inspection and test plans. Pipe fitter shall check first before offering for QC or client inspection.
2. During pipe fit-up, welding, assembly / installation, all stage inspections shall be performed as per approved ITP and stage inspection reports shall be maintained.

Piping assembly / installation inspection include the following but are not limited to

a. Correct materials (quality, rating, size) have been used and installed.
b. Dimensional inspection that shall include length, size, thickness, position, orientation, level.
c. Ensure that all inline instruments / equipment have been installed and comply with AFC drawings.
d. During this check, flow direction is very important. All inline valves, instruments and equipment shall be checked for flow direction and ensure inlet and outlet connections have been made as per approved drawings.
e. Some piping works may require piping installation with slope. Hence, if applicable, pipe slope and direction of slope shall be checked and verified.
f. Ensure that all flanges have been bolted with required gaskets and bolts / studs and nuts. All bolts shall be tightened to the required torques.
g. Stud face shall be outside the nut face. Stud shall protrude at least two threads outside the nut face.
h. Ensure that adequate pipe supports have been installed as required by AFC drawing and specifications.
i. Visual inspection and all required NDT shall be completed and records maintained as required by approved ITP.
j. It shall be ensured that all weld repair works have been completed.
k. All required protective coating shall be completed.

Documentation: Documentation and records are used throughout the manufacturing process and as well as supporting process (quality control) they must meet the basic requirements.

The different types of documentation as per industrial needs include:

1. Material receiving inspection reports
2. Material release note
3. Piping spool fabrication reports (visual inspection report) and production reports
4. Stagewise Inspection Reports

Manufacturing stage inspection report

The format gives the details of the product being inspected showing the details.

Table - 3 Inspection report

Sl. No.	ISO Drawing No.	Weld Joint No.	Pipe Bevel			Pipe Fitup misalignment	Flange alignment	Visual Inspection	Remarks
			Bevel Angle	Root Face	Root Opening				
1.	DRG. No. ONGC / ML / 05 / 62	J1	35°	1.6	2.4 - 3.2	1 MM (max)	ACC	Fitup Accepted	

Return all tools and equipments to the store on completion of shop and field piping work and all subassemblies should be cleaned from the inside and outside by suitable methods ensuring that they are free from all loose foreign materials.

Carryout house keeping: Keep the workarea in a safe and tidy condition on completion of pipe fitting and installation activities.

Advantages of House keeping

1. Helps an Industrial organization to function efficiently. 2. Helps to prevent injuries and improve productivity.
3. Eliminates fire Hazards and controls dust.


Fig. 1.7.51 Good House keeping practice

1.7.11 Gasket Installation, Flange Bolting and Torquing

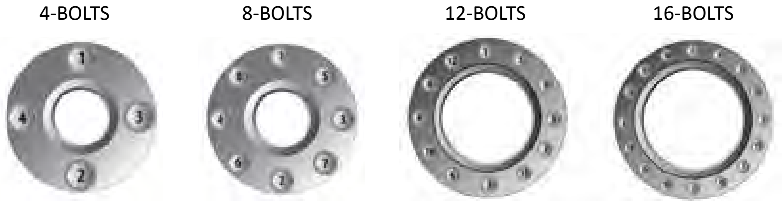
At the end of this exercise, you will be able to:

1. perform flanged piping spools assembling
2. install gaskets, bolt and nuts
3. perform flanged piping spools assembling and bolt tightening in sequence.

Practical

Requirement				
Tool/Instruments		**Materials / Components**		
Measuring Tape	– 1 No.	Pre fabricated flanged piping spools		
Try square	– 1 No.	Gaskets		– 1 No.
Spirit level	– 1 No.	**Equipment / Machines**		
Ball peen hammer	– 1 No.	Torque wrench	– (manual)	– 1 No.
Set of – open end spanners	– 1 No.	Torque wrench	– pheumatic	– 1 No.
Screw driver	– 1 No.	(With calibration certificate)		

- Clean the flange faces and ensure it is free from defects.
- Visually inspect all bolts and nuts for damaged threads.
- Lubricate the threads of the bolt and the surface of the nut.
- Align the flanges duly ensuring parallelity of the raised space. Use feeler gauges and ensure uniform gap is there.
- Ensure that all gaskets and bolting materials have been supplied as per AFC drawing.
- Install the new gasket and be sure that the gasket is properly centered. Do not reuse old gaskets.
- Adjust the position of the nuts to ensure that 2-3 threads are visible above the top of the nut.
- Tighten all nuts initially by hand.
- Tighten two bolts diametrically opposite each other to 30% of the required bolt stress.
- Tighten another pair of bolts approximately 90° further round the circumference. Continue untill all bolts have been tightened to 30% of the required bolt stress.
- Tighten another pair of bolts approximately 90° further round the circumference. Continue until all bolts have been tightened to 30% of the required bolt stress.
- Torque each nut to approximately 60% of the required torque is the same sequence is diametrically opposite sequence as is the above step.
- Torque each nut to approximately 80% of the required torque is the same sequence is diametrically opposite sequence as is the above step.
- Torque each nut to full (100%) torque. Apply at least one final torque to all nuts in the clockwise direction until all torque is uniform.



Tips

Safety

Use appropriate PPE.

Over torquing shall not be performed the it may damage the gasket.

Stud and nut shall not be shorter than the bolt space.

Exercise

I. Answer the following questions.

1. State the name of piping components that are not to be included during pressure testing.

   ----

2. Name the different methods used to protect bolting and flange faces from corrosion.

   ----

3. List the parameters to be checked by pipe fitter during and after fitup work.

   ----

4. Explain the piping assembly process in detail.

----

5. State the advantages of housekeeping.

II. State whether the following statements are True or False.

1. Piping spool end should be protected with suitable cap or cover.

   True ☐ False ☐

2. After completion of pressure testing, the piping assembly should be dried by dry air.

   True ☐ False ☐

3. Control valves and instruments should be dismantled prior to pressure testing.

   True ☐ False ☐

Notes

1.8 Different Types of Joining in Piping and Pipeline

Unit Objectives

At the end of this unit, you will be able to:

1. identify various improper practices while working in the fabrication field
2. importance of personnel protection
3. recognise the important safety rules associated with all phases of welding
4. emphasize the safety standards requirements
5. recognise the various regulations, acts and standards with respect to health, safety and environment.

1.8.1 Pipes Classifications and Joining Methods

At the end of this topic, you will be able to:

1. identify pipe, pipe classification and the material.

1.8.1.1 Pipe Classification

Pipes are classified in different ways based on shape and the intended use. General classifications are:

a Standard Pipe

b Line Pipe: It is used for the transportation of oil, gas and water in cross country pipelines.

c Pressure Pipe: It is used to transmit fluids or gases at elevated temperatures or pressures or both.

d Structural Pipe: It is used for structural work.

e Oil country goods: Line Pipe is usually made of carbon steel or of low alloy, high strength steel. Special pipe lines have been made from corrosion, resistant steels and stainless steels. Line pipe is made to API specifications.

1.8.1.2 Steel Pipe Specifications

In industrial applications, the material used to manufacture products is never selected by chance. During the design phase, engineers study each material's characteristics carefully and choose the material deliberately. Careful selection prevents subsequent complications when the product is put into use and helps to prevent incurring unnecessary costs. Only certified materials shall be used and all relevant certificates for supplied materials shall be maintained. For example: SA 106 Gr B, API 5L Grade, API 5L Grade X42, ASTM A 333 Grade 6, Duplex stainless steel 22% Cr. (Grade 2205)

1. High Strength Pipe

Higher strength steels can be used with if it lets them use a thinner wall pipe, which can reduce transportation costs and the amount of filler metal used to weld it. Higher strength also permits increasing operating pressure, which increases the pipe's carrying capacity. Hydrogen sulphide in gas or oil can be a source of corrosion cracking in the transport pipe. To guard against corrosion cracking, it is recommended that the pipeline operates at low stress levels. The wall thickness of soft pipe material such as X - 42 has to be increased to provide the suggested low stress level operation.

2. Corrosion Resistant Alloy (CRA) Pipe

Sour natural gas must be processed prior to its sale to remove the hydrogen sulphide that makes it sour, corrosive and, therefore, unusable. CRA clad or lined equipment and pipelines can be used in the construction of sour natural gas production and processing facilities when it is more economical to flow the contents of the well "as it is". There is a distinct economic advantage to using ordinary carbon steel, protected from the effects of corrosion by a thin layer of CRA, to carry the loads. The raw natural gas is extremely corrosive due to the high Co_2 content which led to the selection of API 5L Grade 60 pipe internally clad with Type 316L stainless steel. The 20 inch diameter seam welded pipe has a nominal 19 mm wall thickness of API 5L X 60 and an internal cladding of Type 316L stainless steel, 3 mm thick.

1.8.1.3 Pipe joining methods

1. Methods of Joining Pipe

There are three main methods of joining pipes together and attaching fittings to them: welded joints, flanged joints, threaded joints. Pipelines of 2 inch or larger are usually butt welded, being the most economic, leak proof method. Smaller pipeline are usually joined by socket welding or screwing. Where large diameter piping is required to join up with flanged vessels, valves and other equipment, or where the line has to be opened for periodic cleaning, bolted flange joints are used instead of butt welding.

2. Welded Joints – Piping

Butt welds

Butt welds can be used for all sizes, except for socket welded joints.

Fillet welds

Fillet welds may be used to attach a reinforcing pad, saddle or structural attachments, slip-on flanges, small bore connections and socket welding components. The fillet weld shall have fusion and melting of the edge and shall not reduce the throat thickness to below that is specified.

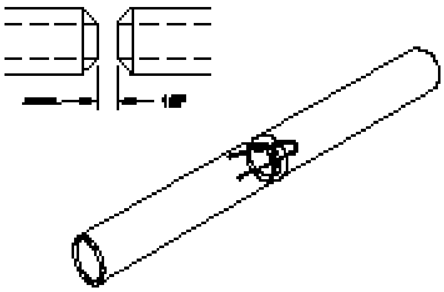


Fig. 1.8.1 Pipe to Pipe Fitup

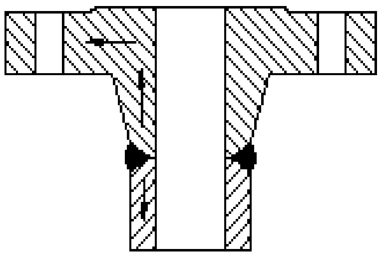


Fig. 1.8.2 Weld Neck Flange with Pipe Fitup

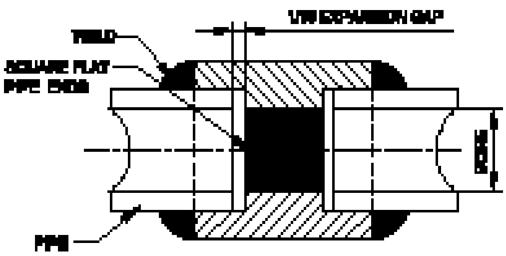


Fig. 1.8.3 Socket Welded Pipe Joint

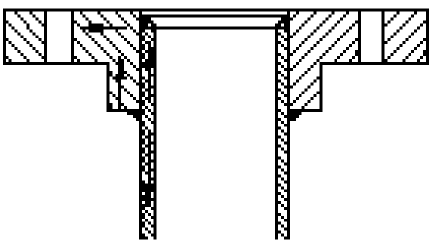


Fig. 1.8.4 Socket Welded Flange

3. Flanged joints

Flanged joints are used whenever the pipes, valves, vessels, fittings, etc., require to be connected together by bolting for ease of dismantling and reassembly. A flange and its bolting shall comply with a nominated standard.

4. Installation of gaskets

For the installation of gaskets uniform distribution of the pressure over the gasket circumference shall be applied to achieve satisfactory sealing. To accomplish this the bolts shall be tightened in the following sequence:

1. Hand tighten all nuts
2. Tighten two bolts diametrically opposite or diagonally to each other to 50% of the required bolt stress.
3. Tighten another pair of bolts approximately 90 degrees further round the circumference.
4. Continue until all bolts have been tightened to 50% of the required bolt stress.
5. Repeat steps 2, 3 and 4 to 80% of the required bolt stress.
6. Repeat steps 2, 3 and 4 to 100% of the required bolt stress.

Gaskets used for the installation of orifice assemblies and between flanges located within the required straight length of pipe upstream and downstream of these assemblies shall not protrude into the free area of the pipe. Gaskets shall never be re-used, since not enough resilience is left in the gasket material to give a leak proof joint when compressed for second time.

5. Flange alignment

The flanges shall be lined up so that the bolts can be inserted without force. Nuts shall have a height equal to the bolt diameter. Hydraulic bolt tensioning provides more uniform bolt stress and eliminates the variations due to different lubricants.

6. Threaded joints

Threaded joints may be used for all fluid services. Threaded joints may be used only in galvanized piping for fire water systems) DN 50 and smaller. Threaded joints shall not be used in services where severe erosion, crevice corrosion, shock or fatigue are expected to occur and in process piping. Threaded instrument connections may be used in process piping of downstream of a piping valve. Sealing compound shall not be used when threaded joints are to be seal welded.

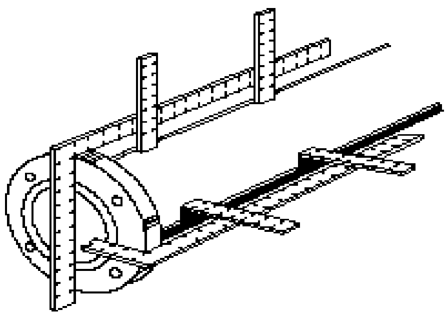


Fig. 1.8.5 Method of flange allignment

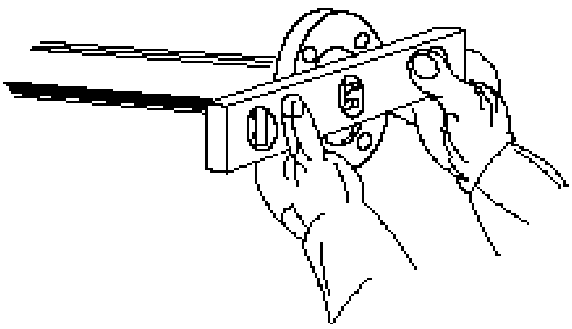


Fig. 1.8.6 Flange Alignment

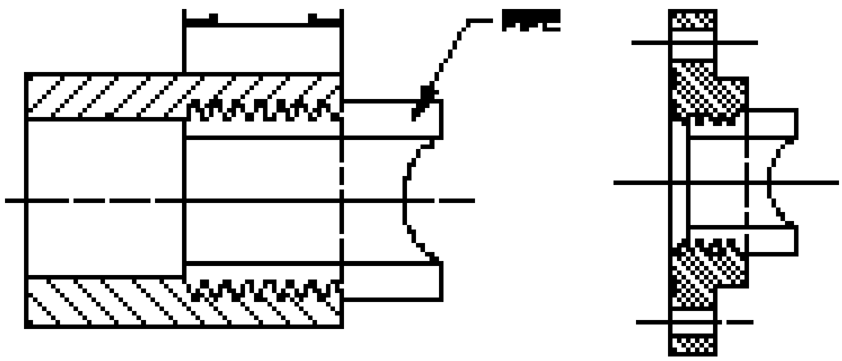


Fig. 1.8.7 Threaded Joints

Exercise

I. Answer the following questions.

1. What are the flange ratings?

---

2. Mention the steps to be followed in installation of gaskets.

---

3. Why are gaskets not to be re-used?

---

4. Explain the method of pipe joining by welded joints.

II. State whether the following statements are True or False.

1. Hydraulic bolt tensioning provides more uniform bolt stress.

   True ☐ False ☐

2. Thread joints shall not be used in services like process piping.

   True ☐ False ☐

3. In Pipe dimensions, if schedule number increases the wall thickness decreases.

   True ☐ False ☐

4. Hydrogen sulphide in gas or oil can be a source of corrosion cracking in the transport pipe.

   True ☐ False ☐

Notes

1.8.2 Welding Methods and Processes

At the end of this topic, you will be able to:

1. state and identify electric arc welding processes
2. state the applications of various welding processes.

1.8.2.1 Introduction to welding methods

The piping industry is roughly divided into three major categories: pressure piping, transmission and distribution piping, noncritical piping.

Transmission and distribution pipelines transmit oil, gas and petroleum products from the producing fields to the consumers. Welding this type of piping necessitates special techniques and procedures.

The crosscountry transmission pipeline welding techniques have become extremely sophisticated. Welding procedures and techniques vary based on the diameter of the pipe.

Welding methods

There is more than one method of applying welding and some require manipulative skills. The methods of applying welding are defined as follows:

1. **Manual welding:**

   Welding with the electrode holder, torch or gun held and manipulated by hand. Example : SMAW, GTAW processes.

2. **Semiautomatic welding:**

   In semiautomatic welding, the wire feeder maintains the arc and feeds the wire ; the welder's job is to manipulate the arc along the joint. Example : GMAW, FCAW, SAW processes.

3. **Automatic welding:**

All the welding parameters are preset and the entire operation from start to finish is accomplished by the equipment. The operator's role is nil / negligible.

Fully automatic welding demands expensive sophisticated controls and perfect fitup and alignment of the joint, which are beyond the capability of an average fabrication shop. For example, SAW, GMAW, FCAW processes. Automatic welding without filler metal additions shall be done using the flash butt welding process.

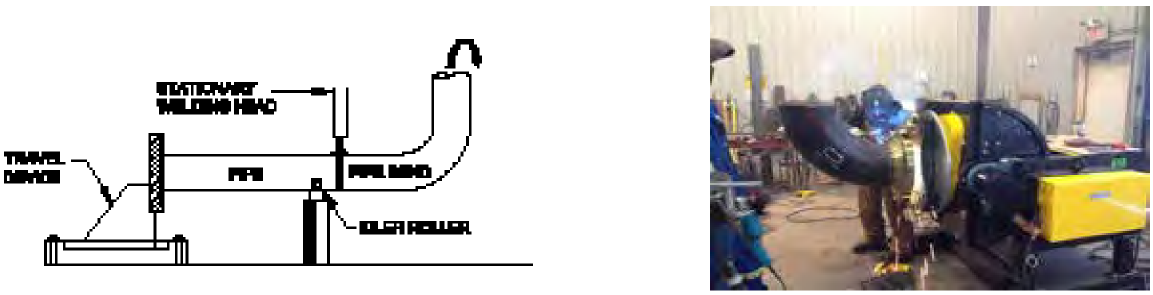


Fig. 1.8.8 Universal Positioner

4. **Machine (Mechanised) welding :**

It is an intermediate step between semiautomatic and automatic versions. In machine welding, the wire feeder maintains the arc and feeds the filler wire, and a travel device provides the relative motion between the arc and the joint.

5. Automatic Pipe Welding

Automatic welding uses the same basic elements of machine welding plus a welding cycle controller. In arc welding, the electrode or welding rod is fed automatically into the arc to compensate for its melt-off and thus maintain the correct length of arc. Granulated flux or shielding gas, when called for by the specific process, is also fed automatically through the welding head.

The shielded metal arc welding process has been used and is still the predominant welding process for field girth welding. However, the use of semiautomatic and automatic gas metal arc welding is increasing steadily. Self shielding and gas shielding flux cored arc welding is also used. In some cases, automatic welds are made on the inside diameter of the pipe.

6. Welding Operator

One who operates machine or automatic welding equipment is the welding operator. Each welding unit and each operator shall be qualified by producing an acceptable weld using the qualified welding procedure. Each operator shall have received adequate training in the operation of the equipment prior to the start of welding and shall be thoroughly familiar with the equipment they operate.

Fig. 1.8.9 Auto Weld bead appearance

7. Welder

Welder is one who performs manual or semi-automatic welding.

1.8.2.2 Introduction of welding processes

There are approximately 50 distinct welding processes. The arc welding group of processes is the most popular, with 6 distinct arc welding processes and numerous variations. The standard practice in the fabrication fields is that nearly all welds are made using these processes only. The most common welding processes are:

1. Shielded Metal Arc Welding (SMAW)
2. Gas Tungsten Arc Welding (GTAW)
3. Gas Metal Arc Welding (GMAW)
4. Flux Cored Arc Welding (FCAW)
5. Plasma Arc Welding (PAW)
6. Submerged Arc Welding (SAW)
7. Electrical Resistance Butt Welding
8. Flash Butt Welding method

1. Arc welding

The term arc welding applies to a large and diversified group of welding processes that use an electric arc as the source of heat to melt and join metals. The welding arc is struck between the workpiece and the tip of an electrode. The electrode will be either a consumable wire or rod or a non–consumable carbon or tungsten rod which carries the welding current. The electrode is manually or mechanically moved along the joint, or it remains stationary while the workpiece is moved.

When a non–consumable electrode is used, filler metal can be supplied by a separate rod or wire, if needed. A consumable electrode, however, will be designed not only to conduct the current that sustains the arc but also to melt and supply filler metal to the joint. It may also produce a slag covering to protect the hot weld metal from atmospheric conditions.

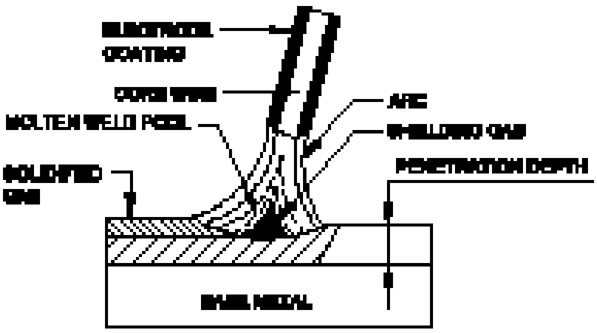


Fig. 1.8.10 Arc Welding

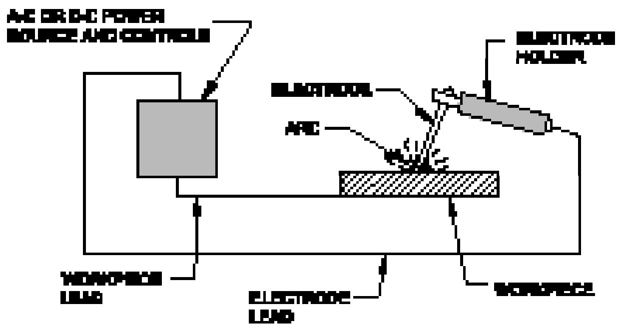


Fig. 1.8.11 SMAW

2. Shielded metal arc welding (SMAW)

SMAW is an arc welding process with an arc between a covered electrode and the weld pool. SMAW is one of the oldest welding processes. It is also the simplest and perhaps the most versatile for welding ferrous base metals. More than 70% of the weld deposited, today is by this process inspite of the large number of sophisticated processes coming into the field.

Shielded metal arc welding (SMAW) is also known as manual metal arc welding (MMAW) and as stick electrode welding.

The shielded metal arc welding (SMAW) process uses an electrical circuit that supports a welding arc to convert electric line power or fuel into heat. The heat from the welding arc is intense, extremely concentrated, and immediately melts a portion of the workpiece and the end of the electrode. The welder maintains the arc length by holding a consistent space between the electrode and the weld pool that forms on the workpiece. As the arc is removed, the liquid fuses and the metal solidifies into continuous metal.

Figure 1.8.11 shows the power source is connected into a circuit with the electrode and workpiece in series. The welding cable used in the circuit, the electrode holder, and the connection between the cable and the workpiece are also important elements of the circuit. The power source has two distinct output terminals. From one terminal, a connection is made to the workpiece, from the other, a connection is made to the electrode.

a. Metals welded

The SMAW process is used in joining and surfacing applications on a variety of base metals. Electrodes are also available for the application of wear impact or corrosion resistant surfaces on the same base metals.

b. Welding procedure

A suitable electrode diameter is chosen depending on the thickness of the material to be welded, type of joint, position of welding, groove design and, finally, the experience of the welder. A suitable power supply is chosen. Depending on the electrode, the amperage to be used is selected and set on the equipment.

During welding, the welder maintains a normal arc length by uniformly moving the electrode toward the work as the electrode melts. At the same time, the electrode is moved uniformly along the joint in the direction of welding to form the bead. After welding, the slag should be completely removed before the next layer is deposited. Proper grounding is required to avoid arc blows.

c. Weld quality

Discontinuities are, sometimes, encountered in welds made by SMAW process that include porosity, slag inclusions, incomplete fusion, incomplete penetration, undercut, cracking, etc.

d. Process limitations

1. The operator factor (arc time as a percentage of the welder's total labour time) for SMAW is, usually, lower than that obtained with a continuous electrode process.
2. The weld cost is relatively high.

3. Gas Tungsten Arc Welding (GTAW)

GTAW is an arc welding process that uses an arc between a tungsten electrode (non–consumable) and the weld pool. The process is used with shielding gas and without the application of pressure. A commonly used gas is Argon (99.99%, vol). Filler metal may or may not be used. This process was developed in the late 1930s as heliarc or TIG welding, and was used to weld non–ferrous metals, particularly, stainless steel and aluminium and to join hard to weld metals. This process is also called as "TIG". TIG stands for tungsten inert gas welding. GTAW shall be used for all piping materials with a diameter equal to or less than DN 80. All GTAW machines shall be equipped with arc starting devices (high frequency, lift arc). Scratch starting shall not be used.

4. Gas Metal Arc Welding (GMAW)

GMAW is an arc welding process in which an electric arc is formed and maintained between a continuously fed consumable electrode wire and the workpiece. The arc and the weld pool are protected from atmospheric contamination by the shielding gas, supplied through the nozzle.

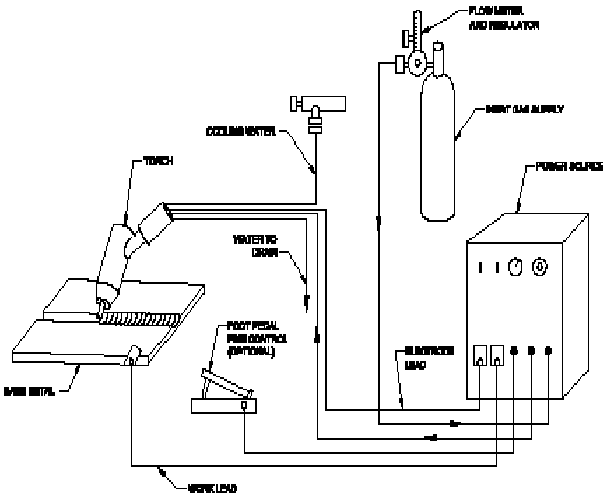


Fig. 1.8.12 GTAW

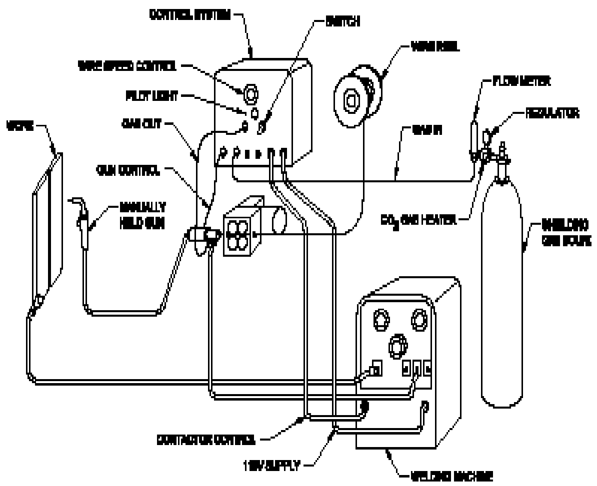


Fig. 1.8.13 GMAW

GMAW process has been given many names, including MIG, MAG, CO_2 welding, depending on the type of shielding gas, the type of metal welded. The following gas mixtures are available: Argon, CO_2 (85/15% vol. or 80/20% vol.) These gases maintain a stable arc and give little spatter. The latter mixture is recommended when deeper penetration is required. CO_2 gas can be used, but procedure has more weld spatter. GMAW process can be used either semi automatic, machine welding or automatically. GMAW is used for welding ferrous metals and aluminium has become popular.

5. Flux Cored Arc Welding (FCAW)

FCAW is an arc welding process in which the heat for welding is produced by an arc established between the flux cored tubular consumable electrode wire and the workpiece. FCAW is normally a semiautomatic process with combined characteristics of SMAW, GMAW and SAW processes. FCAW is almost identical to GMAW, except for the electrode filler wire (a tubular wire filled inside the flux). During welding, an extensive slag cover is produced on the face of a weld bead. FCAW has found wide application in workshop fabrication pressure vessels / piping structural steels, storage tanks and field erection work.

6. Plasma Arc Welding (PAW)

The arc has a very deep penetrating ability into the metals welded and also the fusion takes place in a very narrow zone of the joint. PAW is similar to gas tungsten arc welding processes except for the arc initiation.

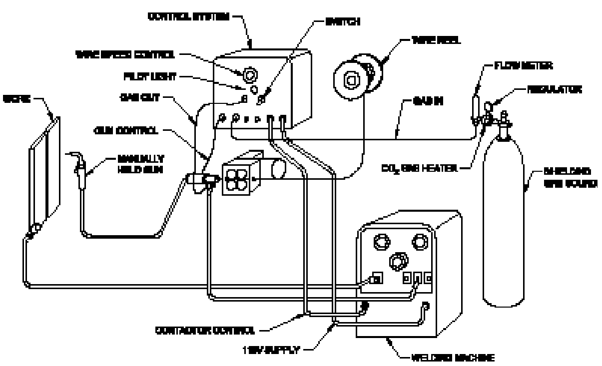


Fig. 1.8.14 Flux Cored Arc Welding

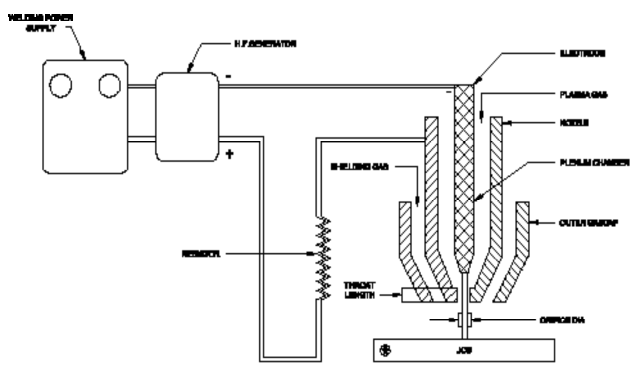


Fig. 1.8.15 Plasma Arc Welding

7. Submerged Arc Welding (SAW)

SAW also called 'Sub-arc' welding is an arc welding process where the welding arc is submerged under a granulated flux. The arc is initiated between the electrode wire and the weld joint under the medium of flux.

The SAW process is used in both mechanized and semiautomatic operations, although the former is by far more common. SAW Welds can only be made in the flat and horizontal positions. SAW shall not be used for repair welding of pipelines. Welding fluxes shall be specified by manufacturer and type. Only fully mechanized SAW systems shall be used.

SAW is widely recognized as a very productive welding process in industry because of its inherent advantages:

- high deposition rate due to the use of high welding currents
- deep penetration and a smooth bead
- high travel speed, high quality and reliability
- no spatter, no fumes.

8. Electron Beam Welding (EBW)

Electron beam welding is a process in which the heat required to produce fusion welds is obtained from the impact of a high velocity, high density stream of electrons on the workpiece. Upon impact Kinetic energy of the electrons is converted to thermal energy causing both vapourisation and melting. The vapourization of material immediately beneath the beam enables the beam to penetrate into or through the material to be welded, with the beam and vapour forming a hole. As the beam moves along the joint face, the molten material flows around the hole leaving the welded joint behind the beam. EBW is an automatic welding process performed in vacuum without a shielding gas. Neither an electrode nor a filler rod is used.

9. Laser Beam Welding – LBW

'Laser ' is an acronym for Light Amplification by Stimulated Emission of Radiation. Light is a source of energy which can be used for welding and cutting. But ordinary light is not useful since it is not 'coherent'. To get a coherent light, light waves in the same phase, different methods have been developed.

As the concentration of energy or power density is quite high, it can weld very fast. Laser process can also be used for surfacing, cutting and scribing. In type of laser depends upon the lasing source. In solid laser some type of crystal such as the ruby is used for its lasing ability. LBW is most suited for thin job applications and, especially, for thermal sensitive jobs, which are difficult to weld by conventional arc welding processes. This is a method of welding in which the 'welding' heat is generated by sliding or rubbing together of two mating surfaces under pressure.

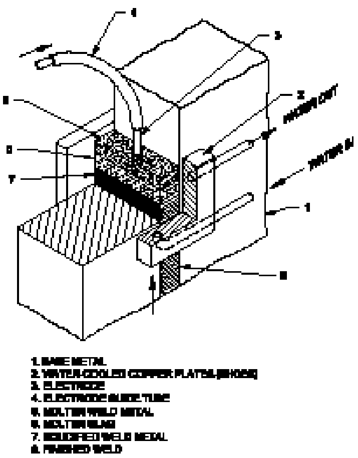


Fig. 1.8.16 Schematic of Electro-Slag Welding

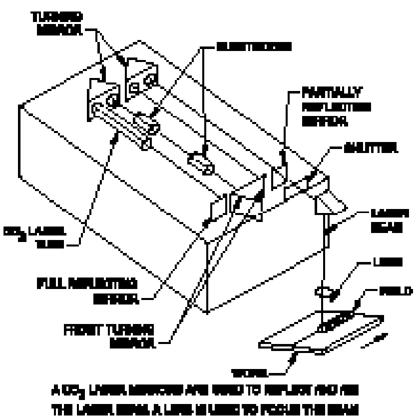


Fig. 1.8.17 Laser Beam Welding Process

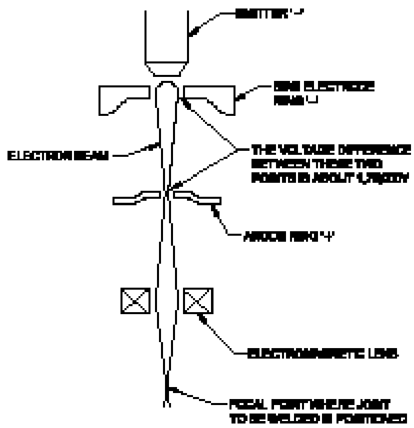


Fig. 1.8.18 Electron Beam Welding Process

10. Electrical Resistance Butt Welding

A number of welding processes are based on the principle that a current passing through a resistance generates heat. The maximum amount of heat is generated at the point of maximum resistance, which is at the surface between the parts being joined. The resistance welding processes differ from arc welding in that pressure is used, but filler metal or fluxes are not. Flash butt welding is a resistance welding process in which fusion is produced by the high localised heat obtained from the electrical resistance existing between two touching surfaces.

Applications

The most common application of flash welding is in making butt welds. It is used to join thin walled tubes, large pipelines, rounds, squares and annular blanks (flanges, wheel rims, etc).

American Petroleum Institute (API) Standard 1104, Welding of pipelines and related facilities covers automatic welding without filler metal additions, shall be done using the flash butt-welding process.

11. Flash Butt Welding Method

The parts clamped in the jaws are moved towards each other at a constant or accelerated rate until they come into contact. As the initial contact area is small, an intense current is generated between the parts. The term flash welding derives its name from the flash produced during the process. Flash butt welds are made on a machine having one stationary and one opposing movable platen, on which are provided with clamps orders. These clamps securely hold the two workpieces to be welded while, simultaneously, serving to conduct the welding current through these workpieces.

Basic steps

1. Position and clamp the parts
2. Apply flashing voltage and start platen motion
3. Flash
4. Upset and terminate current.

Flash welds produce a fin around the periphery of the weld, which is normally removed by grinding.

Tips

Safety

The operator should wear face and eye protection and a barrier or shield should be used to block flying sparks. Hands must be kept clear of moving machinery and contact with electrically charged surfaces must be avoided.

Exercise

I. Answer the following questions.

1. What is the purpose of shielding gas?

   ----

2. List the most common arc welding processes.

   ----

3. Write a short note on GMAW process.

   ----

4. What are the arc starting devices used in gas tungsten arc welding process?

   ----

5. What is the expansion of LASER?

----

6. In what direction does the current flow in the SMAW (MMAW)?

----

7. What is the function of a electrode in SMAW?

----

8. What are the four methods of welding?

----

9. Explain the difference between the welder and the welding operator.

II. State whether the following statements are True or False.

1. Manual metal arc welding is also known as shielded metal arc welding.

   True ☐ False ☐

2. The SMAW process yields higher deposition rates than the gas metal arc and flux cored arc welding processes.

   True ☐ False ☐

3. Submerged arc welding can only be made in the flat and horizontal positions.

   True ☐ False ☐

4. Plasma arc welding is similar to gas tungsten arc welding process except for the arc initiation.

   True ☐ False ☐

5. Flux cored arc welding is almost identical to gas metal arc welding except for the electrode filler wire.

   True ☐ False ☐

6. Thicker steel section can be welded in a single pass in the vertical position.

   True ☐ False ☐

Notes

1.8.3 Welding Procedure Specification

At the end of this topic, you will be able to:

1. describe the job instructions
2. state the importance of welding procedure specification.

1. Importance of welding procedures

Only high quality pipe welds are acceptable in modern industry. The failure of a pipe weld can not only disrupt the operation of a plant, it can be the cause of a serious accident with the possible loss of life and property. For this reason, a pipe fitter must be a thoroughly qualified person. The pipe fitter (tack welder) will be provided with the related information necessary for to do the job correctly.

2. Welding Procedures

Welding procedures should be written whenever it is necessary to:

- comply with specifications and codes
- maintain dimensions by controlling distortion
- reduce residual or locked up stresses
- minimize detrimental metallurgical changes, etc.

3. Welding procedure specification (WPS)

The welding procedure specification is the primary tool used to communicate to the pipe fitter, welder, supervisor and inspector on how a specific weld is to be made. A WPS is a written welding procedure prepared to provide direction for making production welds to code requirements. No welding shall be carried out until welding procedures, welders and tack welders (pipe fitter) are qualified according to the design code and approved by the client. Welding procedures shall be qualified before performance qualification of welders.

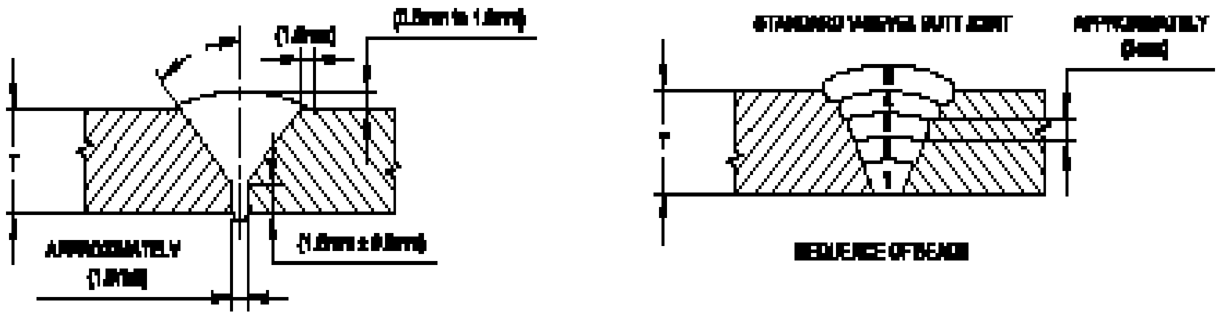


Fig. 1.8.19 joint design and sequence of weld beads in WPS format

4. Basic steps

The basic steps in the qualification of a welding procedure as follows:

a) Written preliminary welding procedure specifications are submitted by the contractor to the client for content approval.

b) Once the content of a written procedure has been approved, a weld is made in accordance with the requirements of that procedure.

c) The weld is inspected and tested and satisfied by the non–destructive testing and mechanical requirements to the relevant specification.

d) If these tests meet the minimum requirements, the document becomes the procedure qualification record (PQR).

e) Prepare welding procedure specification from the approved PQR.

Tack welder and welder performance qualification testing shall be carried out in accordance with the design code, WPS and / or as specified by the client.

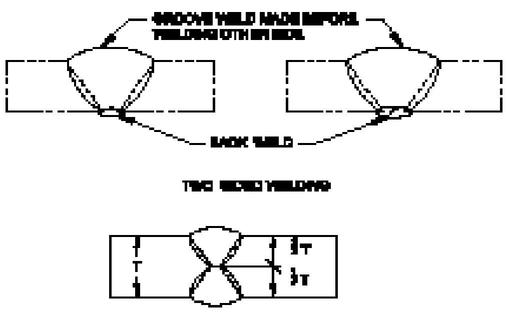


Fig. 1.8.20 Sequence of Beads

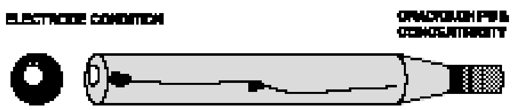


Fig. 1.8.21 Damaged Electrode

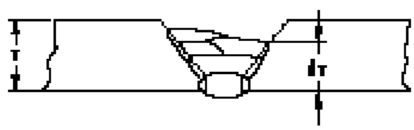


Fig. 1.8.22 Weld Interruption

5. Job instructions site survey by fire and safety officer

No welder, tack welder pipe fitter is allowed to perform on the job unless he has been successfully qualified by passing the required tests. WPS will be applicable equally for a plate, pipe and tube joints. Two sided welding shall be carried out whenever possible / whenever allowed. All welding consumables shall have specified or actual mechanical properties equal to or greater than the material being welded, unless otherwise specified. A welder who is qualified with an E6010 is not necessarily permitted to use a low hydrogen electrode E7018. If he is qualified with a E7018, it is possible for him to use an E6010 if the job permits. Electrodes shall not be baked more than twice. Electrodes that show signs of damage or deterioration, for example, cracked or flaked coating, rusty or rusted / damaged core wire, shall be discarded. Irrespective of the base material, root runs shall be made without interruption other than for changing electrodes or to allow the welder to reposition himself. Welds shall not be allowed to cool until at least half the wall thickness has been welded.

- Scale and slag shall be removed from each bead and groove. When semi automatic or machine welding is used, surface porosity clusters, bead starts and high points shall be removed by grinding before weld metal is deposited over them. Thorough inter- run cleaning and slag removal shall be carried out. The contractor shall maintain the list of WPS, PQR, qualified welders tack welders and the qualification records. The list and records shall be agreed by the client prior to production welding.

6. Intruction

Follow these instructions when you perform any welding job:

- collect safety equipment and tools such as safety glasses, helmet with correct lens shade, heavy duty gloves, wire brush, chipping hammer and pliers on welding table
- clean working table
- collect materials for the job
- set up welding power source
- power OFF and clean work area when the job is completed.

Welding procedure specification number ____________________________________

For _________________________________Welding of ______________________ Pipe and fittings

Process ____

Material ____

Pipe outside diameter and wall thickness ____

Joint design ____

Filler metal and number of beads ____

Electrical or flame characteristics ____

Position ____

Direction of welding ____

Number of welders ____

Time lapse between passes ____

Type and removal of lineup clamp ____

Cleaning and / or grinding ____

Preheat /post weld heat treatment ____

Shielding gas and flow rate ____

Shielding flux ______________________________

Speed of travel ______________________ Plasma gas flow rate ______________________

Plasma gas composition______________________________

Plasma gas orifice size______________________________

Sketches and tabulations attached______________________________

Tested by: ______________________________

Welder______________________________

Approved by: ______________________________

Weldingsupervisor______________________________

Adopted______________________________

Chiefengineer______________________________

Exercise

I. Answer the following questions.

1. What is the importance of welding procedures?

----

2. List out the instructions to be followed when you perform any welding job.

----

3. What is welding procedure specification?

----

4. Give the expansion of the following:
   WPS, PQR

----

5. When is it permissible to interrupt the pipe joint weld once welding is started?

II. State whether the following statements are True or False.

1. The position of the welding is to be done as stated in the welding procedure.
   True ☐ False ☐
2. Coated electrodes shall not be baked more than twice.
   True ☐ False ☐
3. No welding or hot work shall be carried out on post weld heat treated job.
   True ☐ False ☐

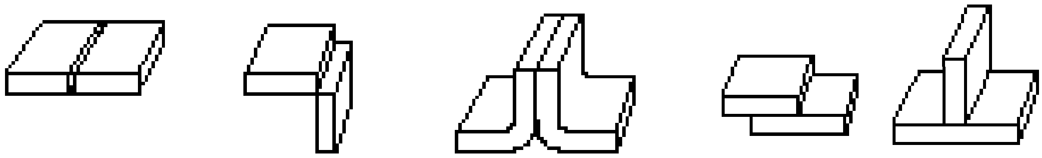
Notes

1.8.4 Preparation of Pipe Joint and Fitup

At the end of this topic, you will be able to:

1. select appropriate methods for the preparation of pipe
2. identify different tools and equipment used for preparation of pipe.

1.8.4.1 Types of Joints: There are only five basic types of joints**.** They can, however, be used in combinations.



Butt *Corner* *Edge* *Lap* *Tee*

Fig. 1.8.23 Basic Type of Joints

1. The butt joint results when the two members to be joined lie in the same plane and they are connected at their edges.
2. With a corner joint, the two members to be joined lie in perpendicular planes and again, their edges are connected.
3. The edge joint also has the two members lying in parallel planes.
4. In a lap joint, the two members lie in parallel planes, but not the same plane. The joint occurs where the two members overlap each other to form a double thickness region.
5. The T-Joint is similar in that the two members lie in perpendicular planes, except, now the edge of one member is joined to the planar surface of the other.

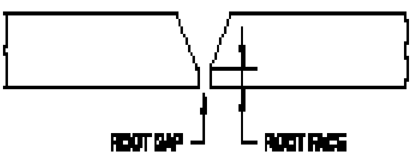


Fig.1.8.24 Root Gap

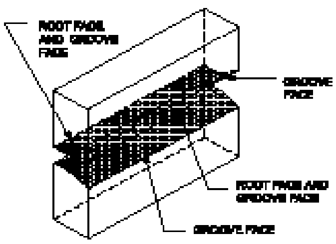


Fig. 1.8.25 Root Face

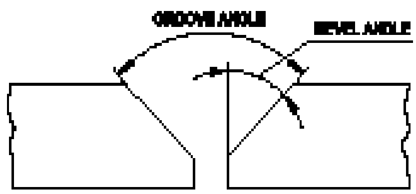


Fig. 1.8.26 Groove Angle

Root Gap

The separation between the members to be joined at the root of the joint.

Various features of a joint

Some of these elements include:

Root Face

Groove face adjacent to the root of the joint.

Groove Angle

The surface of a member included in the groove.

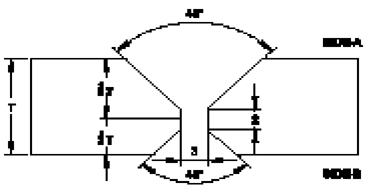


Fig. 1.8.27 Double 'V' butt Joint

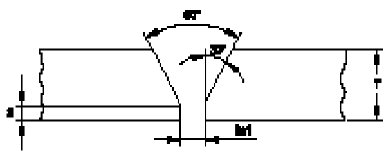


Fig. 1.8.28 Single 'V' butt Joint

Bevel Angle

The angle formed between the prepared edge of a member and a plane perpendicular to the surface of the member.

Groove Face

The total included angle of the groove between parts to be joined by a groove weld.

1.8.4.2 Types of Welds

There are numerous welds which can be applied to the various types of joints. Some of the basic types of welds include– square groove weld, bevel groove weld, V-groove weld, J-groove weld, U-groove weld, Fillet weld, spot weld. All of these groove weld and fillet weld types can be applied to joints which are welded from a single sides or both sides. With a variety of groove weld geometries available, the pipe desinger can choose the one which best suits the needs. This choice based on accessibility, type of welding process being used, method of joint preparation and adaptation to particular designs.

1.8.4.3 Preparation and cutting

Cutting and bevelling of pipe may be done either by mechanical means or by flame or plasma cutting, when the following is taken into account:

a) For carbon steel, flame cuts shall be reasonably smooth and all oxides shall be removed from the surface by grinding to bright metal.

b) For low alloy steel, after flame cutting approximately 2 mm of material shall be removed from the cut surface by grinding.

c) For stainless steel, flame cutting shall not be used but plasma arc cutting may be used. The surface shall be cleaned or ground to bright metal after plasma cutting.

Non–destructive test, including ultrasonic lamination checking and magnetic testing shall be carried out on all site (field) cuts and bevels, if required.

Mitre joints shall not be permitted. Pipes for socket weld joints shall be cut square. Pipes for insertion into slip on flanges and socket welds shall be cut square and ground, if necessary. Cut edges which are to be incorporated into the weld shall be free from notches, sudden changes of shape, or imperfections which could be the cause of weld imperfections.

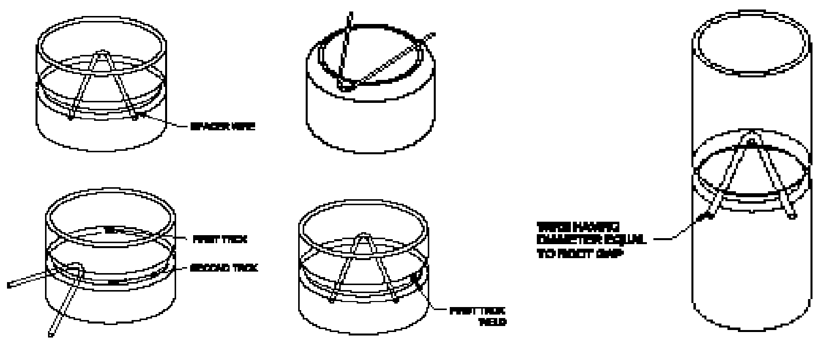


Fig. 1.8.29 Maintain Uniform Root Gap

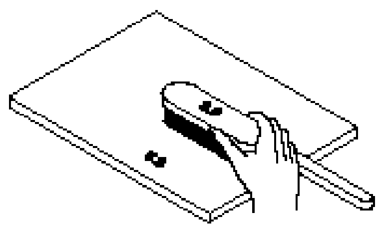


Fig. 1.8.30 Stainless Steel Wire Brush

1.8.4.4 Assembly of piping components

All welded joint preparations shall be in accordance with the relevant details of the construction drawing and welding procedure specification. Prior to assembly, all weld preparations shall be free of rust, scale, moisture, grease and any other substance which could affect the integrity of the deposited weld metal. To achieve this, grinding or scratch brushing may be used. Stainless steel wire brushes are exclusively used for stainless steel fabrication. For butt welding of all piping components (pipe ends, fittings and weld neck flanges) a uniform root gap shall be provided as specified in the relevant welding procedure specification. To maintain the specified alignment and gap during welding, the parts to be welded shall be securely held in position by mechanical means, for example, welded on bridge pieces, bars, jacks, clamps or tie rods or tack welding. Where tack welds are used to maintain the specified alignment and gap on joints that require preheating, the preheat shall be applied and maintained.

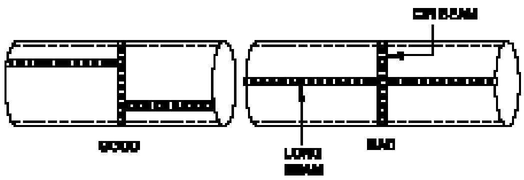


Fig. 1.8.31 A Weld Seam Orientation

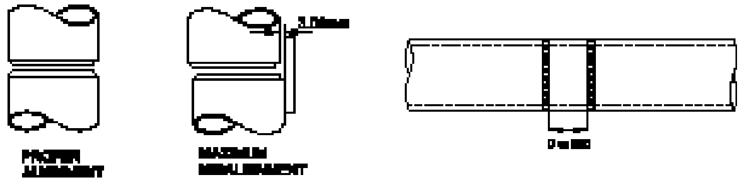


Fig. 1.8.32 A Minimum Distance Between Welds Seams is often Specified

1.8.4.5 Pipe orientation

Seam orientation of welded pipe shall be selected to ensure that at the circumferential welds, the longitudinal welds shall be staggered over the top of the pipeline by a minimum angle of 90° or 250 mm, whichever is lesser. The minimum allowable distance between girth welds shall be D (Diameter) or 500 mm whichever is larger. The alignment of abutting ends shall minimize the offset between surfaces. For pipe ends of the same specified thickness, the offset should not exceed 3 mm. Hammering to the pipe to obtain proper line up should be kept to a minimum. A minimum distance between welds seams is often specified.

1.8.4.6 Line up clamps

Line up clamps are used to align the pipes and to hold them in place while welding: They are:

Internal line up clamp, External line up clamp.

Tack welds shall only be used where it would be impracticable to use an internal or external line up clamp.

Use of line up clamps

Line up clamps shall be used for butt welds in accordance with the welding procedure specification. When it is permissible to remove the line up clamp before the root bead is completed, the completed part of the bead shall be in approximately equal segments spaced approximately equally around the circumference of the joint. Line up clamps shall not damage the pipes and shall achieve the specified fit up. Non-welded fit up clamps shall be used for alignment of all pipe, pipe line and equipment work.

1. Internal line up clamp

An internal line up clamp shall be used for all line circumferential welds except at tie-ins and other points where it would be impractical. In such instances an external clamp shall be used. The use of internal line up clamps for all nominal pipe sizes of 6 inches and larger is mandatory. However, when an internal line up clamp is used and conditions make it difficult to prevent movement of the pipe or if the weld will be unduly stressed, the root bead shall be completed before clamp tension is released. In other words, an internal line up clamp shall not be removed until the root bead is 100% complete.

2. External line up clamp

Root bead segments used in connection with external clamps should be uniformly spaced around the circumference of the pipe and shall have an aggregate length of at least 50% of the pipe circumference before the clamp is removed. In other words, an external line up clamp shall not be removed until the root bead is at least 50% complete equally distributed around the joint.

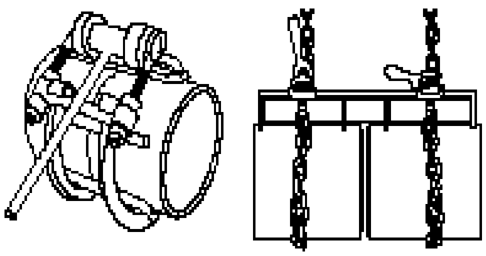


Fig. 1.8.33 External Pipe Clamp

Fig. 1.8.34 Internal Clamp

1.8.4.7 Weld fitup

Pipe ends should be field beveled by machine tool or machine oxygen cutting. Manual oxygen cutting may also be used. All surfaces to be welded shall be thoroughly cleaned from oxide, scale, oil or other foreign matter and be dry. The cleaned surface shall extend at least 25 mm beyond the substrate surface touched by the arc. Tack welding shall be carried out by qualified welders in accordance with the same requirements and parameters as for the root pass of the base material. The minimum number of passes (root and hot) to be deposited before the pipe is lowered off shall be maintained. Temporary tack welds shall be removed by grinding or chipping and the area ground smooth without reduction of wall thickness, followed by MT or PT inspection to confirm the absence of linear indications.

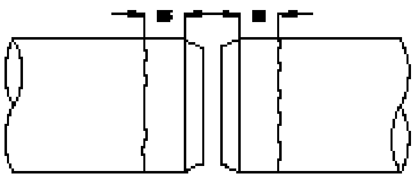


Fig. 1.8.35 Cleaning of Pipe Ends

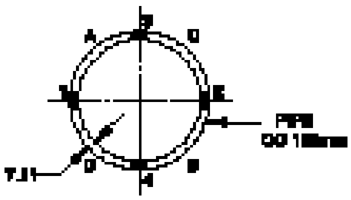


Fig. 1.8.36 Take Welds on Pipe

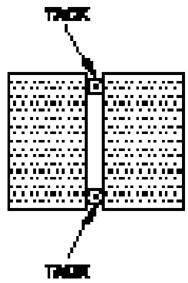


Fig. 1.8.37 Temporary Tack welds on plate pipe

Clearance

When the pipe is welded above the ground, the working clearance around the pipe at the weld should not be less than 400 mm. When the pipe is welded in a trench, the bell hole shall be large enough to provide the welder or welders with ready access to the joint.

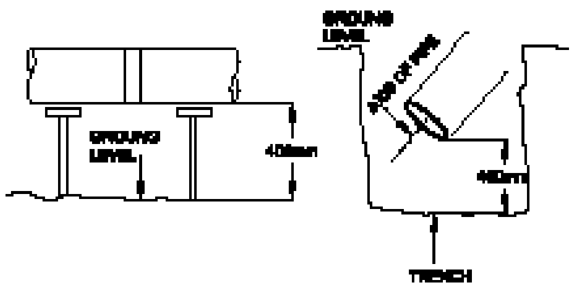


Fig. 1.8.38 Working Clearance around the pipe

Exercise

I. Answer the following questions.

1. What are the five basic types of joints?

----

2. Draw the simple sketch of a single -V- butt joint.

----

3. When is it permissible to remove an external line up clamp before the root bead is completed?

----

4. Why are stainless steel parts fabricated in separate or designated workshop area?

----

5. Describe the methods of cutting and bevelling of steel pipes.

----

7. How are tack welds performed during the assembly of piping?

----

8. What are the uses of line up clamps?

----

9. When is it permissible to remove an internal line up clamp before the root bead is completed?

----

10. What makes plasma arc cutting different from oxy fuel cutting?

II. State whether the following statements are True or False.

1. The working clearance around the pipe at the weld should not be less than 400 mm.

   True ☐ False ☐

2. For pipe ends of the same specified thickness, the offset should not exceed 1.6 mm.

   True ☐ False ☐

3. Stainless steel wire brushes are exclusively used for stainless steel fabrication.

   True ☐ False ☐

Notes

1.8.5 Welding Power Sources and Process Sequences

At the end of this topic, you will be able to:

1. state the necessity of an arc welding machine
2. name the different types of an arc welding machines.

1.8.5.1 Necessity of the welding machine

The welding process requires enough electric current (measured in amperes) to produce melting of the work and the metal electrode and the proper voltage (measured in volts) to maintain the arc. Depending on their size and type, electrodes require 18 to 45 volts and approximately 50 to 500 amperes. The current can be alternating or

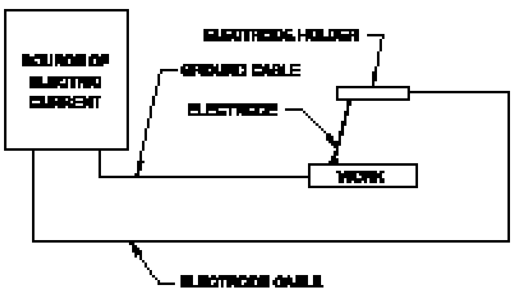


Fig. 1.8.39 Simple Welding Circuit

Fig. 1.8.40 Pipeline Truck for field welding

direct, but it must be provided through a source that can be controlled to meet the many conditions encountered on the job. The voltage supplied for industrial purposes is too high to use directly in arc welding. Therefore, the welding plant must convert the high voltage, low current main supply, to low voltage, high current characteristics required for welding. Alternatively, the welding plant may provide an independent supply. Welding machines are available in a wide variety of types and sizes to suit the demands of different welding processes, operations and types of work.

1.8.5.2 Selection of a power source

Selecting the power source is based on:

1. **Process selection:** It will generally determine the output characteristics of the power source required.
2. **Welding current:** Most arc welding processes use direct current, but some proceses utilise either direct or alternating current.
3. **Machine Rating:** This is how to determine the size or capacity of the arc welding power sources.
4. **Duty cycle:** Also measures the amount of work that the power source can do.
5. **Availablity of Power:** Location and whether electric power is available or gas or diesel power has to be used.
6. **Auxiliary devices:** Auxiliary devices and controls might be necessary for some work.

1.8.5.3 Various power sources

Welding power sources are also known as power supplies and welding machines. All machines may be classified by output slope, whether constant current or constant voltage and power source type such as transformer, rectifier, inverter or generator. Power sources for welding may be grouped under four main headings:

1. Transformers – for a.c welding
2. Rectifiers – for a.c /d.c. welding
3. Generators – for d.c. welding
4. Inverter – a modern type of power source, a.c/d.c

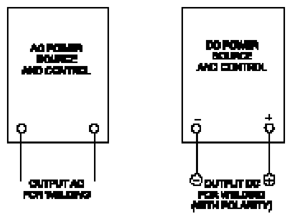


Fig. 1.8.41 AC and DC Welding

1.8.5.4 Pipeline welding applicable power sources

It is necessary to find and change the best welding equipment, for appropriate welding process is. The welding of the root pass the most critical portion of a pipe weld. In many cases, the root pass was made with traditional SMAW or GTAW and the fill and cap passes are made with one of the wire fed processes GMAW, FCAW-G, SAW. The welding machines used for the wire-fed processes are different than the standard, constant current (CC) unit. The power source would have to provide the CC output for SMAW/GTAW of the root, but would also need to provide a constant voltage (CV) output, as well as withstand the field environment on the pipeline.

The gas shielded flux cored process, FCAW-G is secure and presents the best overall solution. It provided good deposition rates and it could be used with basic wire feed equipment. FCAW-G process had considerable success on large diameter pipeline projects. Further, it is necessary to be some way to supply electrical power to the welding power source. This was accomplished by assembling a support trackter. Generator on tracter for provides three-phase electrical power and an air compressor along with enclosures and boxes for the welding power source and all of the other various tools needed at the welding location. Transformers and rectifiers can output alternating current or direct current. Direct current is the current of choice for most welding applications. Inverters are the most versatile power sources because they can output constant current and constant voltage. Inverters use solid state components to boost incoming 60 Hertz power to very high frequency current in the range of 18 to 100 kilohertz. An inverter based machine, is a portable, which is small, light weight and is often used for field welding. A plasma cutting power source is also mounted on the tracter.

1.8.5.5 Duty cycle

Power sources are rated by duty cycle. Duty cycle is the percentage of time the machine can operate at rated output during a 10 minute period. Welding grounds shall be connected directly to the work as close as possible to the working area and in such a manner as to provide the best welding circuit possible.

1.8.5.6 Pipe joint preparation

The preparation of the pipe joint is an essential part of pipe fitup and welding as the quality of the weld is affected by the care used in preparing the joint. Indeed, in many instances, the failure of the pipe joint can be attributed to faulty joint preparation. The pipe fitter must understand and then assemble the parts required to prepare the joint properly for welding. This is the first step in making a successful pipe weld. There are four steps to check the weld joint conditions:

prepare the edges, clean the joint surfaces, fitup and alignment of the pipes, and, tack weld the pipes together with temporary supports to control the distortion.

1.8.5.7 Welding process condition and control

Condition for welding joints prior to and during welding of piping, the following shall be observed:

a) The joint surfaces shall be cleaned and aligned as required. Fitting up pipe is one of the basic skills of pipe welding. In simple terms, fitting up means to position the pipes in the correct location as specified by the drawing.

b) Joint preheat for inter pass temperature and arrangements for delayed cooling, when required, shall be in accordance with the qualified welding procedure for the respective joints. No fitup and welding shall be carried out when the parts to be welded are wet. When the base metal temperature is below 20°C both sides of the weld preparation shall be preheated to a temperature of approximately 50°C or the preheat temperature prescribed in the WPS, whichever is higher.

c) Ambient air movement should be limited to that covered by the qualified welding procedure. No welding shall be performed unless the welder and the work should be properly protected from weather conditions including but not limited to rain, snow, air, moisture, blowing sands and excessive wind and preferably from sub-zero air temperatures. Such conditions shall be observed, in particular, for site fabrication. Wind shields may be used when practical. Wind shields or tents shall be required when the wind is strong enough to affect arc stability or shielding gas coverage or when deemed necessary. The wind velocity in the weld area for GTAW, GMAW or FCAW shall not exceed 8 kph.

d) All welding procedure variables shall be maintained in accordance with the qualified welding procedure. The minimum number of passes before the joint is allowed to cool to ambient temperature shall be followed. The minimum shall be three layers or one third of the joint or qualified WPS whichever is greater.

e) Distortion caused by welding can seriously affect the alignment and the locational accuracy of a pipe installation unless preventive measures are taken to avoid these problems. On the job, the pipe fitter must always be aware of the distortion and must take those steps required to prevent this from affecting the quality of his work. The following examples will describe how this is done.

- Use of line up clamps to align the pipes and to hold them in position.
- Use of a strong back to add to the stiffness of the header pipe.
- Plan to weld the branches in the correct sequence in order to minimize the effect of distortion.
- The root beads are welded in all pipe joints and in the correct sequence.
- Using a temporary support to maintain the correct alignment of a right angled pipe joint.
- Make allowance for the contraction of the weld lengths of pipe to be welded together.

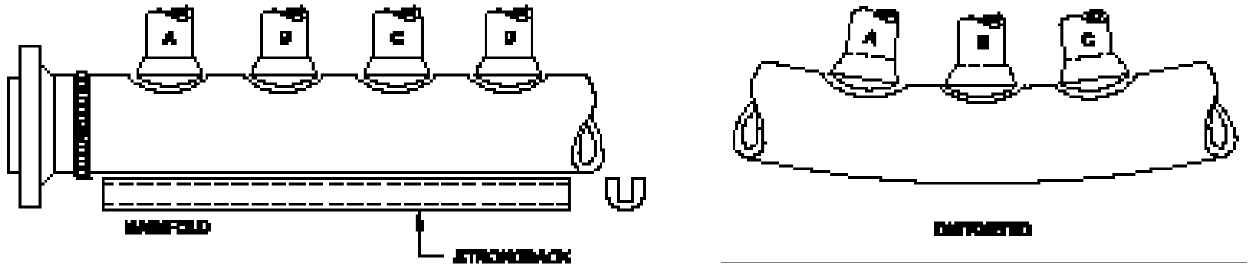


Fig. 1.8.42 (Top) Use of a strongback to prevent distortion (Bottom) Pipe distorted (Bent) As A Result Of Welding

Exercise

I. Answer the following questions.

1. What is duty cycle?

----

2. How is the output of an arc welding machine indicated ?

----

3. What are the factors to be considered while selecting the power source?

----

4. What are the practical methods to minimize distortion during fabrication?

----

5. Why is preheating required prior to welding?

----

6. Mention the four steps to check the weld joint conditions for pipe fitter activities.

----

7. Why are wind shields or tents required during field welding?

II. State whether the following statements are True or False.

1. No fitup and welding shall be carried out when the parts to be welded are wet

   True ☐ False ☐

2. The pipe fitter must always be aware of the distortion and its control

   True ☐ False ☐

3. Alternating current (A.C) is the current of choice for most welding applications

   True ☐ False ☐

4. There is no difference between open circuit voltage (OCV) and arc voltage.

   True ☐ False ☐

Notes

1.8.6 Electrode Classification

At the end of this topic, you be will able to:

1. explain the necessity of coding electrodes
2. describe the electrode coding as per AWS.

1. Introduction

The primary element of the shielded metal arc welding (SMAW) process is the electrode. It is made of a solid metal core wire covered with a layer of granular flux held in place by a bonding agent.

Since the electrode is an important feature of the process, it is necessary to understand how the various types are classified and identified.

2. AWS specifications

American Welding Society (AWS) specifications A5.1 to A 5-34 describe the requirements for various electrodes filler wires, flux, gas. They describe the various classifications and characteristics of these electrodes. Most of the industrial countries issue filler metal specifications. In the United States, the AWS provides filler metal specifications. They are approved by ANSI (American National Standards Institute) and have become an American national standard. The American Society of Mechanical Engineers (ASME) in its "Boiler and pressure vessel code" issues filler metal specifications that are identical to AWS specifications. ASME adds the prefix letters SF to the specification number.

ASW A 5.1/ASME SFA 5.1

Many countries use specifications of the industrialized countries (American, European, Canada) All welding consumable (filler metals and fluxes) shall conform to one of the following specifications:

AWS

A 5.1, A 5.20, A 5.2, A 5.23, A 5.5, A 5.28, A 5.17, A 5.29, A 5.18

Consumables that do not conform to the specification above may be used provided the welding procedure specifications involving their use is qualified.

3. AWS Codification (Classification)

The American welding society has a classification system to identify SMAW electrodes for mild steel, low alloy steel, stainless steel and cast iron. AWS classifications for filler metals provide valuable information to welders about their usability, includes what materials are best suited and how to use these products in a way that maximizes performance. They also offer insight into the mechanical properties that a given filler metal will provide. A simple numbering system is used for electrode classification. The welding electrodes are classified according to: type of current, type of covering, welding position, mechanical properties of the weld metal in the welded condition.

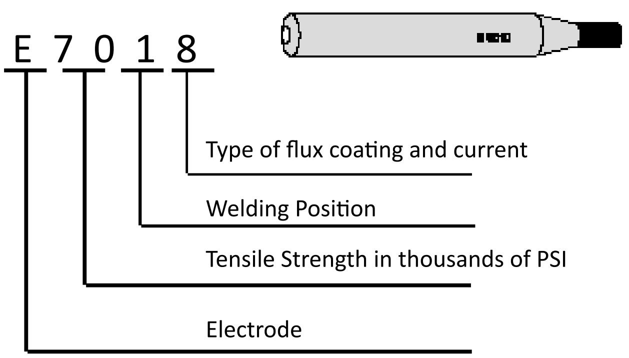


Fig. 1.8.43 SMAW Electrode codification system

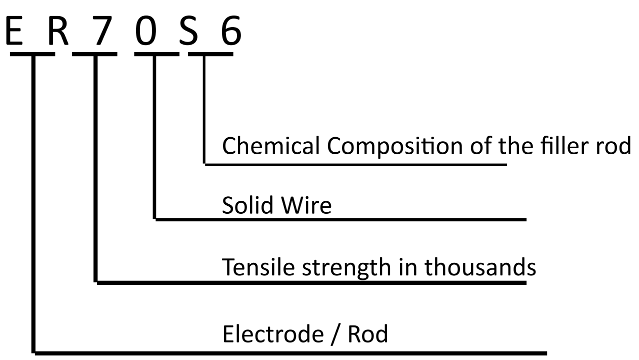


Fig. 1.8.44 GMAW filler wire

The AWS classification such as E 6010, E 7018 is printed on the flux coating near the end of the electrode. It indicates that the electrode manufacturer has qualified the electrode to the AWS specification for mechanical and chemical properties. The identification consists of an 'E', which stands for electrode, followed by four or five digits.

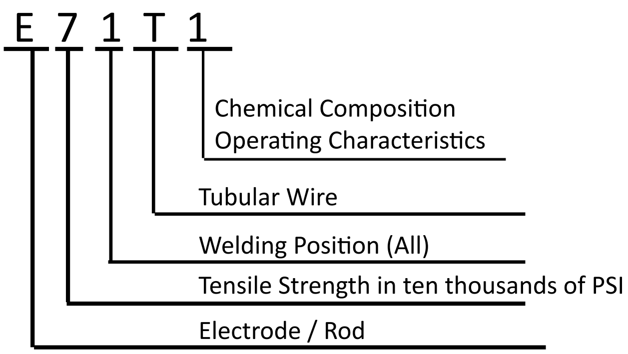


Fig. 1.8.45 FCAW filler wire

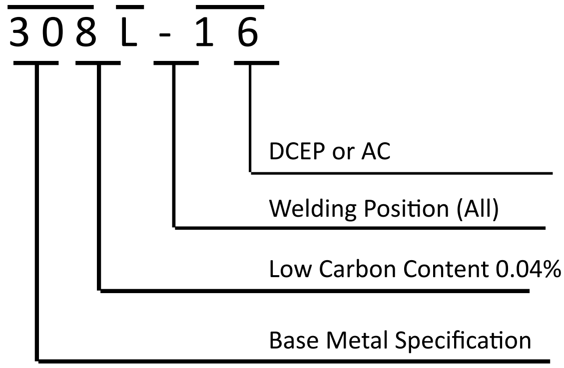


Fig. 1.8.46 SMAW Stainless steel electrode

The first two or three digits refer to the minimum tensile strength of the deposited weld metal. These numbers state the tensile strength in thousands of pounds per square inch. For example, '70' means that the tensile strength of the deposited weld metal in at least 70,000 psi.

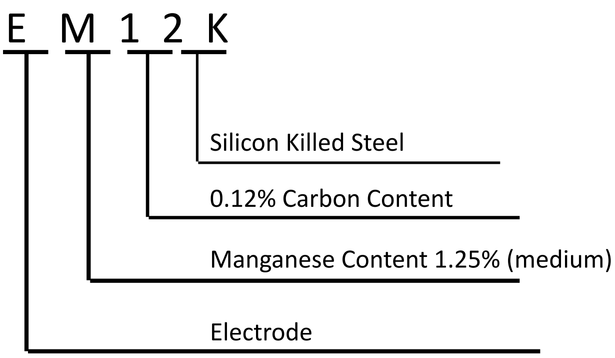


Fig. 1.8.47 SAW Filler wire

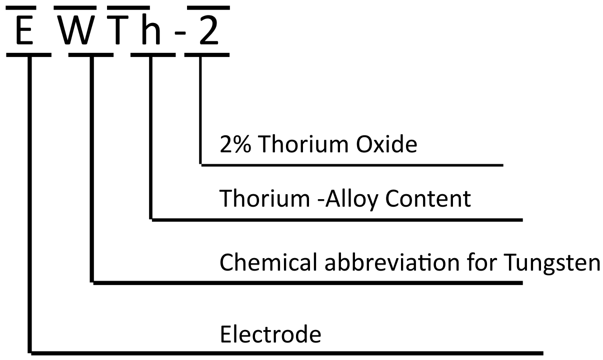


Fig. 1.8.48 GTAW electrode - Tungsten

The next digit refers to the positions in which the electrode can be used. A '1' denotes that the electrode is suitable for use in any (all) positions. A '2' means that the electrode can be used only in the flat or horizontal fillet positions.

The last digit describes the usability of the electrode by the type of flux coating and recommended current conditions (AC, DCEP or DCEN). The electrode ending in '8' is classified as low hydrogen types and is used in AC or DCEP. The electrode ending in 'O (Zero)' is classified as cellulose coating, deep penetration used in DCEP (E6010).

4. Electrode identification

The electrode classification number is imprinted is stamped on the electrode covering filler wire within 65 mm of the grip end of the electrode. All manual electrodes shall be properly identifiable upto the time of usage, each electrode being distinguishable by a coding marked near the grip end.

Electrodes without a code marking shall not be used.

5. Electrode storage

Electrodes, filler wires and fluxes shall be stored in a dry storage room in accordance with the manufacturer's instructions. Basic low hydrogen electrodes, after removal from the containers, shall be baked in ovens. The baking ovens and the holding ovens shall have automatic heat controls and a temperature read-out display.

Exercise

I. Answer the following questions.

1. What is the minimum tensile strength of an E6010 electrode?

----

2. Write the different electrode classifications (codifications).

----

3. What do the first two numerical digits of a SMAW process electrode indicate?

----

4. Write any three AWS specifications numbers of welding electrodes.

----

5. How are welding electrodes classified and identified?

----

6. Explain E7018 codification system.

II. State whether the following statements are True or False.

1. 'W' on a tungsten electrode designates 'welding'.

   True ☐ False ☐

2. According to the AWS electrode codification, the letter 'E' stands for 'Electric Current'.

   True ☐ False ☐

Notes

1.8.7 Electrode Angle and Arc Striking Method/ Technique

At the end of this topic, you will be able to:

1. familiarise with the electrode angle and its effects on the quality of welds.

1.8.7.1 Electrode

The electrode is consumed in the arc and provides the filler metal for the joint. The electrode consists of a straight piece of solid metallic wire called core wire, that has a concentric covering / coating of flux.

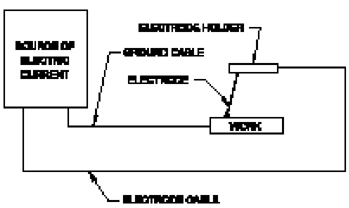


Fig. 1.8.49 Simple Welding Circuit

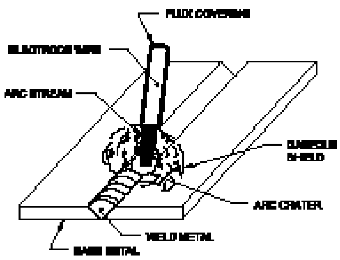


Fig. 1.8.50 SMAW Electrode

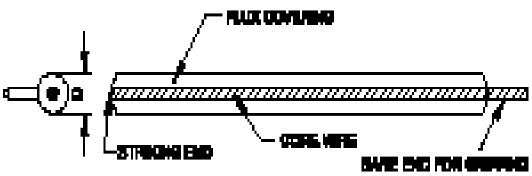


Fig. 1.8.51 SMAW Electrode During Welding

1.8.7.2 Electrode Angle

The angle of the electrode with respect to the weld puddle is very important while welding. Improper electrode orientation causes slag entrapment, undercuts and porosities. The type and the size of the electrode and the welding position combined decide the angle that the electrode is to be kept with respect to the work and the weld joint. Electrode travel angles (both pushing angle in case of forehand welding and pulling angle in case of back hand welding) is to be kept correctly. The travel angle is the angle between the joint and the electrode along the axis of the weld. A push angle exists when the electrode points in the direction of travel. The push angle reduces heat input because the arc is pointing away from the puddle. A pull (drag) angle points away from the direction of travel. The pull angle increases heat input because the arc is pointing into the puddle.

Also, the work angle (the angle of the electrode to work surface toward side ways), is equally important to avoid under cutting or lack of side wall fusion. A large travel angle may cause a convex shaped weld profile with insufficient penetration, whereas a very small travel angle can cause slag entrapment. This is more so in vertical and overhead welding and in girth welding of pipes.

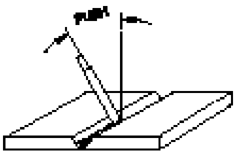


Fig. 1.8.52 Push Angle

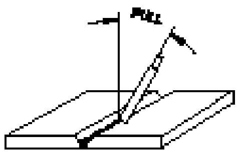


Fig. 1.8.53 Pull Angle

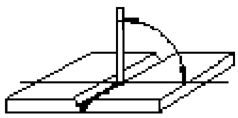
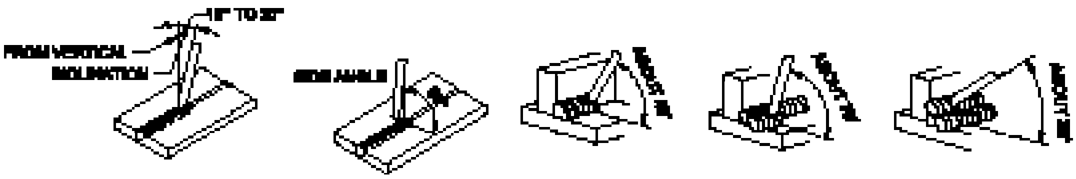


Fig. 1.8.54 Work Angle



1.8.55 Electrode Angle

Welders should be trained by experienced welding instructors in controlling the electrode angle and other aspects of electrode manipulation, to attain the standard as per specification.

The angle of electrode should be 90° to the base metal surface and at 5° to 15° to the direction of the weld in the overhead position. The correct angle for welding of pipe in 5G-up position. The electrode is brought back to the 6.30 position which is the actual starting position for the root bead. The angle is especially critical in pipe welding since it changes constantly as the weld progresses around the pipe.

1.8.7.3 Striking the arc

In shielded metal arc welding the coalescence is provided by the electric arc which struck between the electrode and the work. Striking the arc is the operation of touching the work with the electrode and taking it back from the work to a proper distance in order that the arc is sustained and not extinguished. Striking the arc is a basic action throughout the entire welding operation. It occurs every time an electrode is changed or the weld is started. In shielded metal arc welding with coated electrodes, the arc is 'struck' in the following two ways:

a. The 'touch and retract' method. b. The 'scratch' method

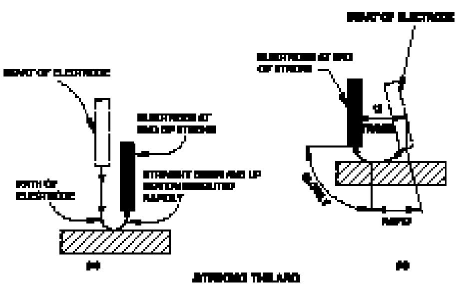


Fig. 1.8.56 Striking the Arc

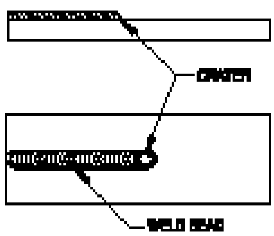


Fig. 1.8.57 Weld Crater

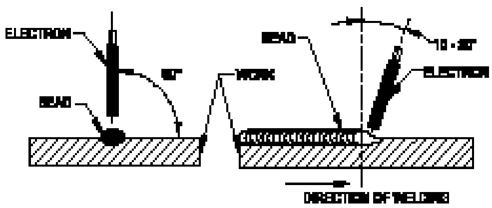


Fig. 1.8.58 Electrode Position when making flat beads

1. The 'touch and retract' method

- Ensure personal protective equipment are worn.
- Put on the welding helmet or bring the welding shield in front of your eyes.
- Hold the coated electrode in the electrode holder.
- Strike the arc by moving the electrode down to touch the job surface lightly.
- Bring the electrode down almost vertically to touch the plate and then swiftly retract or withdraw through a short distance to ignite an arc.
- Once the arc is struck, as the electrode is being consumed, the electrode is to be moved down slowly, and at a uniform rate to sustain the arc.
- The touch start method is mostly recommended as it does not put pit marks on the job surface.

2. The 'scratch' method

- Strike the arc by dragging the electrode quickly and softly across the welding job using wrist movement only.
- Withdraw the electrode approximately 6mm from the surface for a few seconds and then lower it to approximately 3 mm distance to maintain the arc.
- If the arc has been properly struck, a 'burst of light with a steady sharp cracking sound' will be produced.
- To break the arc quickly withdraw the electrode up.
- The welder will have to, in the beginning, practice this 'striking' till adequate experience is obtained in striking (without sticking) and maintaining a stable arc.

3. Maintaining the arc

Once the arc is struck, it is necessary to maintain and sustain it. The experience gained and the skill of the welder play a vital role in the maintenance of a stable arc. However, stability of the arc is also dependent on the electrode and the power source employed. The type of coating influences the arc length to a large extent. While it is easy to maintain an arc with 'touch' electrodes, it is less easy with 'rutile' (E6013) electrodes. Cellulosic type of electrodes (E6010) are even more difficult while the basic coated (E7018) variety requires deft control.

4. Stopping the arc

When the arc is to be extinguished, the electrode is to be lifted so that the gap between the electrode and the work is too large for being bridged by the flow of electrons and ions.

5. Crater

When the arc is extinguished abruptly, there is a likelihood of a crater being left in the puddle as it solidifies. Such craters could give rise to increased stress levels and often are likely to have cracks in them. Such cracks are more predominant in low alloy steels and stainless steels. As crater cracks are undesirable, it is necessary to avoid crater cracks or deep craters by filling up the crater before the arc is extinguished. This is done by retracting the electrode as the weld is about to be complete, to obtain a longer arc length and tracing back the weld in the opposite direction of travel for a short distance and when extinguishing it. This will provide for metal transfer through the 'long' arc which will fill the crater cavity.

6. Tack welder

During fitup of the piping components, tack welding shall be carried out by qualified welders in accordance with the same requirements and parameters as for the root pass of the base material. A welder can not be engaged for tack welding only. So, the pipe fitter will be qualified as a tack welder by visual inspection and bend testing of fillet weld prior to commencing production welding.

1.8.8 Straight Line Beads on M.S. Plate

At the end of this exercise, you will be able to:

1. select the electrode, current and polarity for deposting the weld beads
2. maintain constant arc length, electrode angle and travel speed
3. deposit straight line beads.

Practical

Requirements	
Tool/Instruments Welding helmet - 1No. Chisel - 1No. Wirebrush - 1No. Chipping hammer - 1No. **Equipment/Machines** Welding Machine with accessories – 1No. Grinding Machine AG4 – 1No.	Personal protective equipment – 1 Set **Materials / Components** M.S. Plate – 10mm x 100mm x 150mm – 1No. Electrode E6013 / E7018 ϕ 3.15mm each – 1No. Grinding Disc 4" dia – 1No.

Bead on plate welding

The pipe fitter would be able to deposit straight line bead upon completion of this exercise. This consists of laying weld beads on a plate in the flat position. The exercise involves the following steps.

i) Take a plate of suitable dimensions length (150) x width (100) x 10MM thickness. Usually a mild steel plate is selected.

ii) Grind lightly the surface of the plate, clean and wire brush the surface to be free of dust, rust, oil, grease, etc.

iii) Using a chalk, a ruler, centre punch and hammer, lay out parallel lines on the face of the plate.

iv) Connect the ground or earth connection to the plate. Check for proper connections to the electrode holder and polarity.

v) Set proper current.

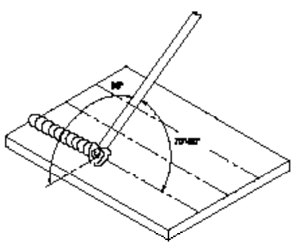
vi) Strike the arc a little away from the edge nearest the operator.

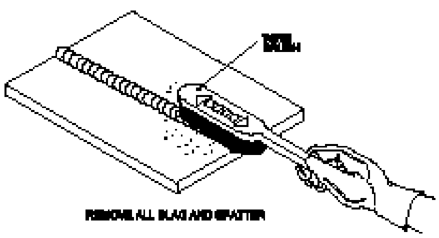
vii) Move the electrode maintaining the arc, along the line drawn on the plate, slowly across away from the operator.

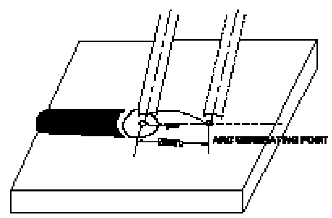
viii) Do not allow the arc to get extinguished except for changing the electrodes.

ix) When one bead is completed, repeat the same process on the other lines.

x) Repeat the exercise till adequate steadiness is obtained in laying straight string beads and uniform beads that could be produced consistently.







Exercise

I. Answer the following questions.

1. How is the welding arc started? Explain the usual methods for striking an arc.

---

2. How can the crater at the end of the weld bead be eliminated?

---

3. What are the tests to be conducted to qualify a pipe fitter for tack welding?

---

4. What is the difference between a push and pull travel angle?

---

5. What are the possible consequences of an incorrect work angle?

---

6. Explain the electrode angle in 5G up hill position.

II. State whether the following statements are True or False.

1. Correct electrode angle is not so important to make good welds.

   True ☐ False ☐

2. The angle reduces the heat input.

   True ☐ False ☐

3. The electrode angle is not critical in pipe welding.

   True ☐ False ☐

4. A welder can not be engaged for tack welding only.

   True ☐ False ☐

Notes

1.8.9 Welding Techniques 1F, 1G, 5G Vertical Up and Downhill Positions

At the end of this topic, you will be able to:

1. make edge preparation of pipes
2. tack weld the fitup
3. weld a joint in vertical up (5G) position, uphill and 5G downhill positions.

1.8.9.1 Basic pipe welding procedures

Before starting to learn pipe welding, a pipe fitter should be proficient in welding in the four basic positions:

flat, horizontal, vertical and overhead. All of these positions are used to weld pipe. Since the pipe has a round shape, there is usually a gradual transition from one position to another. When the pipe is in the 5G position, with its axis horizontal it can readily be identified by their likeness to the numbers on the face of a clock. Pipe axis horizontal and pipe is fixed in horizontal. Rotation of pipe is not possible in “5G fixed position. Welding is to be accomplished in the vertical position.

Two different welding procedures are used when the pipe is in the horizontal position: downhill and uphill pipe welding.

1.8.9.2 Welding technique

Perhaps, the most difficult position in which to weld pipe is in the 5G position. Once this is mastered, welding pipe in other positions is less difficult to learn. For this reason, it is best to start by learning how to weld in the 5G position. Vertical up welding uses lower current and slower travel speed to produce a joint with fewer, but heavier beads. The slower travel speed of vertical up welding and the highly liquid pool melts out gas holes more effectively than vertical down welding. Vertical up welding requires a larger root opening and bevel angle than vertical down. The best way to weld an open root is to use a deep penetrating electrode like E 6010.

1.8.9.3 Pipe Clamps

One difficulty encountered in assembling pipe to be fabricated / installed, is the positioning of the pipe before tacking. External line up clamps are made to hold virtually any type of pipe joint. The use of clamps to secure proper alignment is highly recommended. The pipe joint should be clamped using the external line up clamp.

T. - Thickness, A - 60° - 70°, B - ±5mm, C - 1 - 5 ± 0.75mm

1.8.9.4 Welding technique 5G downhill position

a. Introduction

Pipe joints are often used in industries that include pipeline projects, refineries, tanks etc. In butt joints, the letter ‘G’ is used to signify a groove joint (edges are beveled) and a number is assigned to signify welding position. 5G-Multiple positions (flat, vertical and overhead), pipe is fixed, groove weld, pipe axis is horizontal and is not rotated. Welding is done without rotating the pipe.

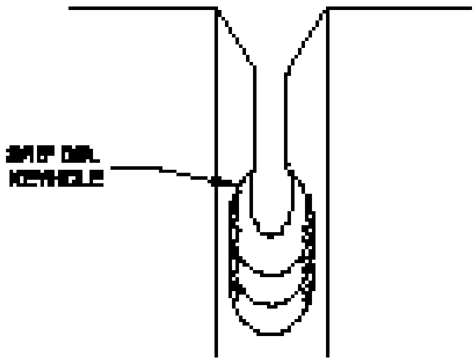


Fig. 1.8.59 Key Hole

b. Shielded Metal Arc Welding (SMAW)

SMAW is one of the principal processes for welding pipe both in the shop and in the field. Standard welding power sources which produce direct current such as a rectifier, inverter or an engine driven machine may be used.

Welding may be done in 5G position and the direction of welding may be downhill or downward.

c. Pipe welding electrodes

E60 10 This type of electrode is frequently selected for joining pipe and generally are capable of welding in the vertical position with either uphill or downhill progression.

1.8.10 SMAW – 1F Position – M.S. Plate

At the end of this exercise, you will be able to:

1. Set the tee joint in flat position for welding
2. deposit root run in ‘T’ joint of proper size
3. deposit final run in the ‘T’ joint of proper leg size.

Practical

Requirements	
Tool / Instruments Chisel, File – as required Wire brush, Try square, Chipping hammer **Equipment / Machine** Welding machine with accessories – 1 No.	**Material / Components** M.S plate 10 X 50X 150 mm – 2 Nos. Welding Electrode E 6013. Ø 3.15 mm – 2 Nos.

Set the pieces in alignment forming 92° between plates. Presenting to 92° is done to compensate the effect of shrinkage forces when weld deposit cools down.

Tack weld the pieces at both of the Tee joint by using a 3.15 mm diameter, electrode and 110/120 amps welding current.

Follow weld sequence to avoid distortion.

Ensure the alignment of the Tee joint after tacking.

Perform root pass welding after tacking.

Complete fillet joint welding with hot and fill passes till required fillet

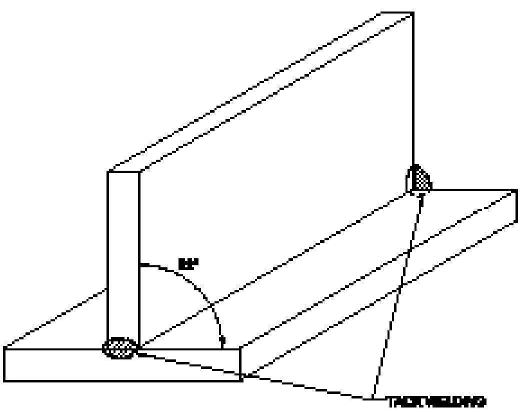
Use a channel to place the joint in a flat position.

The electrode angle of 45° will help to fuse both plates equally and the 80° angle will help to get a good root penetration.

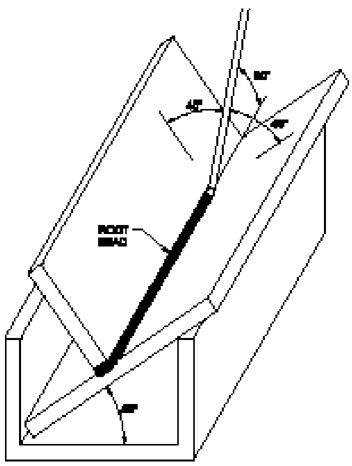
- Proceed along the welding line with uniform travel speed and short arc to get uniform fusion and root penetration. The slag has to be removed thoroughly from the root run so that the slag inclusion defect can be avoided in the next run.
- Use a slightly side-to-side weaving motion. The width of weave should give a leg size of 10mm.
- Maintain the same electrode angle as in the root bead.
- If the leg size is less than 10mm, then deposit a third run using the same technique used for the second run.
- Clean the final covering bead thoroughly.
- Stop the electrode weaving for a moment at the toes of the weld to avoid undercut. Fill the crater at the end of the bead.

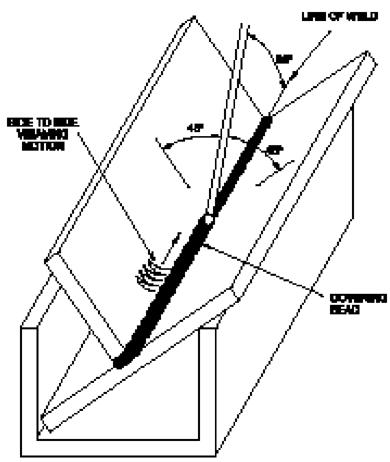
Inspection of fillet welds

Inspect the fillet for defects, correct shape and size of fillet and equal leg length on either side of the weld.



SETTING AND TACKING A TEE JOINT





1.8.11 SMAW – 1G Position – M.S. Plate

At the end of this exercise, you will be able to:

1. prepare the bevel by gas cutting and /or grinding
2. deposit root run in single-V-butt joint
3. deposit filling and covering runs with proper fusing and reinforcement.

Practical

Requirements	
Tool / Instruments Welding helmet, Chisel, File, Wire brush, Try square Chipping hammer **Equipment / Machine** Welding machine AG7 / AG4 machine	**Material / Components** M.S plate 10 X 50X 150 mm – 2 Nos. E 6013 / E 7018, Ø 2.5, Ø3.15 mm

Preparation of the pieces

Cut a 30° bevel on each piece using oxy-acetylene cutting. Grind the bevel edges to remove oxide deposits on the bevel. Prepare uniform root faces 1.5 mm by filling on both the bevelled edges.

Setting the single Vee butt joint and tacking

Keep the bevel edges upside down with a root gap of 2mm.

Tack weld on both ends without any misalignment.

Ensure safety apparels are worn.

Place the joint in flat position after tacking.

Deposition of root bead

Deposit root bead suing a 3.15 diameter. M.S. electrode and 110 amps welding current.

Proceed with a uniform normal speed holding a short arc.

Keep the electrode angle at of 800 to the line of weld.

Give a whipping motion to the electrode to maintain the size of the keyhole for correct penetration.

Deposition of covering and intermediate beads

Deposit the 1st covering bead using a 4.00mm dia electrode and 160 amps welding current.

Ensure the electrode angle is the same as it was for the root bead.

Clean the bead thoroughly and grind the humps in beads (if present).

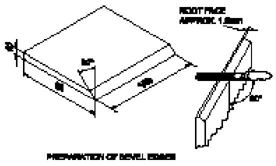
Rectify possible defects, if any.

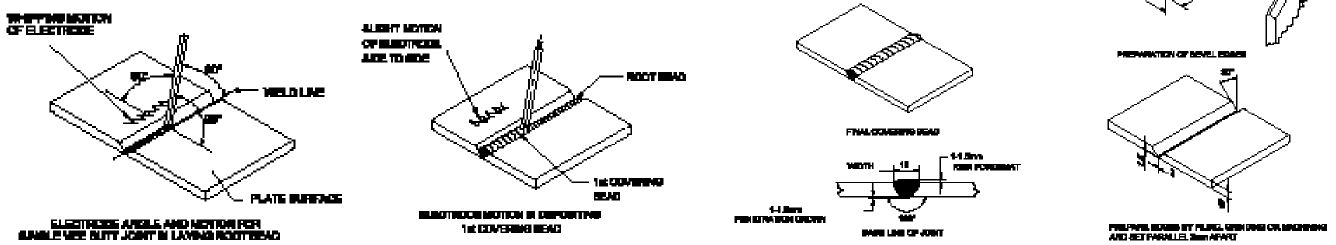
Deposition of final bead

Deposit the final covering bead using a 5.00mm 220 amps welding current, and imparting a wider side-to-side weaving motion to the electrodes. Pause (stop) the electrode weaving at the toes of the weld so that undercut defect will get eliminated. Follow the other steps as done for the 1 st coering bead.

Cleaning and inspection

Clean the welded joint thoroughly from both sides. Inspect the weld size, surface defects, root penetration and distortion.





1.8.12 Welding Techniques 5G Vertical, Up and Down Hill Positions

At the end of this exercise, you will be able to:

1. preparation of pipe bevel
2. fitup and tack weld the pipe
3. weld a joint in vertical up (5G) position.

Practical

Requirements	
Tool/Instruments	**Materials / Components**
Welding helmet – 1No.	M.S. /CS Pipe ϕ 6" sch 40, 150mm long – 4 Nos.
Chisel – 1No.	100mm long – 2 Nos.
Wirebrush – 1No. Chipping hammer – 1No.	Welding Electrode – 2 Nos. E 6013 / E7018, ϕ 3.15 mm
	Grinding Disc 4” dia – 1 Nos.
Equipment/Machines	
Welding Machine with accessories – 1 Set	
Grinding Machine - AG4 – 1No.	

Practising for 5G position

Prepare a pipe diameter 168mm OD (ϕ 6”), 7-11mm thickness, 100mm long. Mark lines at a pitch of 20mm. Tack weld the pipe in its axis in the horizontal.

Strike the arc at the 1’o clock position and maintain the correct electrode angle and arc length. Move the electrode towards 6’o clock position (clockwise).

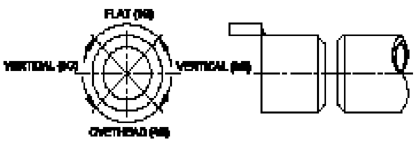


Fig. 1.8.60 Pipe Horizontally fixed Position - 5G

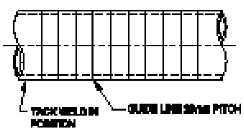


Fig. 1.8.61 Practicing for horizontal fixed position

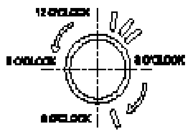


Fig. 1.8.62 Movement of electrode in horizontal fixed position

Do not support or rest your hand on the pipe or the table. Break the arc, at the 7’o clock position above (anticlockwise). Repeat the above steps several times, till the pipe fitter is able to produce uniform weld beads using the arc, restarting and merging techniques.

Preparation of pipes

Clean the bevel face and the pipe surface at least 1 inch from the edge of the welding groove to remove rust, scale, paint, oil and grease. Grind or file the bevel surfaces smooth to remove all traces of scale and any cutting irregularities. Make sure that the bevel angle conforms to the welding procedure specification. The groove angle must be large enough for the electrode to fit into the groove.

Tack welding (Fit-up)

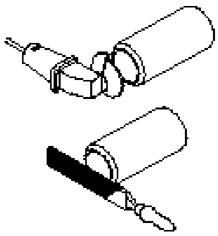


Fig. 1.8.63 Bevel Preparation

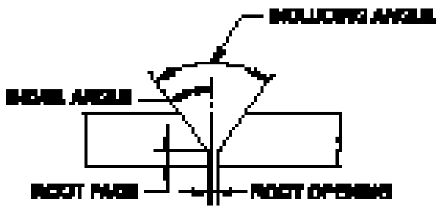


Fig. 1.8.64 Weld Joint Definition

T. Thickness
A. 37.5° ± 2.5°
B. 1.6 ± 1.6mm
C. 1.6 ± 0.75mm

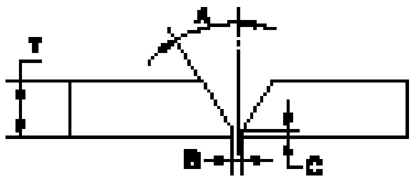


Fig. 1.8.65 Typical Single -V- Butt Joint

Make sure that the proper root opening between the pipe ends has been set up. The simplest way to secure and maintain an accurate root opening is to use a 3.2 mm gas welding wire of the proper size. By crossing the wire, you have accurate spacing at four points along the circumference of the joint. The pipe fitter should align the pieces of pipe as well as possible, then tack weld them to ensure that they do not shift during welding. The best method for tacking the pipe depends upon its size, but can usually be done with four 1 inch (25 mm) long tack welds. Make sure that the faces of the welds are flat. Good fitup always improves results.

Welding technique – 5G Position

Vertical down welding is a cross-country pipeline technique. Welding is from the top to the bottom. The vertical down method requires 50 to 75 more amperes than the vertical - up method. Larger electrode sizes are specified for vertical down.

For the joint design shown, the travel speed for vertical down is more than twice that for vertical up.

Deposition of root pass

Root Pass is the basis for success or failure in making a pipe weld. It is also the basis of a sound weld.

Electrode – E 6010, f 4.00 mm

Current setting – 150 – 200 amps

Electrode Angle – 30 to 45° from the horizontal center line.

Start the root pass at 11’o clock or 1’o clock position. Weld across the top of the pipe and downward past the 6’o clock position to the 7’o clock or 5’o clock position.

Make the stringer bead with a drag technique. Rest the electrode coating on the bevel as you drag the electrode downhill around the pipe.

Maintain a small visible keyhole at all times to obtain adequate penetration on the inside of the pipe.

After the root pass is completed on one side of the pipe, weld the other side in the same manner.

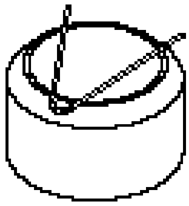


Fig. 1.8.66 Spacer Wire in V-Form

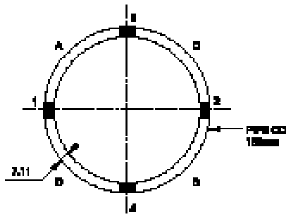


Fig. 1.8.67 Tack Weld

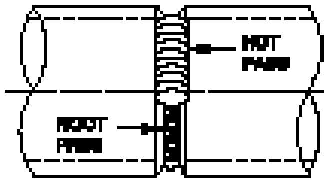


Fig. 1.8.68 Hot Pass (Welding Sequence)

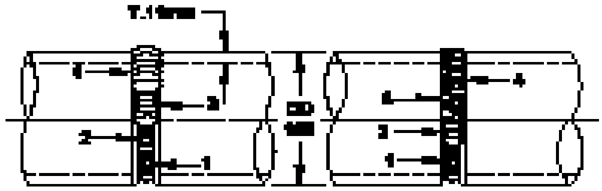


Fig. 1.8.69 Welding Sequence in 5G Down Hill Position

Second (Hot) pass

Remove all slag before making the hot pass (second pass).

Electrode – E 6010, ϕ 4 mm or f 5 mm

Current setting – 150 - 190 amps

Electrode angle – 30° to 45°

The hot pass should be started within 5 minutes. Welding should start at the top of the joint outside of the area of the previous starting point, proceed downhill and stop at the bottom outside the area of the previous stopping point.

Fill Passes

The filler passes should be made with a 5 mm electrode and a current setting of 160 - 200 amps. Use a slight side-to-side weave and ensure that the weld deposit fills the groove and fuses into the side walls.

Final pass

This pass is also referred to as a cover pass or capping pass. The final pass is made with a 4 mm electrode and a current setting of 120 to 160 amperes. A weave motion with some hesitation at each is used to prevent undercut. Take more care and maintain the same electrode angle and travel speed as practiced previously.

The completed weld should be from 1.0 mm to 1.5 mm higher than the pipe wall and should overlap the groove by 1.5 to 3 mm on each side. Remove the slag and clean thoroughly. Visually inspect the weld. The pipe joint welded by SMAW in 5G position depends upon the v - groove width.

Requirement

Before any production welding is performed, the individual shall be qualified according to the applicable requirements. The specified minimum preheat shall be applied before any tack welding.

Root tack welding shall be performed in accordance with the root pass parameters of the approved WPS. Tack welders shall be qualified to weld with the WPS.

Dollymix welding technique

Dollymix welding is a term used to define the progression of welding technique for pipeline welding. Dollymix means the root pass will be welded in uphill progression and the remaining passes will be in downhill welding progression.

Tips

Safety

The electrode holder must be effectively insulated and properly maintained.

Exercise

I. Answer the following questions.

1. Briefly explain how a root pass weld is produced.

   ----

2. Describe root and final pass welding in 5G position (a pipe joint).

   ----

3. What is the type of electrode to be used for downhill welding in pipe joint?

   ----

4. Explain about 'tack welding'.

   ----

5. State any three requirements of pipe welding.

II. State whether the following statements are True or False.

1. A typical pipe end prepared bevel is 37.5°, which would make the included angle 75°.

   True ☐ False ☐

2. During 5G position, welding may be done with or without rotating the pipe.

   True ☐ False ☐

Notes

1.8.13 Welding Defects

At the end of this topic, you will able to:

1. name different weld defects in welded joints
2. define weld defect
3. describe the repair procedure.

1.8.13.1 Defect: If a weldment is to have the required reliability throughout its life, it must have a sufficient level of quality or fitness for purpose. A weld that does not meet any or all of the specific requirements of a particular specification or code is considered a defective weld. In the correct sense of the word, a defect is a rejectable discontinuity or a flaw of rejectable nature.

Certain flaws acceptable in one type of product need not be of acceptable nature in another product.

a. Type of defects

Defects in weldments in general can be classified as follows:

1. Defects involving inadequate bonding
   - Lack of fusion
   - Incomplete penetration.

2. Foreign inclusions
   - Slag
   - Tungsten
   - Oxide films.

3. Geometric defects
   - Undercut
   - Excessive reinforcement
   - Burn through or excessive penetration
   - Distortion
   - Improper weld profile.

4. Metallurgical defects
   - Cracks
   - Gas porosity
   - Arc strikes.

b. General reasons for defects

Defect generally occur because of:

- Lack of know-how and experience
- Welding process characteristics
- Base metal composition.
- Defective welding consumables
- Joint design
- Welding environment (wind, fitup, temperature)

c. Defects Acceptance levels

Defect acceptance levels are included in certain client/project specifications or respective standards containing acceptance criteria as cross reference. Some specifications contain defect acceptance tolerances which are stricter than others, depending on the criticality rating of the structure or application to which the specification applies.

d. Effects of weld defect

- The effective thickness of the base metal is reduced.
- The strength of the weld is reduced.
- The joint will break, when loaded, causing accidents.
- The properties of base metal will change.
- The weld appearance will be poor.

1.8.13.2 Identification of weld defects

Weld defects may be indentified during visual or non–destructive testing.

1. Inadequate penetration (IP)

Inadequate penetration is defined as the incomplete filling of the weld root. One or both root faces may be inadequately filled at the inside surface.

2. Lack of fusion (LF)

LF is defined as a surface imperfection between the weld metal and the base metal that is open to the surface and also an imperfection between two adjacent weld beads or between the weld metal and the base metal that is not open to the surface.

3. Root concavity or suck back: Bead that is properly fused to and completely penetrates the pipe wall thickness along both sides of the bevel but whose center is somewhat below the inside surface of the pipe wall.

4. Burn through: A burn through is defined as a portion of the roof bead where excessive penetration has caused the weld puddle to be blown into the pipe.

5. Slag inclusion: A slag inclusion is defined as a non–metallic solid entrapped in the weld metal or between the weld metal and the parent material.

6. Undercut: Undercut is defined as a groove melted into the parent material adjacent to the toe or root of the weld and left unfilled by the weld metal.

7. Porosity and gas holes: This refers to the entrapment of gases evolved during weld metal solidification. Porosity is usually spherical in shape.

8. Cracks: These are grouped under metallurgical defects. Cracks are with a sharp tip and linear ruptures of the metal under stress. Cracks are dangerous defects and most of the manufacturing codes do not accept cracks irrespective of their dimensions. Crack shall not be repaired. When cracking is observed, the weld shall be cut out entirely.

9. Arc strikes: Arc strikes outside the area of permanent welds should be avoided on any base metal. Cracks or blemishes caused by arc strikes shall be ground to a smooth contour and checked to ensure soundness.

Fig. 1.8.70 Inadequate Penetration

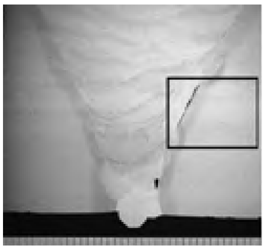


Fig.1.8.71 Lack of Fusion

Fig. 1.8.72 Root Concavity

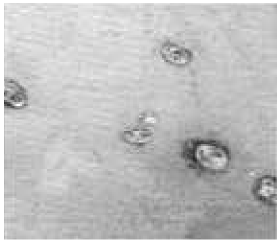


Fig. 1.8.73 Arc Strike

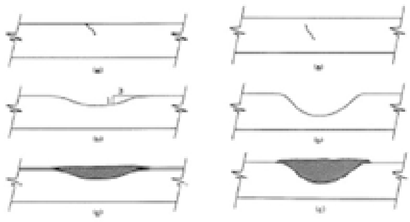
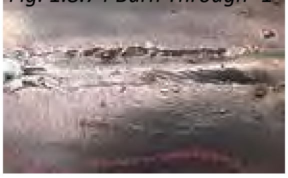


Fig. 1.8.77 Repair Welding Steps

Fig. 1.8.74 Burn Through -1

Fig. 1.8.75 Burn Through -2

Fig. 1.8.76 Slag Inclusion



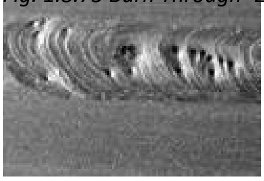


Fig. 1.8.78 Under Cut

Fig. 1.8.79 Porosity

Fig. 1.8.80 Crack (HAZ)

1.8.13.3 Rectification of weld defects (Repair welding)

Once the decision has been made to make a weld repair, it is necessary to review why the part failed or was worn out. There is no guarantee that a repair weld produces a more sound joint than the first one.

Defects may be rectified with prior client authorization. A qualified repair procedure shall be required whenever a repair is made by welding. The welding procedure specification (WPS) may be supported by an appropriate pipe butt weld procedure qualification record (PQR). The repair weld shall be made by a qualified welder experienced in methods used for repair of a defective weld. A repair procedure, as a minimum, shall include the following:

a) Locate the defective portion.

b) Excavation shall be done by grinding. It shall be done in such a manner that the adjacent weld metal or base metal is not nicked or removed.

c) After excavation, penetrant test or magnetic test shall be performed to confirm defect removal.

d) At the ends and the sides of the excavation, there shall be a gradual taper from the base of the excavation to the surface of the weld metal. The profile shall be such that adequate access for welding is achieved.

e) The surfaces shall be cleaned thoroughly before welding.

f) Weld metal shall be deposited to compensate for any deficiency in size.

g) After completion of the repair welding, the full extent of the repair shall be visually inspected and non– destructive testing to a length extending 50 mm beyond each end of the repair.

h) The repaired or replaced weld shall be retested by the method originally used, and the same technique and quality acceptance criteria shall be applied.

Exercise

I. Answer the following questions.

1. An unfilled groove along the toe of the welding is called:

   a) Overlap   b) Undercut

2. What are the common defects encountered in arc welding?

   ----

3. What is root concavity?

   ----

4. List out the general reasons for the occurrence of defects.

   ----

5. What are the effects of weld defect?

   ----

6. List out the geometric defects.

   ----

7. What is slag inclusion? How is it caused and how is it prevented or avoided?

   ----

8. What non–destructive testing method is performed to confirm defect removal after excavation?

II. State whether the following statements are True or False.

1. Testing of all repair welds should be as per the same non–destructive testing method previously used.

   True ☐   False ☐

2. Defects may be rectified without prior client authorization.

   True ☐   False ☐

3. When cracking is observed, the weld shall be cut out entirely.

   True ☐   False ☐

Notes

1.8.14 Knowledge of Non – Destructive Testing (NDT)

At the end of this topic, you will be able to:

1. determine the applicable NDT and required surface preparation
2. prepare the weld and parent metal surfaces to perform the required NDT works
3. coordinate NDT works.

1.8.14.1 Introduction and purpose of NDT knowledge requirement

All NDT works shall be performed with written and approved procedure and inspected with respect to applicable acceptance criteria. All NDT shall be performed only by trained, qualified and certified personnel in the respective NDT method. Though pipe fitters won't do any NDT, they must know about the basics of NDT

- to perform surface preparation for NDT and offer for NDT inspections
- to perform visual inspection themselves
- to perform preliminary penetrant examination themselves without waiting for NDT technician
- to coordinate NDT works, where required
- to be aware that some standards / specifications require NDT on materials and material edges, prepared for welding
- to know though NDT shall have been done for all pipe fittings, if edges are trimmed or cut to suit site condition, or bevels are modified, appropriate NDT shall be performed before commencing fitup / assembly works
- When welds are repaired, surface NDT should be performed to ensure the defect removal
- to ascertain that if weld repairs are more in a joint or cut and re-weld is required, then cut edges shall be prepared again and tested by appropriate NDT methods, prior to fitup.

1.8.14.2 Visual Examination

Visual examination also called Visual Testing (VT) is a primary non-destructive testing. All types and methods of NDT require visual examination. Visual examination is a non–destructive examination method used to visually inspect / examine:

i. raw material, cut edges, weld edge preparations, joints, fitup, alignment, tack welds, welds and welding works (prior to welding, during welding and after welding), weld heat affected zones, etc.

ii. evaluate an item by observation, such as the correct assembly, surface conditions, or cleanliness of materials, parts such as bolts and bolting works, nuts, gaskets, flanges, fittings, and piping and pipeline components used in the fabrication and construction of piping and pipeline works

Visual examination can be performed with natural or auxiliary lighting. Minimum light intensity required at examination surface is 1000 lux. Lux (lx) is a unit of illumination equal to the direct illumination on a surface that is everywhere one meter from a uniform point source of one candle intensity or equal to one lumen per square meter. Visual inspection can be either direct visual examination, remote visual examination, or translucent examination.

a. Direct visual examination

Direct visual examination is a visual examination technique performed by eye and without any visual aids (excluding light source, mirrors, and/or corrective lenses), for example, magnifying aids, borescopes, video probes, fiber optics, etc.

Visual inspection may usually be made directly, when access is sufficient to place the eye within 24 in. (600 mm) of the surface to be examined and at an angle not less than 30 degree to the surface to be examined. The minimum light intensity shall be 100 fc (1 000 lx). The light intensity, natural or supplemental white light source, shall be measured with a white light meter prior to the examination or a verified light source shall be used.

b. Remote visual examination

- Remote visual examination is a visual examination technique used with visual aids for conditions where the area to be examined is inaccessible for direct visual examination. Remote visual examination may use visual aids such as mirrors, telescopes, borescopes, fiber optics, cameras, orother suitable instruments. Such systems shall have a resolution capability at least equivalent to that obtainable by direct visual observation. Borescopic examination is a remote visual examination aided by a mechanical or electromechanical device to examine the inside diameter and inaccessible welds.

c. Translucent visual examination

- Translucent visual examination is a technique using artificial lighting intensity to permit viewing of translucent laminate thickness variations (also called candling) The method of translucent visual examination uses the aid of artificial lighting, which can be contained in an illuminator that produces directional lighting. The illuminator shall provide light of an intensity that will illuminate and diffuse the light evenly through the area or region under examination. The ambient lighting must be so arranged that there are no surface glares or reflections from the surface under examination. It shall be less than the light applied through the area or region under examination.

1.8.14.3 Liquid penetrant examination

The liquid penetrant examination method is an effective means for detecting discontinuities which are open to the surface of materials and welds. Typical discontinuities detectable by this method are cracks, seams, laps, cold shuts, laminations, porosity, cold laps, incomplete fusion, lamination on the edges, etc.

1. Penetrant testing methods and techniques

Either a color contrast (visible) penetrant or a fluorescent penetrant shall be used with one of the following three penetrant processes: water washable, post-emulsifying, solvent removable. The visible and fluorescent penetrants used in combination with these three penetrant processes result in six liquid penetrant techniques.

Surface temperature limits As a standard technique, the temperature of the penetrant and the surface of the part to be processed shall not be below 40°F (5°C) nor above 125°F (52°C) throughout the examination period.

2. Penetrant testing procedure

a. Precleaning and Cleaning

Surface preparation by grinding, machining, or other methods may be necessary where surface irregularities, heavy scales / rusts, etc., could mask indications. Prior to each liquid penetrant examination, the surface to be examined and all adjacent areas within at least 1 in. (25 mm) shall be dry and free of all dirt, grease, lint, scale, welding flux, weld spatter, paint, oil, and other extraneous matter that could obscure surface openings or otherwise interfere with the examination.

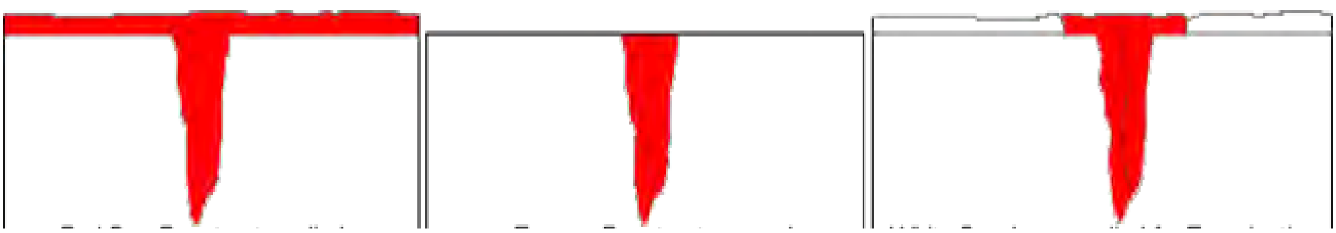


Fig. 1.8.81 Stages of Penetrant Testing

b. Application of penetrant

The penetrant is then applied to the surface of the item being tested, after precleaning and solvents evaporation. The penetrant is allowed to remain in the inspection surface for a period called "dwell time" to soak into any flaws (generally 5 to 30 minutes).

c. Excess penetrant removal

The penetrant removal method is controlled by the type of penetrant used. The remaining traces shall be removed by wiping the surface with cloth or absorbent paper, lightly moistened with solvent. To minimize removal of penetrant from discontinuities, care shall be taken to avoid the use of excess solvent.

3. Application of developer

The developer shall be applied as soon as possible after penetrant removal. Insufficient coating thickness may not draw the penetrant out of discontinuities. Conversely, excessive coating thickness may mask indications.

Developing time for final interpretation begins immediately after the application of a dry developer or as soon as a wet developer coating is dry.

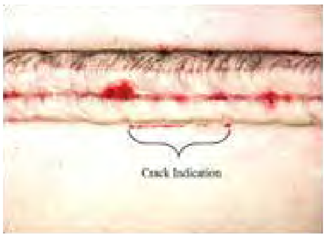


Fig. 1.8.82 HAZ Crack

Fig. 1.8.83 Cluster Porosities

Fig. 1.8.84 Cold lap

Fig. 1.8.85 Transverse Crack

4. Penetrant testing- inspection, interpretation and evaluation

Inspection of the test surface should take place after 10 to 30 minutes development time, depending on product kind. This time delay allows the blotting action to occur.

All indications shall be evaluated in terms ofthe acceptance standards of the referencing code section.

1.8.14.4 Magnetic particle inspection

The magnetic particle examination / inspection method (often abbreviated MT or MPI) is a non–destructive inspection method, applied to detect cracks and other discontinuities on the surfaces and near surfaces of ferromagnetic materials. The sensitivity is greatest for surface discontinuities and diminishes rapidly with increasing depth of discontinuities below the surface.

Typical types of discontinuities that can be detected by this method are cracks, laps, seams, cold shuts, laminations, lack of sidewall fusion in welds, etc., in magnetic materials.

1. Magnetic particle examination methods / techniques

A ferromagnetic material can be magnetized either by passing an electric current through the material or by placing the material within a magnetic field originated by an external source. One or more of the following five magnetization techniques shall be used:

prod technique, longitudinal magnetization technique, circular magnetization technique, yoke technique, and multidirectional magnetization technique

The most versatile technique is using a 110v AC handheld electromagnetic yoke magnet, a white strippable paint as contrast background and a magnetic "ink" composed of iron powder particles in a liquid carrier base, normally, in aerosol cans for portable techniques.

b. Magnetic particle inspection is performed in four steps:

i. Induce a magnetic field in the specimen.

ii. Apply magnetic particles to the specimen's surface.

iii. After stopping field application, view the surface looking for particle groupings that are caused by defects.

iv. Demagnetize and clean the specimen.

The magnetic ink is applied and the iron powder particles will bridge the gap caused by the defect and give a visible indication against the white contrast background.

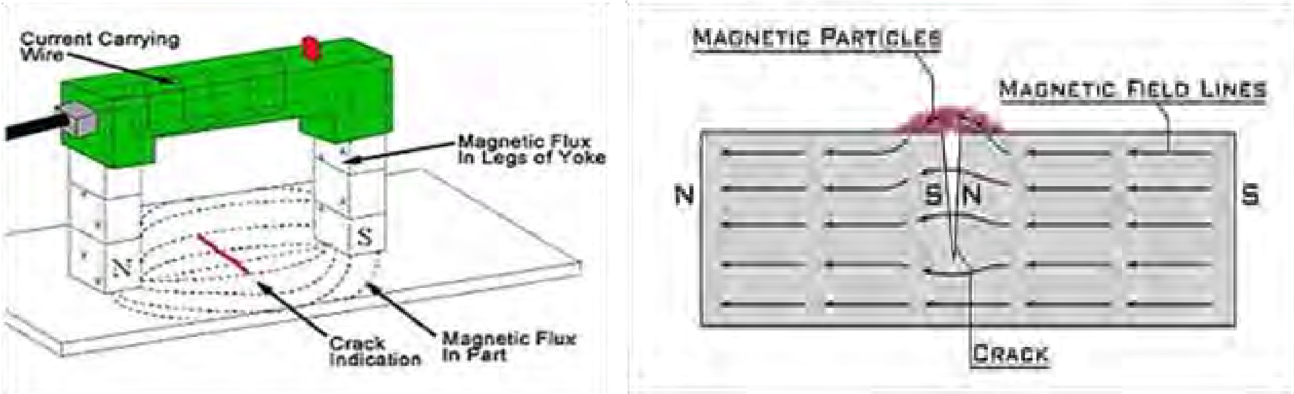


Fig. 1.8.86 Magnetic field application and discontinuity formation mechanism

Fig. 1.8.87 Flux lines flowing past perpendicular& parallel defect

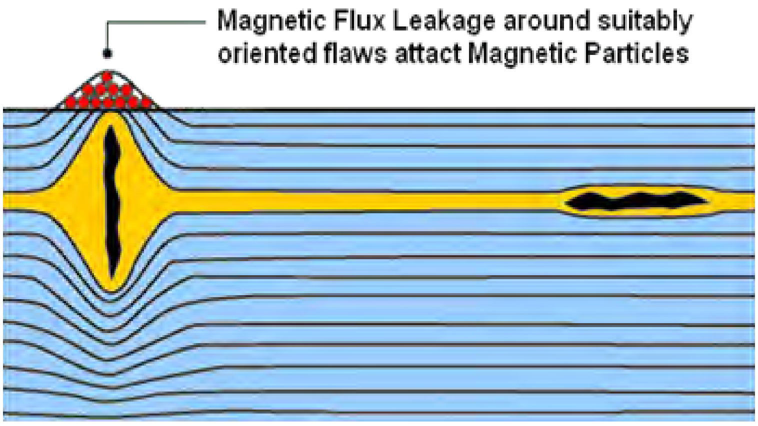


Fig 1.8.88 MPI indication formation

2. Magnetic particle inspection–Interpretation, evaluation and recording

Interpretation shall be carried out to identify the locations of indications and characterise the indication. All indications shall be evaluated in terms of the acceptance standards of the referencing code section.

1.8.14.5 Radiographic testing

Radiographic testing (RT) is a non-destructive testing (NDT), exposing test object / specimen and radiography film to X-ray or Gamma ray. Gamma rays are produced by radioactive isotopes such as Iridium 192, Cobalt-60, Selenium 75, etc. RT is usually suitable for testing welded joints that can be accessed from both sides.

By radiography method, detects such as, porosity, cluster porosity, slag / oxide inclusions, tungsten inclusions, cracks, voids, lack of fusion, incomplete penetration, undercut, etc., can be identified and inspected.

Fig. 1.8.89 Gamma Ray Equipment

Fig. 1.8.90 X-Ray Equipment

1. Radiographic techniques

i. A single wall exposure technique shall be used for radiography whenever practical. When it is not practical to use a single-wall technique, a double wall technique shall be used. In Double Wall technique, one of the following double wall viewing techniques shall be used.

(a) Single wall viewing: For materials and for welds in components, a technique may be used in which the radiation passes through two walls and only the weld (material) on the film-side wall is viewed for acceptance on the radiograph.

(b) Double Wall Viewing For materials and for welds in components 31/2 in. (89 mm) or less in nominal outside diameter, a technique may be used in which the radiation passes through two walls and the weld (material) in both walls is viewed for acceptance on the same radiograph. For doublewall viewing, only a source-side Image Quality Indicator (IQI) shall be used. (Once film exposing completed, the film shall be unloaded inside the dark room, processed at dark room under controlled temperature conditions (normally 20˚C to 24˚C), dried and made ready for interpretation).

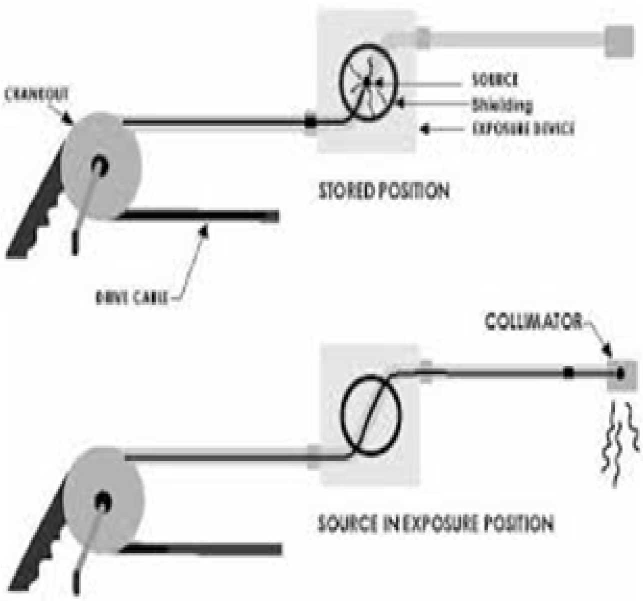


Fig. 1.8.91 RT Exposure equipment set-up

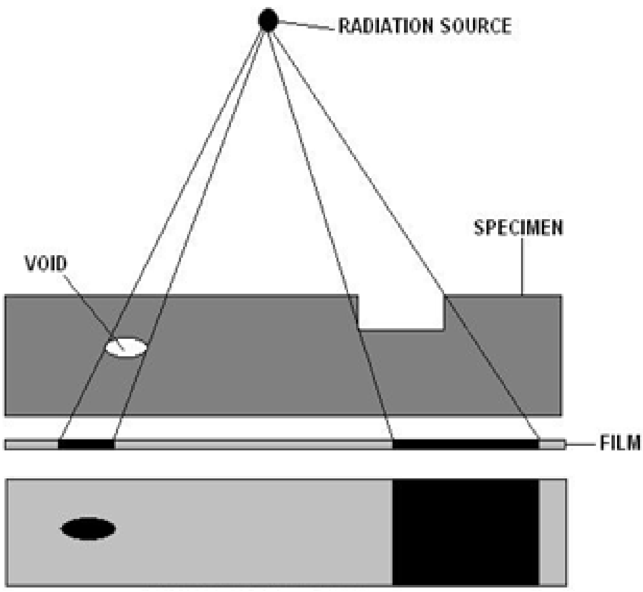


Fig. 1.8.92 RT film set-up and image formation

2. Radiography film interpretation, evaluation and reporting

Radiography film shall be checked for any artefacts and film processing marks. If more artefacts and process marks are noticed in area of interest, then, it shall be reshot (to be radiographed again). Radiographic sensitivity is a measure of the quality of an radiography image in terms of the smallest detail or discontinuity that may be detected in exposed and processed radiograph. Radiography films density shall be between 1.8 and 4.0. In general, RT film sensitivity shall be 2% or less than 2%. However, applicable code / standard requirements shall be followed. Once sensitivity and density are checked and found to be within the acceptable limit, then the film shall be interpreted for any discontnuities present. Inclusions of low density, such as slag will appear as dark areas on the film, while inclusions of high density such as tungsten, will appear as light areas. Discontinuities shall be evaluated with respect to the appecptance criteria. Defects shall be recorded and reported.

1.8.14.6 Ultrasonic Testing

Ultrasonic non–destructive testing, also known as ultrasonic NDT or simply UT, is a method of characterizing the thickness or internal structure of a test piece through the use of high frequency sound waves. The sound wave frequencies used for ultrasonic testing are many times higher than the limit of human hearing, most commonly in the range from 500 KHz to 20 MHz. In industrial applications, ultrasonic testing is widely used on metals, plastics, composites, and ceramics.

1. UT equipment and calibration blocks

i. UT Equipment

An ultrasonic flaw detector is an instrument that generates and processes ultrasonic signals (longitudinal wave and transverse waves) to create a waveform display that can be used by a trained operator to identify hidden discontinuities, if any, in a test piece.

2. Calibration blocks

Ultrasonic equipment shall be calibrated using appropriate calibration blocks such as V1 block, V2 block, flat bottomed hole sets. Basic calibration block and simulated calibration blocks with appropriate calibration reflectors shall be available for calibration.

3. Ultrasonic testing procedure

Surface Preparation: The surface to be subject to ultrasonic testing shall be free from any of lubricants, dirt, residue, rust and sharp edges. Surface preparation shall include the areas to be examined, heat affected zones and skip distances.

Fig. 1.8.93 Calibration using V1 block

Fig. 1.8.94 Typical UT testing set up and screen pattern

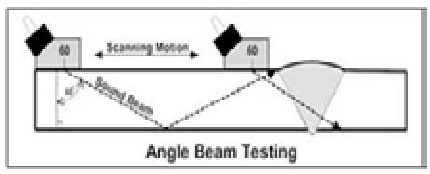


Fig. 1.8.95 UT scanning motion and sound beam bath

4. Ultrasonic testing–interpretation, evaluation and reporting

Evaluation: Any imperfection which causes an indication in excess of 20% DAC (Distance Amplitude Correction Curve) shall be investigated to the extent that it can be evaluated in terms of the acceptance standards of the referencing code.

Acceptance standard: All imperfections that produce an amplitude greater than 20% of the reference level shall be investigated to the extent that the operator can determine the shape, identity and location of all such imperfections and evaluate them in terms of respective / applicable acceptance standards. Imperfections that are interpreted to be cracks, lack of fusion or incomplete penetration are unacceptable regardless of length.

Reports: A report of the examinations shall be made. The report shall include a record indicating the welds or volume examined (this maybe marked in sketches) the location of each recorded reflector, and the identification of the operator performed the examination.

1.8.14.7 Ultrasonic thickness measurement

1. **Equipment:** Ultrasonic thickness gauge is used to measure thickness of a metallic and non–metallic material from one side applying non–destructive test technique. Access from one side of the object / test specimen is sufficient to measure the thickness. Whereas, micrometer and caliper need access from bothsides to measure the thickness.

2. **Working Principle:**

An ultrasonic thickness gauge also known as “D-Meter” is an instrument that generates sound pulses in a test piece and very precisely measures the time interval until echoes are received. Having been programmed with the speed of sound in the test material, the gauge uses that sound velocity information and the measured time interval to calculate thickness through the simple relationship [distance] equals [velocity] multiplied by [time].

Thickness, Tk = (V) x (t/2) where

Tk = the thickness of the part

V = the velocity of sound in the test material (this velocity will be different for different materials).

t = the measured round-trip transit time (sound travelling time from thickness measuring probe to reach the backwall and return to the thickness measuring probe).

Exercise

I. Answer the following questions.

1. Why should a pipe fitter have knowledge on NDT?

---

2. Describe the principle and processes of penetrant testing.

---

3. What are the different penetrant testing methods and techniques?

---

4. How do magnetic particles get accumulated and form tge defect image ?

---

5. What are the three main steps in magnetic particle examination procedure?

II. State whether the following statement True or False.

1. Liquid penetrant examination method is suitable for detecting subsurface discontinuities.

   True ☐ False ☐

2. "Dwell time" is the period the developer remains in the inspection surface.

   True ☐ False ☐

3. In magnetic particle testing, maximum sensitivity will be to linear discontinuities oriented parallel to the lines of flux.

   True ☐ False ☐

4. Ultrasonic thickness gauge is used to measure thickness of a metallic and non-metallic material.

   True ☐ False ☐

Notes

1.8.15 Design Datas

At the end of this topic, you will be able to:

1. define and differentiate various terms related to pressure and temperature of piping system
2. list the causes and reasons for pressure drop / pressure losses in fluid carrying piping / pipelines
3. recognise hydrostatic and hydrostatic test pressure.

Pipe fitters should understand the different design and installation data briefly to have idea about the piping / pipeline operating conditions and for participating in hydrotest. Installation data including the required hydrotest pressure will be available in approved drawings / drawing package. Pipe fitter shall go through the drawing packages to know the installation data. In piping / pipeline design, the three major factors need to be considered are- pressure, temperature and nature of process / transmitting fluid.

1. Pressure

a. Absolute pressure: It is measured relative to absolute zero on the pressure scale, which is a perfect vacuum. Absolute pressure can never be negative. Absolute pressure decreases with elevation, just as water pressure increases with depth.

b. Operating pressure (OP): It is the actual gauge pressure which prevails inside the equipment and piping during any intended operation. Operating pressure is the pressure at which the piping / pipeline is going to be operated or being operated at normal conditions.

d. Maximum allowable operating pressure (MAOP): This is the maximum possible safe pressure the pipe / pipeline walls can withstand. This is different from MOP.

e. Design pressure (DP): The DP is the gauge pressure at the top of the equipment / piping, in its operating position that is used as the basis to determine the minimum thickness of equipment parts / pipes.

f. **Maximum allowable working pressure (MAWP)**: The MAWP is the maximum gauge pressure permissible at the top of the equipment or the weakest point of equipment operating position and at a designated temperature.

2. **Temperature**

Operating Temperature (OT): The OT is the temperature which prevails inside the equipment and piping during any intended operation.

Design Temperature (DT): is the highest temperature at which equipment / piping / pipeline may be subjected to. The DT shall not be lower than the MOT. The DT is used for mechanical design (determination of minimum wall thickness and other physical characteristics) of equipment and piping.

Minimum Design Metal Temperature (MDMT): The minimum metal temperature used in the design of a pressure vessel.

3. **Pressure drop / pressure loss and frictional losses**

Pressure drop is due to pressure loss as addressed herewith. Pressure drop due to any leakage is a different case and it is not considered here.

Pressure drop is defined as the difference / decrease in total pressure between two points of a fluid carrying network / fluid flow system. Pressure drop occurs when frictional forces, caused by the resistance to flow, act on a fluid as it flows through the pipe.

4. **Pipe Elevation Changes and Effect on Pressure Loss**

As fluid flows through a piping system, where pipes rise and fall changing elevation, the pressure at a particular point in a pipe is also affected by the changes in elevation of the fluid that flows.

For example, consider a single vertical pipe where the fluid is flowing upwards, gaining elevation height as it goes. The weight of fluid acting 'on top' of the fluid at a point in the pipe reduces as we consider points higher up the pipe, since there is less fluid above it. Therefore, there is a loss of pressure in the pipe as the fluid rises. Conversely, at the bottom of the vertical pipe there is full weight of fluid in the pipe 'pushing down' on that point and due to this, the pressure at that point increases (in comparison to the pressure on the fluid at the top of the pipe). Therefore there is a gain in pressure in the pipe as the fluid falls.

5. **Velocity**

Velocity is a measure of how fast something moves in a particular direction. Its unit is distance travelled per unit time (example- m/sec). The flow velocity of a fluid is the distance the fluid travels in a given period of time.

6. **Hydrostatics:**

Hydrostatics is the branch of fluid mechanics that studies "fluids at rest and the pressure in a fluid or exerted by a fluid on an immersed body" Hydrostatics, is categorized as a part of the fluid statics, which is the study of all fluids.

7. **Hydrostatic test pressure**

Pipe fitter shall understand the hydrotest pressure clearly. In construction sites, pipe fitters also will be involved in hydrotesting so as to install, blinds, valves, bolts / studs, pressure gauges, pressure and temperature recorders, install vents and drains and assemble hydrotest manifold. Hydrotest pressure is a leak test to be performed to check the tightness and integrity of the pipeline. Water is the preferred fluid for hydrotest. For process pipeline as per ASME B31.3, the hydrostatic test pressure at every point in a metallic piping system shall be not less than 1.5 times than that of the design pressure. For liquid hydrocarbons and other liquids pipeline transportation systems as per ASME B31.4, the hydrostatic test pressure shall be not less than1.25 times the internal design pressure. For gas transmission and distribution metallic piping system as per ASME B31.8, the pipe shall be hydrostatically tested at least 1.25 times the maximum allowable operating pressure if installed in a Class 1 location; or to at least 1.5 times the maximum allowable operating pressure if installed in a Class 2, 3, or 4 location that include offshore pipelines.

However, the test pressure stated in approved construction drawings, shall be followed irrespective of above hints.

Exercise

I. Answer the following questions.

1. Explain the term "Maximum Allowable Working Pressure".

   ----

2. What are the factors contribute pressure drop / pressure loss?

   ----

3. Explain the effect of pressure loss likely to occur due to pipe elevation changes.

   ----

4. Write short notes on hydrostatic and hydrotest pressure.

II. State whether the following statement True or False.

1. MDMT stands for "Maximum Design Metal Temperature".

   True ☐ False ☐

2. Up to certain limits, the higher the flow rate, the lower the pressure drop is.

   True ☐ False ☐

3. Maximum Allowable Working Pressure (MAWP) is the pressure permissible at strongest point of equipment operating position and at a designated temperature.

   True ☐ False ☐

4. Velocity is distance travelled per unit time.

   True ☐ False ☐

Notes

1.8.16 Tubes Application, Cutting and Bending

At the end of this topic, you will be able to:

1. define different types of tubes and the manufacturing process
2. state different grades of tubes and their sizes
3. describe various applicationss of metallic tube in oil and gas industry.

1.8.16.1 Tube manufacturing process

Tube is a circular metallic structural member used in oil and gas industry. Tube is a cylindrical body of metal used, especially, for conveying liquid or gases. The three different method of manufacturing tubes include: Seamless method, Welding method, 3. Cold finishing method.

Seamless method

Steel tube products produced by seamless process are made in different diameters by hot extrusion.

Welding method

In this method products produced / longitudinally as cylinders are joined and welded in the longitudinal seam weldings process.

Cold finished tube

Tubes both seamless and welded, may be cold finished. The process may be used to increase or decrease the diameter, to produce a smoother surface.

1.8.16.2 Hot finished tube

Tubes made and finished by a hot working process is, generally applied to seamless tubes.

Types of steel tubes and grade include

carbon steel tubes, alloy steel tubes, stainless steel tubs, copper tubes, nickel and nickel alloy tubes,

aluminium tubes, titanium tubes.

1. Carbon Steel Tube

Carbon steel is an alloy made of iron and carbon. The carbon percentage can vary depending on the grade, Mostly, it is between 0.2% to 0.35% by Weight. Carbon is the main element for carbon steel, and the properties are mainly defined by the amount of carbon it has.

a. Carbon steel tube grades

SA 209 – Grade T1 – Hot Finished

SA 210 – Grade A – 1 – Hot Finished - High temperature application, for example, super heater tubes

SA 333 – Gr – 3 – Normalized – Low Temperature application

MATERIALS IBR - Carbon Steel Tube ASTM A 179, ASTM SA 210 - Grade A

IBR – Alloy Steel Tubes – ASTM / ASME / SA 213 Gr – T1, T5, T9, T11, T12, T21, T91.

Fig. 1.8.96 Pipes and Tubes

Fig. 1.8.97 Carbon Steel Tubes & Pipes

b. Carbon Steel Tube Application

2. Alloy steel tubes

Alloy steel tubes comply to ASTM Grade A 335, the specification that covers seamless ferritic alloy steel tubes suitable for high temperature applications. Alloy steel tubes containing Chromium (cr), Moly (mo) Cobalt (Co), Titanium (Ti) Niobium (Nb), etc.

a. Alloy steel tubes grades

Alloy Steel Tubes Grades – ASTM A 335 Gr T5, T9

ASTM A 335 Gr – T22, T91.

Fig. 1.8.98 Alloy Steel Tubes

b. Alloy steel tubes applications

Alloy steel tubes uses include: oil and gas industry chemical industry, boiler water supply systems. and power plant.

3. Stainless steel tube

Stainless steel tube is made with alloys of Chromium and Nickel, Molybdenum (mo). Stainless steel have a broad range of properties like:

- higher Corrosion and temperature resistance, more attractive appearance. Stainless steel tubes comply to ASTM A 312. It is a specification that covers SS Tubes for corrosive services and high temperature applications.

Applications of stainless steel tubes

Stainless steel is mainly used industries like oil and gas, chemical, aerospace, automobile, construction, instrumentation, heat exchanger's etc.

Fig. 1.8.99 Stainless Steel Tubes & Fitting

4. Copper tubes

Copper tube supplied in accordance with ASTM standard has a minimum of 99.9 per cent pure copper. The copper which is used to these specifications is deoxidized with phosphorus.

a. Copper tube grades

IS 191 – Indian Standard for Copper Specification

Copper Tube Alloy C – 12200 – Deoxidized Copper

Copper Alloy – C 19400 – Good Electrical and thermal conductivity application

ASTM B – 280 – Copper tube for Air Conditioning

ASME B 16.15 – Copper alloy threaded fittings

b. Copper tube application

Main application is for:

- heating, cooling and their systems
- plumbing air conditioning and refrigeration system
- cold and hot water system
- non-flammable medical Gas piping system
- solar energy system.

5. Nickel and nickel alloy tubing

Tubes made of corrosion resistant Nickel alloy,

Fig. 1.8.100 Copper Tubes

adding chromium (cr), Molybdenum, Copper and other elements to the alloy gives them an even higher resistance to oxidation and corrosion. This makes it possible to use them in a wider application.

a. Nickel and nickel alloys tube grade

UNS 8825 – High strength and high corrosion resistance

UNS 6625 – Gr – 1 – High temperature and corrosion resistance service

UNS 6625 – Gr – 2 – Nickel alloy tubes and pipes

ASTM B 163 Nickel Gr 200 - Seamless tube

ASTM B 163 – Gr – 201 – Seamless tube

Fig. 1.8.101 Nickel Alloy Tubes

b. Nickel alloy tubing applications

- Good Resistance to aqueous corrosion
- Chemical Industries
- Oil and Gas Industries
- Marine Industries
- Heat Exchangers
- Instrumentation tubing
- Sub-sea Oil and Gas control instruments, etc.

6. Titanium tubes

Titanium is a chemical element with symbol, Ti seamless tube, with a silver colour, low density with high strength and good corrosion resistance materials.

a. Titanium tubes grade

Pure Titanium Grade 1, 2, 3, 4, 7, 11

Titanium Alloys – 6 AI – 4V ELI – Grade 5, 23

b. Titanium tube application

Titanium tubes various applications include

- Oil and Gas – High pressure and high temperature applications
- Aerospace – Titanium is used for the airframe and Engine componer
- Power generation plants condenser tubing
- Chemical Processing Industries.

Fig. 1.8.102 Titanium Tubes

1.8.17 Tube Cutting and Bending

At the end of this exercise, you will be able to:

1. prepare a layout for tube bending
2. mark and cut tube to the required length using pipe/tube cutter
3. bend the tube to the desired angle using tube/pipe bending machine.

Requirements			
Tool/Instruments		**Materials / Components**	
Measuring Tape	– 1 No.	1” ϕ – Copper tube/CS-tube	– 2 meters
Try Square	– 1 No.	Marker Pen	– 1 No.
Spirit level	– 1 No.	Dune sand	– as required
Tube/pipe cutter	– 1 No.		
Welding Machine with accessories	– 1 No.		
Grinding Machine	– 1 No.		

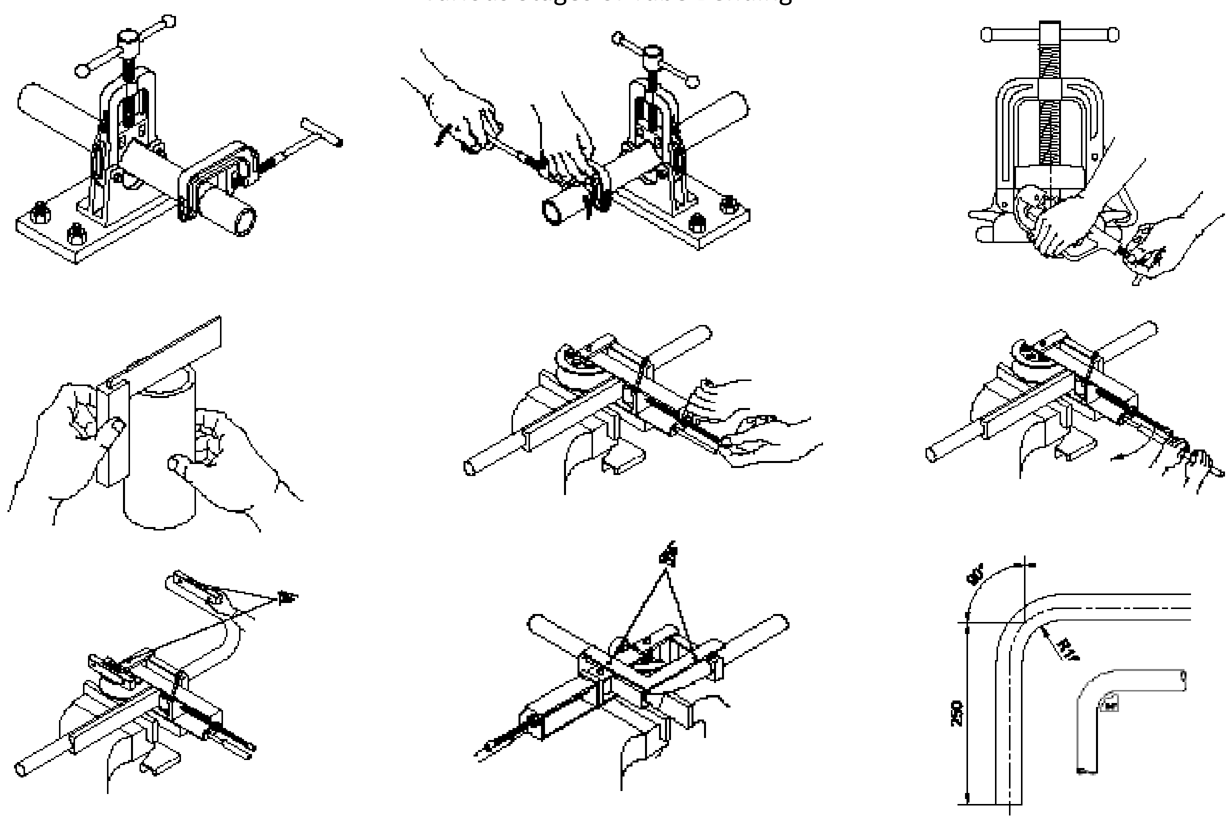
Practical

- Check the outside diameter of the tube using measuring tape.
- Measure the required length of pipe and mark it with marker.
- Place the tube in the pipe vice and tighten it.
- Fix the pipe/tube cutter on the copper tube (on the marked line) and tighten the jack screw of cutting wheel.
- Rotate one or two turns to ensure that the cutting wheel is pointing exactly on the marked line at 90° to the tube.
- Rotate the tube cutter around the tube and increase the pressure gradually to the cutter by repeating the cycle until the tube is cut through.
- Remove burrs using deburring tools and check that pipe ends are square.
- Mark centre line of the tube and fix the tube into bending machine.
- Bend the tube by pulling the bending arm towards your side.
- Check the angle of bend and radius using standard template.

Tips

- **Safety:** Use appropriate 'PPE' (Personal protective equipment).
- Bend former shall be smooth and free from foregin particles.
- Apply gradual/uniform bending force.

Various Stages of Tube Bending



Exercise

I. Answer the following questions.

1. Define tube.

----

2. Which are the three different methods for tube manufacturing?

----

3. State the names of different types of tubes.

----

4. Why nickel alloy tubes are better than stainless steel tubing in heat exchanger?

----

5. What are the applications of titanium tubes?

II. State whether the following statements are True or False.

1. Tubes are always measured by OD (outside diameter).

   True ☐ False ☐

2. Seamless tubes are always used in high pressure and temperature applications in to oil and gas industry.

   True ☐ False ☐

Notes

1.8.18 Branch Connection

At the end of this topic, you will be able to:

1. recognise the function of branch fittings
2. make a template for 'T' joint.

1.8.18.1 Pipe fitting: A fitting is used in pipe systems to connect the straight pipe or tubing sections, adapt to different sizes or shapes and for other purposes such as regulating fluid flow.

a. Tee: A tee is the most common pipe fitting. A tee is used for connecting pipes of different diameters or for changing the direction of pipe runs.

They are categorized as equal, unequal. It is a short piece of pipe with a lateral outlet. Butt welding tees should be used for branches that are equal in diameter to the run pipe.

b. Tee Joint: T - joint is a joint between two members located approximately at right angles to each other in the form of a T. With oil and gas piping, there is a need for cutting holes (run opening) at intersections (main member) and as a result, the branch connections have full penetration butt welds.

1.8.18.2 Branch connection welds: Branch connections that abut the outside surface of the run pipe shall be contoured for groove welds that meet the welding procedure specification requirements.

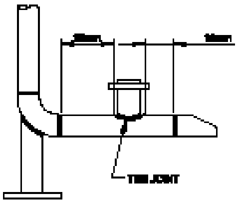


Fig. 1.8.103 Tee Joint

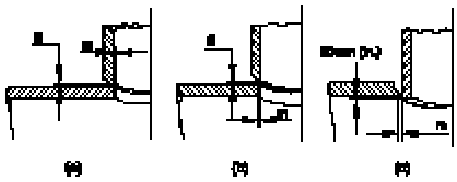


Fig. 1.8.104 Branch connection weld

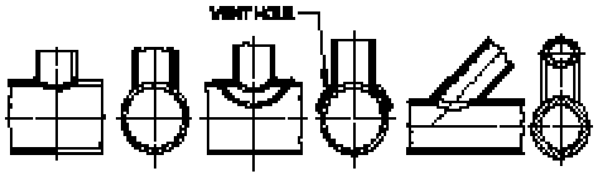


Fig. 1.8.105 Typical Welded Branch Connections

a. Cutting of branch pipe: Branch pipes in mild steel may be cut on a special oxy-fuel gas profile cutting machine. Where such equipment is not available, the branch can be produced by marking the outline using a template and scriber or pointed chalk followed by centre punching. The branch can then be produced by cutting to the marked outline, using manually operated oxy-fuel gas cutting equipment. After cutting to the contour of the branch, align the branch pipe on the top of the main pipe, marking the outline and cut the hole (run opening). Remove any burrs on the inside of the pipe by reaming or filing or grinding.

The joint must be very carefully prepared by beveling the edges as per WPS, so that a good fitup is obtained.

Set and align the branch pipe with the main pipe at an angle of 90° and tack weld the joint.

Use sequence welding technique on 'T' joints. This prevents weld metal contraction from pulling the pipe out of the line. Do not cut or weld in rooms containing inflammable materials, gases, vapours or liquids or flammable paint.

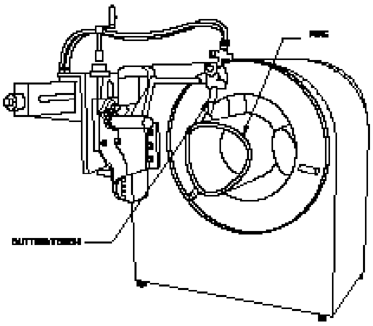


Fig. 1.8.106 Profile Cutting Machine

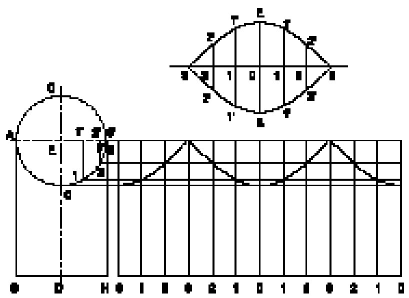


Fig. 1.8.107 Development of the Branch Pipe

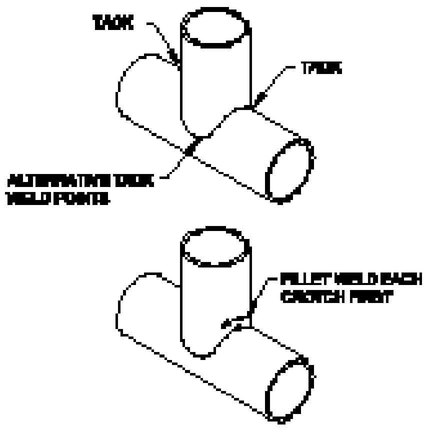


Fig. 1.8.108 Fitup of "T" Joint

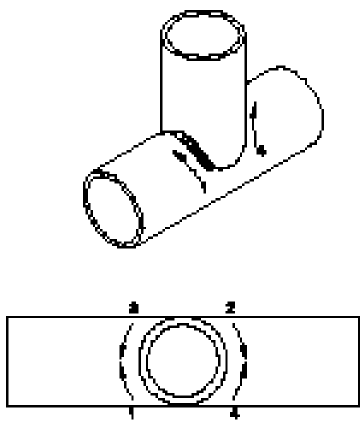


Fig. 1.8.109 Welding Sequence

1.8.18.3 Outlets

Outlet fittings (also called branch connection fittings or Olet fittings) are fittings which provide an outlet from a larger pipe to a smaller one (or one of the same size). The main pipe onto which the branch connection is welded is usually called the run or header size. There are several types of outlets available. The most widely used outlet fittings are weldolets, sockolets, nipolets and nipoflange.

a. Weldolet

Weldolet (weld - o - let) is basically self reinforced fittings. Weldolet is used for butt weld branch connection where standard tee is not available due to size restrictions and the piping is of critical / high pressure service. Every fitting is produced with a base shaped to fit the header pipe or vessel. This provides an accurate alignment aid and base weld definition, for the correct installation of the fitting.

b. Welding of weldolet

The crotch section of the weldolet is fully welded out. The skirt weld profile is achieved by fully welding out this section.

The flanged range of fittings should be welded in a similar manner to the buttweld outlets. Failure to fully weld out these fittings in accordance with the details given above would give adverse effects to strength, stress intensification factors and area reinforcement.

Tips

Saftey: Good house keeping reduces fire risk.

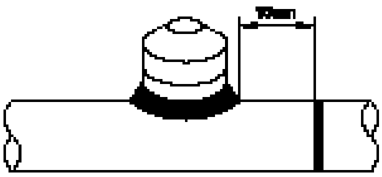


Fig. 1.8.110 Weldolet

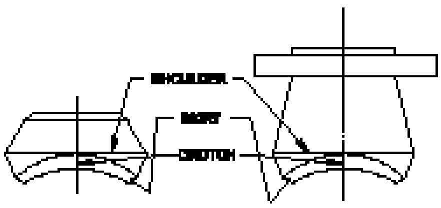


Fig. 1.8.111 Butt Weld Outlet *Fig. 1.8.112 Flanged Butt Weld / Nipple Outlet*

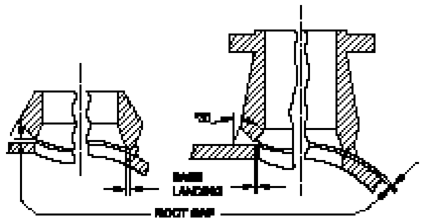


Fig. 1.8.113 Welding of Weldolet

Exercise

I. Answer the following questions.

1. What is weldolet and where is it used?

----

2. How is branch pipe contoured?

----

3. What is the importance of weldolet fittings welding?

II. State whether the following statements are True or False.

1. The crotch section of the weldolet is fully welded.

   True ☐ False ☐

2. Good house keeping increases fire risk.

   True ☐ False ☐

3. A tee is used for connection pipes of same diameter only.

   True ☐ False ☐

Notes

1.8.19 Brazing Operations

At the end of this topic, you will be able to:

1. solder a sheet metal joint
2. braze a pipe fitting joint
3. describe electrical resistance butt welding and flash butt welding methods.

Brazing

Brazing is a group of joining processes that produce coalescence of materials by heating them to the brazing temperature in the presence of filler metal having a liquidus above 450°C and below the solidus of the base metal. The filler metal is distributed between the closely fitted faying surfaces of the joint by capillary action.

The temperature at which filler metal starts to melt on heating is the solidus temperature; the liquidus temperature is the higher temperature at which the filler metal is completely melted. The liquidus temperature is the minimum temperature at which brazing will take place.

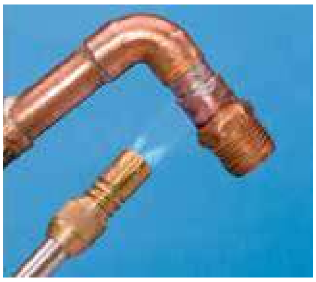


Fig. 1.8.114 Brazing Fitting

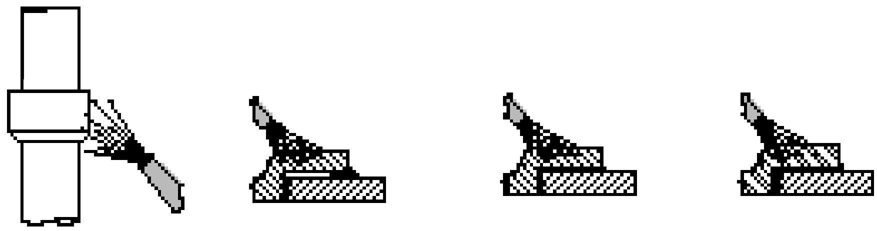


Fig. 1.8.115 Torch Brazing

Applications

The brazing process is used in joining copper and other metals. Corrosion resistance is one of the main requirements of the kinds of piping and fittings commonly assembled by brazing. Accurate assemblies can be made by brazing. Temporary or emergency piping can be assembled rapidly by brazing.

Perform a brazing method

Brazing processes are customarily designated according to the sources or methods of heating. Industrial methods are

- Torch brazing
- Furnace brazing
- Induction brazing
- Dip brazing
- Infrared brazing
- Resistance brazing

Whatever the process used, the filler metal has a melting point above 450°C, but below that of the base metal. It spreads within the joint by capillary action.

Torch brazing

Manual torch brazing is probably the most widely used brazing method. The following procedure should be followed for brazing carbon steel (mild steel) pipe fitting.

(a) Lap joint is the most commonly used since it provides for sufficient faying surfaces to attract the filler material.

(b) Select carbon steel pipe with diameter of 1 1/2 inches and carbon steel fitting to match the pipe diameter.

(c) Choose and apply a flux in accordance with the brazing procedure specification.

(d) Assemble the joint by inserting the pipe into the socket of the fitting, hard against the stop.

(e) Brush additional flux at the joint around the chamfer of the fitting. A small twist of the pipe and fitting helps to spread the flux over the two surfaces. The joint is now ready for brazing.

(f) Use an oxyacetylene torch for brazing and adjust the flame to neutral or slightly excess acetylene.

(g) Heat the pipe. Continuous heating after the flux starts to bubble and until the flux becomes quiet and transparent like water.

(h) The flame must be kept moving to avoid burning the pipe or fitting.

(i) Apply the brazing rod at a point where the pipe enters the socket of the fitting.

(j) When the joint is filled, a continuous fillet of brazing alloy will be visible completely around the joint.

(k) Clean the brazed joints.

Exercise

I. Answer the following questions.

1. Explain the fundamentals of flash butt welding and the steps to be followed.

----

2. Is it possible to obtain a brazed joint stronger than the filler metal?

----

3. What is the difference between soldering and brazing?

----

4. Why is flux required for soldering?

II. State whether the following statements are True or False.

1. In comparison with welded or brazed joints, a soldered joint has considerably less strength.

   True ☐ False ☐

2. Brazing skills can usually be acquired slower than welding skills.

   True ☐ False ☐

Notes

1.8.23 Solders and Fluxes

At the end of this topic, you will be able to:

1. state the types of solders
2. state the functions of soldering fluxes
3. list different types of fluxes and their applications.

Solder

Solder is the filler metal used in Solderings. solders have a melting point below 425°C. An objective of the soldering process is to optimize solder wetting and spreading to promote a minimum amount of porosity in the joint clearance between the two faying surfaces. A simple rule of thumb is of the heating is uniform, then the solder is drawn to the closest fitting surfaces. If the joint clearance is uniform, then the solder is drawn to the hottest surfaces.

Solder selection

The solder is selected to provide good flow, penetration and wettability in the soldering operation and the desired joint properties in the final product.

Types of solders

There is a wide range of commercially available solder filler metals designed to work with most industrial metals and alloys. Tin lead alloys are the most widely used solder filler metals.

1. **TIN - LEAD solders**

   Solders are described to identify the tin content first 40 / 60, 35 / 65, 50 / 50. For example, 40 / 60 – 40 per cent tin and 60 per cent lead.

   Extensive use of these solders found in sheet metal work, non–pottable water plumbing and piping (50 / 50).

2. **TIN – Antimony Solder**

   The 95 per cent tin, 5 per cent antimony solder is used in many plumbing, refrigeration and air conditioning applications because it has good creep properties.

3. **TIN – Silver, TIN – Copper – Silver, TIN – Lead – Silver solders**

   96 per cent tin, 4 per cent silver solder is often used to join stainless steel for food handling equipment. The tin – silver and tin – copper – silver solders are the standard alloys used with copper pipe and tubes in potable water systems. 62 per cent tin, 36 per cent lead, 2 percent silver solder is used in electronic applications, high lead solders for automobile radiators and recommended for cryogenic applications.

4. **TIN – Zinc Solders**

   Alloys containing 70 to 80 percent tin with the balance zinc are recommended for soldering aluminium.

5. **Cadmium – Silver solder**

95 per cent cadmium 5 per cent silver solder used in copper butt joints.

6. **Zinc Based solder**

95 per cent zinc 5 per cent aluminium is specifically for use on aluminium.

Solder product form

Solders are commercially available in variable forms as follows: Wire solid - 0.25 to 6.35 mm diameters on spools, foil, sheet or ribbon, bars, ingots – rectangular or circular in shape.

Fluxes

A flux is a chemical cleaning agent, flowing agent, or purifying agent. As cleaning agents, fluxes facilitate soldering, brazing and welding by removing oxidation from the metals to be joined. All metals gets oxidised when exposed to the atmosphere. This oxide layer must be removed before soldering because it affects proper formation of the joint. For this, a chemical compound called flux is applied to the joint.

Flux selection

The selection of a flux is primarily driven by the base material and specifically by the type and thickness of surface oxide that is to be removed.

Types of fluxes

Commercial soldering fluxes are normally designated by one of the following types: rosin-based (least active), organic (moderately active), inorganic (most active).

(a) Rosin Fluxes: The principal ingredient is white water rosin (a derivative of pine tree sap). It is suitable for use in the electrical industries.

(b) Organic Fluxes: It is composed of such compounds as lactic acid or one of the citric acids. It is used in structural and electrical industries.

(c) Inorganic Fluxes: It contains zinc chloride, ammonium chloride, hydrochloric acid, sulphuric acid or nitric acid. Used widely in automotive radiator industry. These fluxes can be formulated to provide stability over a wide range of soldering temperatures.

Flux forms: The standard flux forms are liquid solutions, pastes and dry salts. For most wire forms of the Sn - Ag and Sn - Ag - Cu solders, the wire has a core of the suitable flux. Such so called 'flux cored wire' allows ease of application with a wire feeder and eliminates the need for a separate fluxing operation.

Tips

Safety

Improper use of solders containing cadmium may lead to health hazards. Therefore, care should be taken in their application, particularly, with respect to fume inhalation. Workers using solders and fluxes should always wash exposed skin areas before consuming food.

Exercise

I. Answer the following questions.

1. Which are the two metals found in a solder?

----

2. Which flux is used for automotive radiator industry?

----

3. Name any three types of solders.

-- --

4. What are the functions of fluxes?

----

5. What are the safety precautions to be followed during soldering process?

II. State whether the following statements are True or False.

1. Solders have melting point above 425°C.

   True ☐ False ☐

Notes

1.8.25 Practising Brazing Techniques

At the end of this exercise, you will be able to:

1. braze an M.S. Square butt joint
2. recognise the brazing process.

Practical

Requirements	
Tool/Instruments Wire brush – 1No. Paint brush – 1No. Cotton rag – 1No. Spark lighter – 1No. **Equipment/ Machines** OXY - acetylene setup	**Materials / Components** M.S. Tube 1” dia X 3mm thickness – 1No. BAg filler metal – 1No. Dune sand – as required

Brazing skill sequence

The brazing process requires the following: Filler metal, Flux, Heat source, Techniques.

(a) Joint

Set the M.S. Tube 1” diameter X 3mm thickness as a square butt joint without root gap.

(b) Filler metal

Silver based AWS filler metal bag is selected. ϕ 1.6 mm.

(c) Flux

Flux residues should also be easy to remove after brazing to prevent corrosion of base metals.

FB 3 – A – AWS Flux classification is selected. Paste form.

When using Ag based filler metals, the flux should completely melt and be active at about 700°C just prior to melting of the filler metal.

(d) Heat source

Apply heat to the parts to be joined, preferably with an oxy – fuel torch. Manual torch brazing involves broad heating of the assembly by a flame. The fuel gas is acetylene.

The most common flame conditions used are reducing and neutral. Oxidising flames are not recommended for brazing. Neutral flame is preferably selected.

Fig. 1.8.116 Brazing Joint

Fig. 1.8.117 Heat Source

Brazing techniques

1. **Cleaning**

   Sound brazed joints require clean, oxide-free surfaces. The surfaces to be joined should be thoroughly cleaned of grease, oil, dirt and oxides to ensure uniform flow of filler metal. Once the parts are cleaned, they should be fluxed as soon as possible.

2. **Fluxing the parts**

   Fluxes commonly come in liquid and paste forms. They must be applied evenly over the surfaces to be joined. Fluxes should be applied to the parts before heating. This way the parts will be protected from further oxidation during heating. Fluxes in paste forms are easiest to apply, generally, by using a brush. Flux reacts with oxygen, and when it becomes saturated, it loses its effectiveness.

3. **Assembly**

   Parts to be brazed should be assembled immediately after fluxing, before the flux has time to dry and flake off. The clearance between the parts should not be too tight nor it should be too loose. An optimum clearance between the parts is about 0.4 mm.

4. **Brazing**

   In most manually brazed joints, the filler metal is fed from the face side of the joint. It is helpful to brush some flux on the brazing rod and to play the flame on the rod briefly to warm it up. Set the neutral flame or slightly reducing flame.

   Heat the plates first, beginning about 25 mm from the edge of the fitting.

   The active temperature is 450° to 800°C.

   It is very important that the flame shall be kept in motion and not remain on any one point long enough to damage the plate.

   Apply the brazing rod at the joint when the flux is completely clear. Because the temperature of the joint is hot enough to melt the brazing alloy. Keep the flame away from the rod as it is fed into the joint.

   Stop feeding as soon as the joint is filled. The key for successful brazing is not to disturb the joint in any way while the brazing filler metal is still in motion. Allow it to solidify completely before quenching or moving. Careful adherence to this principle will prevent a lot of braze quality issues in the brazing operation.

5. **Cleaning the brazed joint**

   After the brazed joint has cooled, remove the flux residue using warm water (about 50°C) and a clean cloth, brush or swab since flux residues are chemically corrosive. Chemical cleaning is also employed using a mild acid solution to ensure. Proper brazed joint.

Tips

Safety :

At brazing temperature, some elements vapourize, producing toxic gases.

Fluxes contain chemical compounds which are harmful when they are inhaled or come into contact the eyes or skin.

Exercise

I. Answer the following questions.

1. What is brazing?

----

2. Name the type of filler rod and flux used for brazing operation.

----

3. Which welding technique is used for brazing of M.S. sheet joints?

----

4. Write down the brazing skill sequences.

II. State whether the following statements are True or False.

1. Mechanical properties of properly made brazed joints are equivalent to those of welded joints.

   True ☐ False ☐

2. Fluxes are not required when using Ag-based filler metals.

   True ☐ False ☐

Notes

1.8.26 Soldering Operations

At the end of this topic, you will be able to:

1. recognise the basic steps to be followed in brazing and soldering processes
2. carryout high quality soldered or brazed joint.

Joining process

Brazing and soldering are the most common methods of joining copper tube and fittings. The choice between brazing and soldering, generally, depends on the operating conditions of the system and the requirements of the governing construction codes. The basic theory and technique of soldering and brazing are the same for all diameters of copper tube. Regardless of the process, soldering or brazing, the same basic steps should be followed, with the only differences being the fluxes, filler metals and amount of heat used.

Soldering

Soldering is a group of joining processes that produces coalesence of materials by heating them to the soldering temperature and by using a filler metal having a liquidus not exceeding 450°C and below the solidus of the base metals. The filler metal is distributed between the closely fitted faying surfaces of the joint by capillary action. Most of the factors involved with brazing apply to soldering.

Applications

Copper tubes are available in a wide variety of diameters and wall thicknesses with clean and efficient fittings to serve every purpose. Joints are made simply and effectively by soldering and brazing.

Copper tubing and pipe are widely used in ship building, oil refineries, chemical plants, oil lines and refrigeration systems.

Soldering differs from brazing in that lower temperatures are involved.

In comparison with welded or brazed joints, a soldered joint has considerably less strength and is used primarily for liquid or air tightness.

Performing a soldering method

1. Quality soldered joints can be made by following the basic principles of cleanliness, fluxing, joint detail and matching the proper flux and filler metal alloy.
2. Solder is the filler metal used in soldering. The solder has a composition somewhat different from that of the base metal.
3. The torch for soldering uses a fuel gas air system. Different torches are used for the different fuel gas and oxygen or air combinations. The basic principle is to provide uniform heating of the parts being joined.

Fig. 1.8.118 Torch Soldering

4. Proper fluxing and proper fitup of the parts is essential to allow capillary action to pull the molten filler metal into the joint.
5. The normal joint is the lap joint and heat is applied to the joint.
6. After the metal surfaces have been wetted and the space between them has been filled with solder, the joint is cooled to room temperature. After the solder joint is cooled, post cleaning is necessary.

1. Measuring and Cutting

Measure the tube length accurately. Inaccuracy can compromise joint quality. Cut the tube to the measured length. The tube can be cut with a disc - type tube cutting tool a hacksaw, an abrasive wheel. Care must be taken to ensure the tube is not deformed while being cut.

The cut must be square so the tube will seat properly in the fitting cup.

2. Reaming

Remove any burrs on the outside of the tube ends created by the cutting operation is necessary to ensure proper assembly of the tube into the fitting cup.

Ream all cut tube ends fully inside the tube to remove the small burs. Tools used to ream tube ends include the reaming blade on the tube cutting device, half-round or round files, a pocket knife and a suitable deburring tool.

3. Cleaning

Clean, oxide-free surfaces are essential to ensure sound joints of uniform quality. Failure to remove them can interfere with capillary action. It is may affect the strength of the joint and cause failure. Lightly clean the tube ends using sand cloth or nylon abrasive pads for a distance slightly more than the depth of the fitting cup. Clean the fitting cups by using abrasive cloth, abrasive pads or a properly sized fitting brush. Chemical cleaning may be used if tube ends and fittings are thoroughly rinsed after cleaning. Do not touch the cleaned surface with bare hands.

4. Fluxing

Apply a thin, even coating of flux with a brush to both tube and fitting as soon as possible after cleaning. The paste and liquid flux should adhere to clean metal surfaces specification. When joining copper or stainless steel or when the heating cycle is long, a concentrated flux is required.

5. Assembly and Support

The parts to be joined should be assembled immediately after fluxing, before the flux has time to dry and flake off. Assemblies designed to be self-locating and self-supporting are the most economical. Insert tube end into fitting cup, making sure the tube is seated against the base of the fitting cup. A slight twisting motion ensures even coverage by the flux. Excessive joint clearance can lead to filler metal cracking under conditions of stress or vibration.

6. Heating

Preheating of the assembly should include the entire tube circumference to bring the entire assembly up to a suitable preheat condition. Heat is, generally, applied using an oxyfuel torch with a neutral flame.

Solder Selection

The solder is selected to provide good flow, penetration and wettability in the soldering operation and the desired joint properties in the final product.

There are a wide range of commercially available solder filler metals designed to work with most industrial metals and alloys metals.

7. Applying the filler metal

Apply the filler metal at a point where the tube enters the fitting. When the proper temperature is reached, the filler metal will flow readily into the space between the tube and fitting drawn in by the natural force of capillary action.

8. Cooling and Cleaning

Allow the completed joint to cool naturally. After, cleaning of any remaining flux residue with a wet rag, a thorough water after-rinse is then necessary.

9. Testing

Test all completed assemblies for joint integrity. Every brazed or soldered joints should be examined visually. It is a convenient preliminary test when other test methods are to be used.

The tests may be non–destructive or destructive. Inspection of joints should always be required to protect the ultimate user. But it is often specified by regulatory codes or by the company / client.

Tips

Safety

Brazing / Soldering fluxes contain Fluorides. Fumes and gases can be dangerous to your health.

Fig. 1.8.119 Cutting Tube

Fig. 1.8.120 Reaming the Tube Ends

Fig. 1.8.121 Deburing of Tube Ends

Fig. 1.8.122 Cleaning of Tube Ends

Fig. 1.8.123 Cleaning of Fitting

Fig. 1.8.124 Fluxing of Tubes

Fig. 1.8.125 Heating of Torch

Fig. 1.8.126 Clean off Flux Residue

1.8.27 Practising Soldering Techniques

At the end of this exercise, you will be able to:

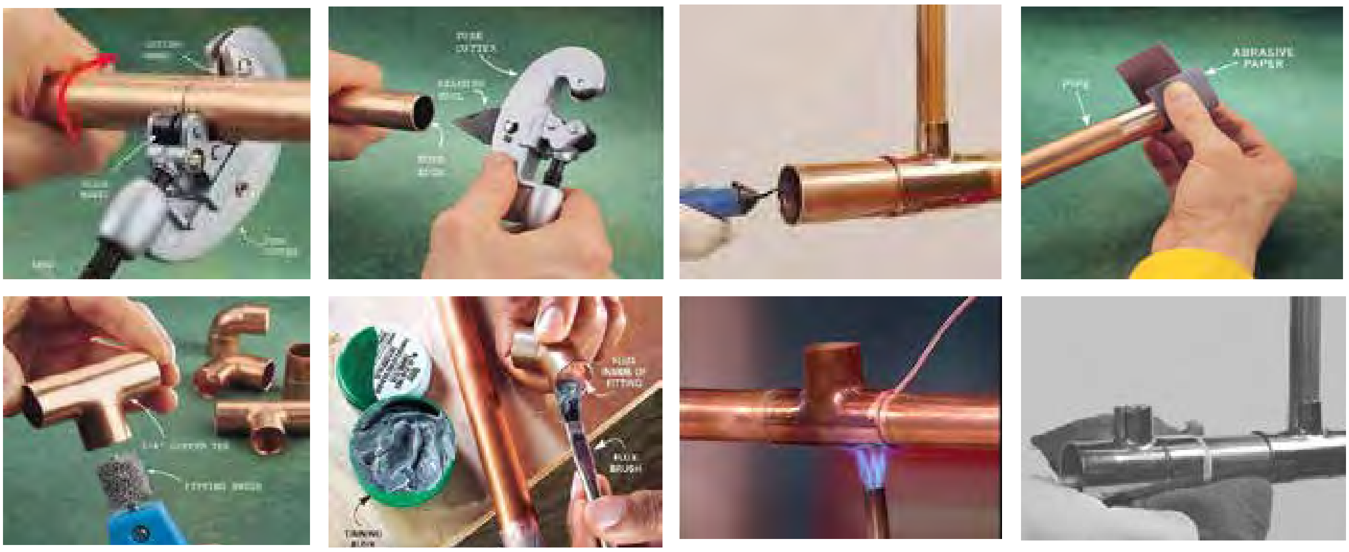
1. solder a sheet metal joint
2. describe the soldering process.

Practical

Requirements	
Tool/Instruments	**Materials / Components**
Copper tube cutter Reamer, Deburring Emery Sheet Cotton Rag	Copper tube ϕ 1” Tin-Lead Solder Organic flux
Equipment/ Machines	
Oxy - acetylene setup	

Performing soldering

1. Quality soldered joints can be made by following the basic principles of cleanliness, fluxing, joint detail and matching the proper flux and filler metal alloy.
2. Solder is the filler metal used in soldering. The solder has a composition somewhat different from that of the base metal.
3. The torch for soldering uses a fuel gas air system. Different torches are used for the different fuel gas and oxygen or air combinations. The basic principle is to provide uniform heating of the parts being joined.
4. Proper fluxing and proper fitup of the parts is essential to allow capillary action to pull the molten filler metal into the joint.
5. The normal joint is the lap joint and heat is applied to the joint.
6. After the metal surfaces have been wetted and the space between them has been filled with solder, the joint is cooled to room temperature. After the solder joint is cooled, post cleaning is necessary.



Exercise

I. Answer the following questions.

1. What are the most common methods of joining copper tube and fittings?

2. Write the basic steps for making a high quality brazed or soldered joint.

3. What are the safety hazards that may occur during brazing and soldering?

II. State whether the following statements are True or False.

1. Mechanical properties of properly made brazed joints are equivalent to those of welded joints.

   True ☐ False ☐

2. The basic theory and technique of soldering and brazing are the same for all diameters of copper tube.

   True ☐ False ☐

Notes

1.8.28 Practising Mechanical Joint in Piping

At the end of this topic, you will be able to:

1. recognise the flared joint, roll groove, press, push connect joint
2. create mechanical joints.

Practical

Requirements	
Tool/Instruments Tube Cutter Cotton rag Reaming tool **Equipment/ Machines** Flared tool Flared set-up	**Materials / Components** Copper tube ϕ $^3/_4$" abrasive cloth

1.8.28.1 Steps to create a joint

Copper tube used for liquified petroleum gas, propane gas or natural gas may be joined using flared brass fittings of single 45° flare type.

1. It is usually necessary to anneal the end of the tube to be flared, prior to flaring.
2. The copper tube must be cut square using an appropriate tubing cutter.
3. After cutting, the tube must be reamed to the full inside diameter leaving no inside burr.
4. Cleaning can be accomplished with the use of an abrasive cloth.
5. Place a flare nut over the end of the tube with the threads closest to the end being flared. Insert the tube between the flaring bars of the flaring tool in the appropriate opening.
6. Position the yoke with the flaring cone over the tube end and clamp the yoke in place. Turn the handle of the yoke clockwise. This lowers the flaring cone and forces the lip of the tube against the base of the flaring bar to create an angled flare that will make securely with a corresponding flare type fitting.

Fig. 1.8.127 Flared Joint

7. The final flared tube end should have a smooth, even, round flare of sufficient length to fully engage the mating surface of the flare nut without protruding into the threads .
8. No material (pipe joint compound) should be applied to the mating surfaces of the flare fitting and the flared tube end before attaching the flare nut to the fitting body.

The system offers a practical alternative to soldering and brazing large diameter copper tube. And most importantly, it requires no heat or open flame, as do soldering or brazing. Copper roll groove joining takes advantage of copper's excellent malleability and its increased strength when cold worked.

1.8.28.2 Steps to create a joint

1. Examine the roll groove tube to ensure there are no dents, deep scratches, dirt, oil, grease or other surface imperfections.
2. Measure the tube length accurately.
3. Cut the tube end square , perpendicular to the run of the tube.
4. Remove burrs from the I.D. and the O.D. of the tube end by reaming the I.D. and chamfering the O.D. using the appropriate tools.
5. Roll groove the tubing to the proper dimensions as required.
6. Examine the fittings, gaskets and clamps to ensure the proper gasket is inserted into the clamp and the fitting end is not damaged.
7. Lubricate the gasket as per manufacturer's recommendations.
8. Inspect the clamping surfaces to ensure that they are clean and free from debris.
9. Assemble the joint according to the manufacturer's recommendations.
10. Tighten the clamping nuts to the proper torque.
11. Inspect the tightened clamp to ensure it is properly assembled.

1.8.28.3 Press connect joint

Press connect joints for lower pressure plumbing, process piping and many non-medical grade compressed gases utilize a single standard hexagonal press pressing pattern is formed.

Fig. 1.8.128 Different types of mechanical joints

Fig. 1.8.129 Copper Tube press fit joint

Steps to create a joint

1. Full depth of insertion into the fitting shall be clearly marked prior to inserting the tube into the fitting.

2. Crimping jaw choice and jaw placement prior to crimping are to be done.
3. Once the pressing process has been completed, the jaws can be removed from the fitting and visual examination of the final pressed fitting shall be performed. It is imperative that the tube has remained fully inserted after the pressing process.
4. The completed double 360° crimp shall be inspected for the appropriate crimp mark as required by the fitting manufacturer.
5. The crimp locations shall be checked with the go-no-go gauge, provided in the pressing kit, to ensure the press process has been completed correctly.

1.8.28.4 Push - Connect Joints

Like the press connect joining method, the push connect joining of copper and copper alloy tube is fast, economical and also requires no heat or open flame. However, unlike most other joining methods, no additional tools, special fuel gases or electrical power are required for installation. Push connect joining utilizes an integral elastomeric gasket or seal (such as EPDM) and stainless steel grab ring to produce a strong, leak free joint.

There are two common types of push connect fittings. Both create strong, permanent joints. However, one allows for easy removal after installation to allow for equipment service, while the second type cannot be easily removed once the fitting is installed.

Steps to create a push connect Joint

1. Measure the tube accurately to ensure that it will socket to the back of the fitting cup.
2. Cut the tube square, perpendicular to the run of tube, using an appropriate tubing cutter.
3. Remove burrs from the I.D. and O.D. of the cut tube end by reaming the I.D and chamfering the O.D. using the appropriate tools.
4. Chamfering the cut tube end is required to reduce the possibility of gasket damage when inserting the tube. Cleaning of the chamfered tube end with emery paper will ensure that no sharp edges or kicks are present. They might damage the sealing gasket upon insertion of the tube into the fitting.
5. Examine the fitting to be used to ensure the sealing gasket and gripper ring are properly positioned and not damaged.
6. Mark the depth of insertion on the tube prior to inserting it into the fitting.
7. Lubrication of the tube end may or may not be required. Follow the manufacturer's recommendations.
8. Align the tube so that it is straight and in line with the fitting.
9. Using a firm pushing and twisting motion, insert the tube into the fitting and push the tube and fitting together until the tube is seated at the back of the fitting cup as evidenced by the pre-marked tube insertion depth line.

Exercise

I. Answer the following questions.

1. What are the two types of push connect fittings?

----

2. What is the purpose of chamfering the tube end in the push connect joint?

----

3. What is the use of go-no-go gauge in the press connect joint?

----

4. Explain the steps to be followed in the roll groove joint?

----

5. What is the meaning of flared joint?

II. State whether the following statements are True or False.

1. Push connect joint requires no heat or open flame.

   True ☐ False ☐

Notes

Notes

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=uetc3jQGfSk

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=eqwBR-jaEQ4

Skill India
कौशल भारत-कुशल भारत

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

N·S·D·C
National
Skill Development
Corporation
Transforming the skill landscape

HYDROCARBON SECTOR
SKILL COUNCIL

2. Perform Electrofusion Welding

HYC/N 6106

Key Learning Outcomes

At the end of this module, you will be able to:

1. wear proper PPE and exhibit proper safe working principles and practices duly implementing all HSE requirements
2. adhere to work site quality and HSE policies and objectives
3. read and interpret drawings and approved work procedures
4. receive materials, ensure material release for construction and check for any material damage
5. carryout measuring, marking, cutting and transfer / maintain material identification and traceability
6. identify and make readily available appropriate consumables, tools and equipment for piping edge preparation and fit-up work activities
7. prepare joining edges of pipes to the drawing requirements and perform pipe fit-up activities duly complying drawing and approved procedures requirements
8. perform / ensure functional checks of valves and other instruments / accessories and install them as per approved for construction drawings
9. install gaskets, bolts / studs, nuts, washers, clamps etc and perform proper bolt tightening / torqueing in sequence
10. perform pipe stringing, fitting activities at pipeline installation site
11. ensure proper trench preparation and pipe bedding and then pipeline lowering
12. prepare for hydrotest / pneumatic test and perform the test with appropriate work permit duly complying all safety precautionary requirements
13. perform depressurizing, dewatering and cleaning piping / pipeline system.

2.1 Procedures and Techniques for PE Pipeline Installations

Unit Objectives

At the end of this unit, you will able to:

1. describe how conventional buried pipeline trenches, backfilling and compactions are performed
2. perform narrow/chain trenching
3. listout advantages and benefits of pipeline installation by trenchless methods
4. explain how pipe/pipeline installations are performed by mole ploughing, impact moving and directional drilling.

2.1.1 Understanding Conventionally Buried Pipelines

At the end of this topic, you will be able to:

1. explain about conventional methods of trench excavation and preparation for pipeline installation
2. listout general requirements and instructions for conventional excavation and trenching
3. describe how pipelines are buried in conventional trenches
4. specify how backfilling and compaction are performed in conventional trenches.

2.1.1.1 Introduction to Conventionally Buried Pipelines

Natural gas is delivered directly to homes and businesses through local distribution lines from local distribution stations. Large distribution lines, called mains move the gas close to cities. These main lines along with much smaller service lines travel long distances in thousands of kilometers to homes and businesses through underground pipeline system. Gas distribution pipes are installed by many ways. Installing pipeline in conventional trenching and narrow / chain trenching is discussed in this unit.

An "excavation" is any manmade cut, depression, or trench that is made by removing earth. A " open trench" is a narrow excavation made below the surface of the ground that is normally deeper than its width. Excavation and trenching are important parts of construction works of pipeline installation.

Conventional piping installation method is trench cut and cover. In normal sites, open trenches are prepared in conventional methods. Pipes will be lowered into the trench after bedding, joined, backfilled and compacted.

Open trenches may be prepared manually with handheld tools or using excavators. Open trenches are comparatively costlier as they involves more volume of sand removal, bedding before pipe lowering, backfilling after pipe lowering and effective compaction. As much as possible, pipes shall be installed at standardized depths for most projects, particularly utilities that may be needed to access again in the future. If depth is changed, it may damage the existing facilities if any, already installed.

2.1.1.2 Bedding and backfilling

Conventional trenching for pipeline burying is depicted in Fig. 2.1.1. Bedding is preparation of the pipe resting area with soft sand so as to bring the trench bottom to required grade, levels out any irregularities and ensure uniform support along the length of the pipe. Placing and compacting of bedding course on trench bottoms shall be performed as per the approved procedure.

Hunching is backfilling under the lower half of the pipe (haunches) so as to distribute the superimposed loadings. The nature of the hunching material and the quality of its placement are one of the most important factors in limiting the deformation / damage of PE pipe.

- Bedding and backfilling soil around the pipe shall provide an envelope of embedment to protect the pipe from mechanical damage from impact or hard objects in the soil. The soil around the pipe shall be soft and it shall not contain any organic material, debris, rock or stone. If stone / rock or any other sharp object is present, it may damage the pipe or pipe coating. If pipe coating is damaged, the pipe will get corroded, pipe thickness will get diminished and this may lead to fluid leak / pipe burst / accident, etc.

- Initial Backfill / subbase is the critical zone of embedment soil surrounding the pipe for at least 150 mm over the pipe. The pipe's ability to support loads and resist deflection is determined by the quality of the embedment material and the quality of its placement. Initial backfill under pipe haunches shall be compacted carefully and evenly on both sides and along the full length of utility piping.
- The trench backfilled sand compaction shall be properly performed in such a way that it does not damage the installed pipe. If compaction is not effective, ditches may form that may lead to installed pipe damage. Compaction of trench backfill immediately above the pipe facilitates the redistribution of some of the load away from the pipe and into the side-fill soil. Backfilled material shall be placed and compacted layer by layer (in general, each backfilling / filling layer not exceeding 150 mm depth) so as to perform effective compaction.


Fig. 2.1.1 Conventional trenching for pipeline installation– bedding& laying

Exercise

I. Answer the following questions.

1. What are the issues to be considered during planning backfilling and compaction operations?

----

2. What are the general requirements and instructions for conventional excavation and trenching?

----

3. What do you understand about conventional burying of pipelines?

II. State whether the following statements are True or False.

1. Bedding is preparation of the pipe resting area with soft sand to the required grade, levels along the length of the pipeline.

   True ☐ False ☐

2. Conventional piping installation method is cutting open trench, installing pipeline and covering / backfilling.

   True ☐ False ☐

3. Hunching is backfilling under the lower half of the pipe (haunches) so as to distribute the superimposed loadings duly avoiding / limiting deformation of Poly Ethylene pipe.

   True ☐ False ☐

Notes

2.1.2 Narrow / Chain Trenching for Piping / Pipeline Installation

At the end of this topic, you will be able to:

1. recognise how to prepare narrow / chain trenching for piping / pipeline installation
2. prepare narrow trenching
3. listout the benefits of narrow trenching and advantages of trenchless methods of piping / pipeline installation.

2.1.2.1 Narrow / Chain trenching method

Narrow trenching is a fast method of excavating trenches usually no wider than 150mm. While it is not a trenchless construction method, it minimizes disruption of streets and neighbourhood in comparison to traditional trenching techniques. The practice is commonly used for the installation of utility gas distribution piping. When compared to conventional open trenching, the narrow trenching decreases the disturbance / impact on public / community.

A number of devices have been developed to create micro trenches, including mole plows and cable plows.

Narrow trenching can also be accomplished with the use of attachments to construction vehicles or tractors.

When conditions permit, trenching for pipelines which are buried from 2 to 3 feet depth are usually done with a narrow 4 inch wide chain trencher. Where there is little gravel or rocks and the ground is not too wet, these trenchers bring up well pulverized soil that makes good backfill material. The material is usually bulldozed back in the trench with a trencher mounted blade. Where rocks are not present, any of this material may be backfilled directly around the pipe. Traditional subbase materials can be used for backfilling. Formed concreting also can be performed.

Narrow / Chain Trenching can be performed manually or by using trenching machines. For cutting narrow trenches on existing concreted surfaces, narrow twin blade saws can be used to remove the concrete top layers. Narrow trenching is also known as micro-trenching, mole ploughing, or slot cutting.

Fig. 2.1.2 Manual Narrow trenching

Fig. 2.1.3 Pipe installed in narrow trench

2.1.2.2 General instructions for narrow trench preparation

i. Determine the trench dimensions and purpose.

ii. Interpret the drawing and note down the required shape, location, depth, width and length of the trench.

iii. Always know the surroundings and the location of people and objects. Do a full site walk around prior to excavation.

iv. Make sure that all underground utilities have been marked and identified.

v. Mark the trench width along the trench length.

vi. If you are digging near pipes, try to determine where any other pipes may be. New pipes should be at least 1.5 feet away from other pipes.

vii. Avoid obstructions and digging under the tree.

viii. Barricade the trenching area and apply / install necessary signals (refer fig 2.1.4), stop logs prior to commencing trenching operation.

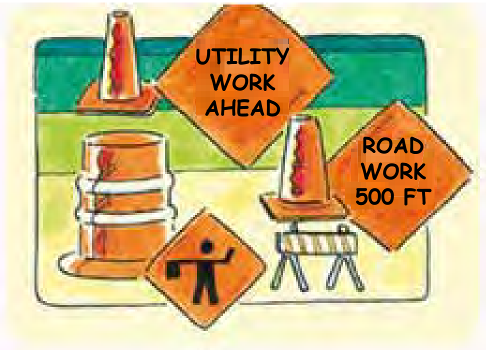


Fig. 2.1.4 Manual Narrow trenching

Fig. 2.1.5 Mattock

2.1.2.3 Narrow trenching by manual tools

After following the above requirements for trench preparation, break up the dirt using a D-handle shovel to loosen the dirt along both sides of the trench. This will make it easier to dig the dirt in the middle while physically establishing dig line alongside the laying guideline.

Use the mattock to break, in case of clay sand / hard surface.

Fig. 2.1.6 Digging shovel

Fig. 2.1.7 Cleanout shovel

Fig. 2.1.8 Trenching Hues

Shovels are to be used where necessary to remove/ lift the clays, sands or broken hard objects.

Trench Digging Shovels are used for digging narrow flat-bottomed trenches 4 / 6 inches wide, and up to 18 inches deep. They are also called step-trench shovels because the upturned back surface lets you push down (step on) the shovel with the toe of your boot while it is in the trench.

Their handles have high lift angles, which helps when raising soil up out of the trench.

Clean out shovels are used to remove the loose soil (also called crumbs or spoil) that is left in the bottom of any trench. This is done to provide a level solid surface for pipes to rest on. A good cleanout shovel has a very high handle angle to reduce bending while reaching the bottom of the trench, and a head with side walls to lift a good amount of soil up and out without spillage.

Various types and shapes of trenching hoes are available in the market. Typical trenching hoe is shown. The trenching hoe is made for digging flat-bottomed trenches up to about 24 inches deep and 5 inches or more wide. To use a trench hoe, stand above the end of the trench to chop soil loose and then drag it up the ramped end of the trench, just like the chain does in a power trencher. It is the same action that a power trencher uses, just in a slower "one-bite-at-a-time" fashion.

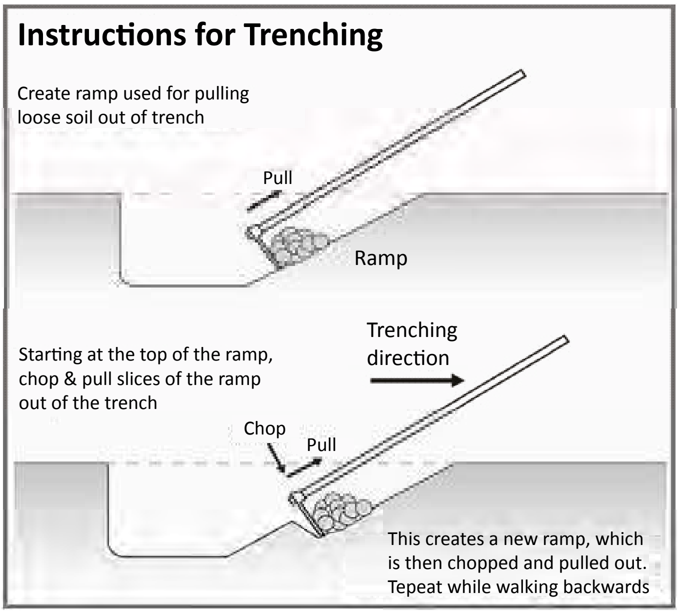


Fig. 2.1.9 Trenching Instructions

Cut both sides of the hole with your shovel, break up the topsoil, and then work both sides of the trench until there is enough loosened soil to clear / remove.

Loosen soil with your spade on one side. Stepping on the spade to drive it through the dirt at about a 45 degree angle, insert the spade about 6 inches into the soil approximately 2 inches out from the guideline.

Angle the spade, so that the trench walls are slightly angled and the bottom outside edge of the trench sits beneath the guideline.

Shovels are to be used where necessary to remove/ lift the clays, sands or broken hard objects.

2.1.2.4 Trenching using trenching machines

A power or chain trencher cuts an angled ramp in the soil, then constantly abrades it and drags the loose soil up and out. Trenching with a grub hoe is the same action, just replace the word "abrades" with "chops".

1. Narrow trenching machine preparation

i. Turn the fuel switch 'ON' and give it a little bit of choke.

ii. Turn 'ON' the key switch and lower the throttle a bit.

iii. Put the transmission in neutral.

iv. Make sure the hydraulic pump is OFF.

v. When trenching, lock the wheels in place. Disengage the wheels to move the unit.

vi. Once the unit is running, give it some gas, activate the hydraulic pump and pop the transmission forward.

2. Performing trenching by machine digging

i. Once you are in position where you want to dig, engage wheels so they work together. Put the throttle up, throw lever to start the chain and auger spinning, and lower the bar into the earth.

ii. The trencher will start digging.

iii. Lower it to the depth you want, usually all the way down.(Note: This could take a few minutes, according to how far down you want to dig).

iv. The auger will push dirt off to the side.

v. Keep the gas on full throttle and control the speed by using the transmission control.

vi. Once bar is all the way down, put machine into reverse to start moving backward. Then, it will trench in reverse.

vii. Caution: Don't stand in front of the machine when it is operating, because it will throw dirt and rocks in a forward direction.

viii. You don't need precision and accuracy of a finishing pass with every movement.

Fig. 2.1.10 Trenching by machine digging

Fig. 2.1.11 Narrow trenching with modified excavator buckets

Work in long layers that fill the excavator bucket just as the stick goes vertical. Begin with the bucket at a 45 degree grade and curl it as you are move the bucket toward you.

Boom up just before you begin the curl, so you finish the cut with the bucket sitting flat. This provides a flatter trench bottom.

Pile spoil at least 2 feet away from the trench for safety. You can save time and streamline each cycle by extending the stick no more than 40 degrees to dump the bucket.

If possible, dump the spoil directly into the truck that will haul it away. This narrow target is ideal for an excavator, which can dump while swinging over the trunk for a smooth range of movements with each pass.

3. Narrow trenches by modified excavator buckets

Narrow trenches can be performed by employing modified excavator buckets as shown in fig 2.1.11. This is very well suitable for laying pipelines in paved / concreted area / surface or adjacent to roads with minimal disturbance to public.

2.1.2.5 Advantages of trenchless methods

Pipeline can be installed by trenchless methods, where open trenching or excavating is not practical / not advisable. The advantages include- less traffic disruption, lower cost, deeper and/or longer installation, no access pit, shorter completion times / time-saving, improved directional capabilities, and environmental safety and avoiding extensive open cut trenches.

Exercise

I. Answer the following questions.

1. What are the instructions to be fulfilled prior to commencing narrow trenching?

----

2. How is narrow trenching performed manually?

----

3. What are the benefits of narrow trenching?

----

4. What are all the advantages of pipeline installation by trenchless methods?

II. State whether the following statements are True or False.

1. In general, narrow trenching increases the disturbance / impact on public / community when compared to conventional open trenching.

   True ☐ False ☐

2. Narrow / Chain trenching can be performed manually or by using trenching machines.

   True ☐ False ☐

3. Mattock is used to break clay sand / hard surface.

   True ☐ False ☐

Notes

2.1.3 Piping / Pipeline Installation – Trenchless Methods

At the end of this topic, you will be able to:

1. describe mole ploughing method and impact molding principles
2. implement mole ploughing installation procedure
3. give instruction for impact molding
4. give instruction/carryout directional drilling.

2.1.3.1 Mole ploughing method description and advantages

Mole ploughing is a method of installing small diameter PE pipes quickly and with minimal disruption and environmental impact. Mole ploughing method can be applied for oil and gas pipes also. Mole ploughing is not strictly a trenchless technology, but it creates a narrow temporary trench for installing small diameter mains and services. It does not involve any of the usual activities of 'open cut' such as spoil / soil removal, shoring, placement of bedding materials, etc. The technique is particularly suitable for less populated rural areas where long pipelines with few connections are required. PE pipe can be laid at depths up to 2.0 metres.

The mole plough pushes the spoils removed by the plough back into the hole as the machine feeds the PE pipe into the hole thus eliminating the need for backfill.

In general, maximum installation depth is 2.0 metres. For diameters larger than DN90, which cannot be installed directly from coils, it is necessary to lay out and fuse the pipe into a single length along the line of the installation. It is picked up by the plough and fed into the narrow excavation.

2.1.3.2 Mole ploughing excavations

Fig. 2.1.12 Mole ploughing equipment in the field

Small entry and exit pits are needed to the depth of the pipe and as narrow as is feasible to excavate. These are to enable starting the installation and also connecting other pipes at each end of the installation. Mole ploughing needs no extensive excavation for these purposes but does need them for connection to existing buried pipes at each end of the works.

2.1.3.3 Mole ploughing installation procedure

Mole ploughing can lay pipes at bend radius of 3.50 metres. Typical installation speed can be up to 5000 metres/ day in ideal circumstances. Marker tape can be installed above the pipe during the installation if required.

Spider Plough: An all-terrain traction unit pulls the plough with a cable winch, with uneven terrain levelled by universally adjustable extensions and hydraulically adjustable rubber tyres, if a spider plough is used.

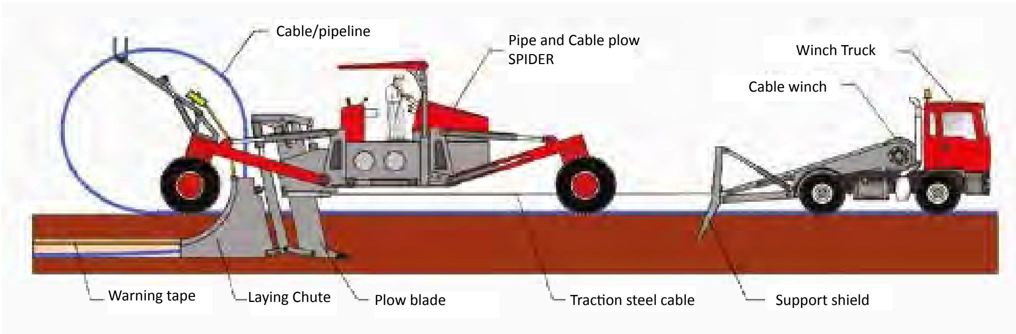


Fig. 2.1.13 Spider Plough up to pipe diameter DN250

When pulled by the winch, the plough share displaces the soil in the pipeline zone and clears any stones within the embedment area settling the trench bottom under its own weight. This creates a hollow space for pipeline installation. By means of an automatic sanding cart attached to the plough, the hollow space can be filled with sand either below the pipe to act as bedding or above it as backfill, or both. Then, the pipe is installed on the bottom of the narrow trench at the desired depth free of any mechanical, tensile stress. The pipe plough installs PE pipes of diameters up to 355 mm. Larger diameters are laid on the ground along the line of the installation and picked up by the plough and installed into the narrow excavation.

Direct Installation

i. Vibrating ploughs for smaller diameter pipes can be mounted directly on excavator arms. At the starting point of the bore path, a launch pit is excavated and the plough share is placed in this pit at the required installation depth.

ii. Diameters up to 90 mm can be installed direct from coils as shown in fig 2.1.16. Several pipes, cables and warning tapes can be installed in one go. The soil closes over the narrow opening behind the plough and the surface can be finished by filling and compaction, if necessary.

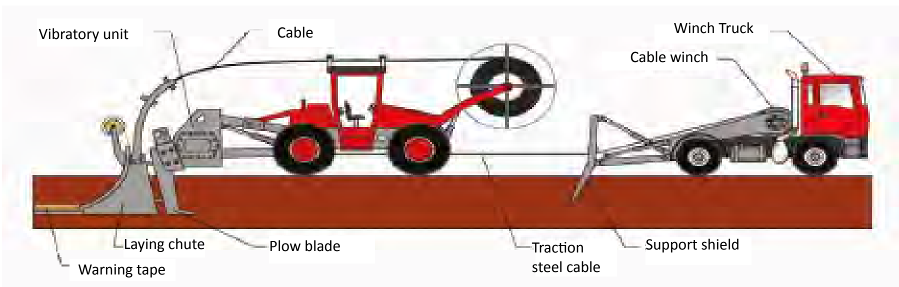


Fig. 2.1.14 Mole ploughing direct from coils up to pipe size DN90

2.1.3.4 Introduction to impact moling

The impact mole (or piercing tool) pipeline installation method is one of the oldest, simplest and mostly used trenchless technologies. It is ideally suited for installation of small diameter PE pipes up to 160 mm in compressible soils over short distances up to 60 m. Oil and gas pipelines can be installed by impact moling. This technique is applicable for both new installations or for replacing pipelines. This method is restricted to relatively small diameter lines in compressible soil conditions.

Impact moling, or 'earth piercing' is defined as the creation of a bore by the use of a tool that comprises a percussive hammer (hammer may be hydraulic or pneumatic) within a suitable cylindrical casing, generally torpedo shaped. The term is usually associated with non-steered or limited steering devices without rigid attachment to the launch pit, relying for forward movement upon the internal hammer action to overcome the frictional resistance of the ground.

Fig. 2.1.15 Impact Moling sample images

2.1.3.5 Feasibility of impact moling

This trenchless method is ideal for the installation of oil pipelines and gas pipelines under roads, existing structures, congested areas, environmentally sensitive areas and waterways. Impact moling is best suited for installing PE pipe in diameters up to 160mm. Length of a single installation is dependent on the soil conditions. Non-steerable moles in ideal conditions can install up to 30 metres in a single shot and steerable moles in ideal condition up to 60 metres, although 10-25 metres is the normal range for most works.

Impact moling uses a small footprint without needing deep excavations and operates through various ground types, but not all. In order to ensure successful completion of an impact moling installation, it is essential to know the ground conditions. Impact moling is suitable in soil types such as clay, silt, fine gravel and, generally, soft cohesive material.

2.1.3.6 Impact moling method – working mechanism and principle

Impact moling is a technique in which a percussive mole (soil displacement hammer) is launched from an excavation pit to displace the soil and form a bore. It forms the bore hole by compressing the earth immediately surrounds the compacting device.

The basic mechanism of impact moling is the reciprocating action of the pneumatically or hydraulically powered hammer within the cylindrical steel body. The piston is driven forward and on striking the forward end of the unit it imparts its kinetic energy to the body, which is driven forward. Repeated impacts of the hammer piston, advance the whole unit through the ground. The energy of the piston for the return stroke is regulated to reposition it for the next forward stroke, rather than reversing the unit out of the bore (unless required to do so).

Refer Fig 2.1.18. Compressed air drives the piston (1) onto the spring loaded chisel (2) and then onto the casing (3) moving the mole forwards whilst compressing the surrounding earth.

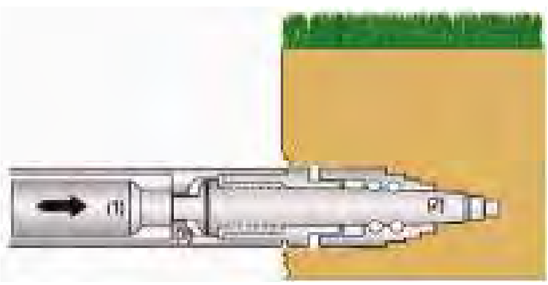


Fig. 2.1.16 Impact mole tool cutaway

Fig. 2.1.17 Impact moling hammer in it's launch pit

Impact moling comes in both steerable and non-steerable types. It works on the simple principle of displacing soil while installing the pipe. The impact mole consists of a steel tube powered by a compressor attached to a piston. The pneumatic hammer is placed at the head of the casing. The impact mole is first positioned at the correct line and grade after which the compressor is activated, pushing the mole forward by the hammering action at the head.

This method involves excavating pits at intervals for the mole to be placed. The mole is then entered into the earth on the horizontal face at the bottom of the pit (Fig 2.1.19). Destination pits of similar proportions are also dug, and this is where the mole emerges. The mole itself is a steel cylinder, it works as a pneumatic cylinder with pulsed compressed air causing the head of the mole to repeatedly hammer against the soil in front of the mole. The mole displaces the soil creating a bore for the new services to then be pulled through. This reduces the installation time, disturbance and cost.

2.1.3.7 Impact moling - equipment

The mole consists of a strong abrasion resistant steel 'torpedo like' cylinder, with a cone shaped sliding head of very tough steel. Inside the cylinder is a heavy piston with an arrangement of valves so that when compressed air is applied, the piston hammers against the back of the head. This imparts a forward momentum to the mole, and sufficient impact to the head to break up small stones that might otherwise deflect the mole from its course.

Two basic head shapes are commonly used for impact moles.

i. The first is the simple cone which, during operation, pierces the ground and pushes the soil aside.

ii. The second is the step or chisel head, which is effectively a stepped cone.

In normal operation, the spaces between the steps fill with soil, and the head operates as a simple cone. However, when the head strikes an obstacle, the stepped edges concentrate the impact energy against the obstruction. Whereas a smooth cone would tend to be deflected by an obstacle, the stepped shape may apply sufficient longitudinal force to move the obstruction or shatter it, reducing the risk of going offline.

Most impact moles are non-steerable and most bores are planned as straight bores. Non-steerable moles can be designed with fixed or moving heads. Various head designs are available for moles including replaceable heads to adjust to the ground conditions.

There are steerable moles, on which the head is angled, and the operator 'steers' by rotating the head(fig 2.1.20) before launching for steering to the right. Steerable systems are now available enabling curved trajectories and bores with multiple direction changes, as well as alignment corrections during the moling process, if needed, but the steering ability is somewhat limited.

Fig. 2.1.18 Steerable mole head

Fig. 2.1.19 Impact moling in rock / hard surface

Most moles are pneumatically powered and require a compressor at the surface adjacent to the entry pit. There are also hydraulically powered moles available and these require a hydraulic power pack instead of the compressor.

Recent development has been of moles for use in rock or boulders. These use a modified impact head to break rock and maintain alignment (fig 2.1.21).

2.1.3.8 Impact moling accuracy and requirements

Impact moling should be carried out at a depth of at least 10 times the diameter of the product pipe or 1 metre, whichever is greater, to avoid surface damage. The speed of moling can affect the accuracy of the bore, and the advance rate is on average about 0.3 – 1.5 m/minute for non-steerable moling, and about 0.3 m/minute for steerable moling.

The accuracy of unsteerable moles can be quite high in stable ground conditions where, with proper initial alignment, the accuracy in both line and level may be within 1% of the length of the bore.[For example if the bore is 20 metres long, the mole should be within 200mm (vertically and horizontally) of its intended location at the reception pit.]

2.1.3.9 Impact moling and pipeline installation procedure

Once the ground investigation has been completed and the desired route is established, the following procedure should be followed to complete an impact mole bore.

1. Set up and alignment of impact moling equipment

Non-steerable moles typically involve the excavation of two pits – a launch pit and a reception pit. A launch pit and a reception pit are first excavated at the ends of the bore path, to a little over the planned depth of the installation. The standard approach to moling is to dig a hole about 1 m square and 2 m deep. Such a hole is small enough that it can be dug by hand instead of by machine in inaccessible locations. The launch pit excavation must be cut square and flat to enable correct alignment at launch. The mole is then entered into the earth on the horizontal face at the bottom of this hole. A destination hole of similar proportions is also dug, and this is where the mole emerges. The launch cradle, if used, is then set up, or the mole can be positioned directly on the floor of the launch pit. Using a ranging rod in the reception pit and a sighting telescope in the launch pit, the initial line of the bore is established by physically aiming the mole towards the ranging rod target. After careful alignment of the mole in the insertion pit, the tool is expected to advance through the ground in a straight line.

Fig. 2.1.20 Impact molingtool in launch pit& receiving pit

Fig. 2.1.21 Impact moling monitoring

2. Impact mole launching, tracking and pipeline installation

Impact moling tool in the launch pit and at the receiving end as shown in fig 2.1.24 for impact moling monitoring.

Motive power is supplied to the rear of the impact mole via pneumatic or hydraulic pressure pipes, which normally pass through the product pipe or duct. The mole is launched and allowed to advance a short distance. The line is checked for a final time before the whole of the body of the mole enters the ground. If the line is not correct, the bore is restarted.

The impact mole is positioned on a skid or cradle at the desired line and level determined by a sighting level positioned on the mole. Once the mole is in the desired position, the compressor is activated advancing the mole through the hammering action of the reciprocating head. The cone-shaped reciprocating or chisel-tip head creates a bore hole. The long body length of the mole helps it to hold line and level as it advances through the ground. Marking on the air hose allows the operator to track the mole's progress as it advances through the ground. Once a bore hole has been completed, the product pipe is pulled in as the mole is extracted, generally by being reversed. A bore hole is typically 15-25% larger in diameter than the product pipe.

The bore is completed when the mole arrives at the reception pit, and the tool can be removed after the product pipe or duct has been drawn into the pit. Once the mole has passed through the earth, the pipe can be pulled through the long horizontal hole.

3. Steerable impact moling

Some newer impact moles are steerable. The method of steering is similar to that used in pilot bores and directional drilling with a slant face on the reciprocating head. The direction of the mole is altered through the positioning of the slant face head. The operator steers the mole by rotating the face in the desired direction. A sonde located in a transmitter-housing near the front of the mole allows the mole to be tracked using a walkover tracking system and transmits the 'clock face' position of the head to the operator for steering purposes. Steerable moles allow longer lengths to be installed because there is less risk of deviation from the required alignment / position / level.

2.1.3.10 Introduction to directional drilling method

Horizontal Directional Drilling (HDD) is a trenchless construction method used to install pipelines of various sizes and materials below the ground surface. Trenchless technologies, such as horizontal directional drilling, allow the entire city gas distribution system of a city to be installed or replaced without causing a major traffic jam and avoiding enormous cost of restoring streets and roads.

Polyethylene pipe is the pipe of choice for trenchless installations using directional drilling. Its flexibility, strength and fused joints as strong as the original pipe itself, make it ideal for horizontal directional drilling applications.

2.1.3.11 Directional Drilling Procedure

Directional drilling is performed in three stages:

i. First, a small diameter pilot hole is drilled along a directional path from one surface point to another.

ii. Next, the bore created during pilot hole drilling is enlarged to a diameter that will facilitate installation of a pipeline.

iii. Lastly, the pipeline is pulled into the enlarge hole, thus creating a continuous segment of pipe underground which is exposed only at the two initial end points. The equipment used in horizontal directional drilling depends on the outer diameter of the pipe, length of the run, ground conditions and the surroundings above the ground.

1. Drilling Pilot Hole

The process requires an entrance pit with drilling fluid and receiving hole. The first stage consists of drilling a small diameter pilot hole. Drilling fluid is pumped through the drill pipe to the drill bit where high pressure jets and the bit will grind the soils ahead of the drill stem. Horizontal directional drilling is done with the help of a viscous fluid known as drilling fluid. It is a mixture of water and,usually, bentonite or polymer continuously pumped to the cutting head or drill bit to facilitate the removal of cuttings, stabilize the bore hole, cool the cutting head, and lubricate the passage of the product pipe. The drilling fluid will also carry the cuttings back to the entrance pit at the drill rig.

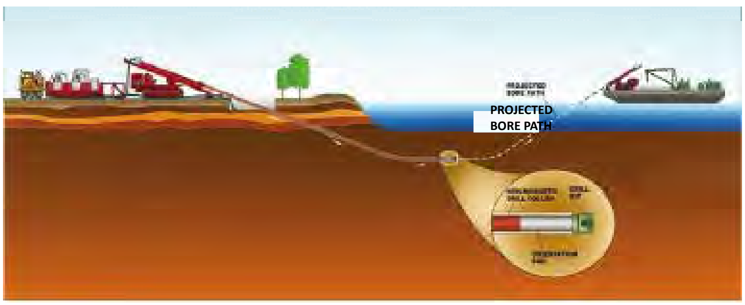


Fig. 2.1.22 Shore approach pilot hole drilling

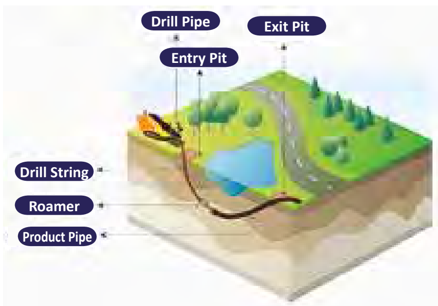


Fig. 2.1.23 Shore approach pilot hole drilling

Tracking of the pilot hole can be done in several ways depending on the size and complexity of the shot.Smaller shots are done using a walkover guidance system, whereas the larger more complex shots have a wire line magnetics type system.

2. Reaming

The second step is to ream the pilot hole and enlarge it to a size sufficient to safely install the product lines. A reamer is pulled back and rotated while pumping drilling fluid to cut and remove solids to enlarge the hole. The reamer's diameter depends on the size of the pipe to be pulled back through the bore hole. Reaming speeds will vary depending on existing soil conditions and the amount of cuttings that are removed from the hole.

Bentonite and other additives will be used to ensure a clean and stable hole. Bentonite is used to create a "cake layer" around the outside of the hole during reaming. This will help with the stability of the bore hole and with fluid loss or infiltration.

3. Pullback of the pipe

The final step is the pullback of the pipe into the reamed hole. Once the hole is drilled and reamed, a steel drill string is extended behind a cutting head swivel which is utilized between the product line and the reamer to prevent any torsional stress from the rotating drill string being transferred to the product pipe. As the product pipe is pulled into the drill hole, drilling fluid is pumped downhole to provide lubrication to the product pipe. The pulling load on the polyethylene pipe must not exceed the allowable tensile load, or safe pull strength of the pipe.

Exercise

I. Answer the following questions.

1. What is directional drilling?

----

2. Briefly address mole ploughing installation procedure.

----

3. Write short notes on directional drilling fluid and its functions.

----

4. Explain impact moling procedure.

----

5. Explain directional drilling procedure.

II. State whether the following statements are True or False.

1. Impact moling hammer may be hydraulic or pneumatic.

   True ☐ False ☐

2. Directional drilling requires excavations at both ends of the works to the depth of the line.

   True ☐ False ☐

3. During impact moling operation, the soil is displayed, not removed.

   True ☐ False ☐

4. In horizontal directional drilling, bentonite is used to help break up the clay soils.

   True ☐ False ☐

5. Impact moling is best suited to installing PE pipe in diameters up to 355 mm.

   True ☐ False ☐

6. For successful pipeline installation, the pulling load on the polyethylene pipe must exceed the allowable tensile load of the pipe.

   True ☐ False ☐

Notes

2.2 Electrofusion Principles

Unit Objectives

At the end of this unit, you will able to:

1. recognise electrofusion principles
2. identify and maintain accurate control of melt pressure and temperature
3. explain why coils are protected from damage prior to, during and after fusion.

2.2.1 Understanding Fusion Technology

At the end of this topic, you will be able to:

1. recognise heat fusion and electrofusion and differentiate the same
2. recognise electrofusion principles and processes
3. define electrofusion control units and explain the functions.

2.2.1.1 Introduction to fusion technology

Fusion process makes the surface of joint conversion to melt temperature or softening temperature. There are two primary fusion technologies mainly considered for PE piping. They are: conventional heat fusion and electro fusion. The main difference between conventional heat fusion and electrofusion is the method by which the heat is applied. In conventional heat fusion joining, a heating tool is used to heat the pipe and fitting surfaces. The electrofusion joint is heated internally by a inbuilt resistor at the interface of the joint. Heat is created as an electric current is applied to the coil in the fitting.

1. Heat fusion – manual heating

Butt fusion is a thermo-fusion process, which involves the simultaneous heating of the ends of two pipe/fitting components which are to be joined, until a molten state is attained on each contact surface. In conventional heat fusion (butt, saddle and socket) joining, a heating tool is used to heat the pipe and fitting surfaces. The two surfaces are then brought together under controlled pressure for a specific cooling time and a homogeneous fusion joint is formed.

Tips

PE is semi crystalline structure and melt point (ref properties) at around 200˚C; trainee may refer to the pipe supplier catalogue or WPS for correct temperature.

Classroom practice – Two small pieces of plastic shall be held in the candle heat and pressed together to understand fusion, joining.

2. Electrofusion

Electrofusion fittings incorporate an electrical heating coil to which an Electrofusion Control Unit (ECU) supplies the electrical energy necessary to heat the coil. When the coil is energised, the material adjacent to it melts and forms an expanding pool which comes into contact with the surface of the pipe. The continued introduction of heat energy causes the pipe surface also to melt and a mixing of pipe melt and fitting melt takes place. This is vital to produce a good weld. Following the termination of the heat cycle, the fitting and pipe are left to cool and the melted material solidifies to form a sound joint.

Resistance heating

Necessary heat to melt the pipe surface is generated by converting electrical energy into heat energy in a controlled method called resistance heating. When the current of AMPS (I) passed through a high resistance wire, It generates a heat (power) in the wire.

2.2.1.2 Fusion Process

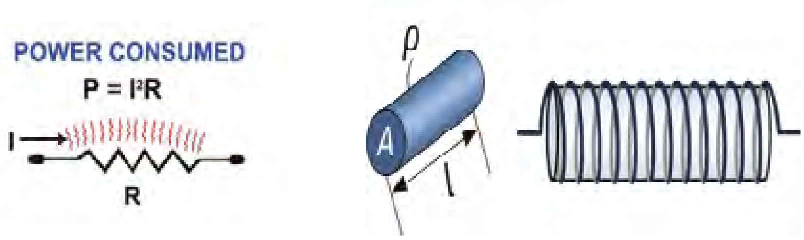


Fig. 2.2.1 Current flow through resister / coil

Fig. 2.2.2 Simple process of melting plastic

1. Heating

Heat is required to melt the PE pipe surface to be joined. This heat is obtained by resister wire coil, which is encapsulated just around the heating surface. The heat is generated when the coil is connected to electricity in the respective plugs at the coupling and energized. The heat melts the PE joining surface around both on the pipe and coupling.

2. Heat distribution and fusion

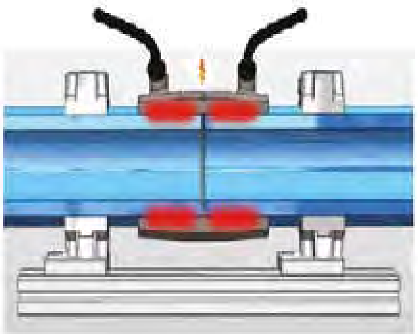


Fig. 2.2.3 household energy conversion – Electric power into heat

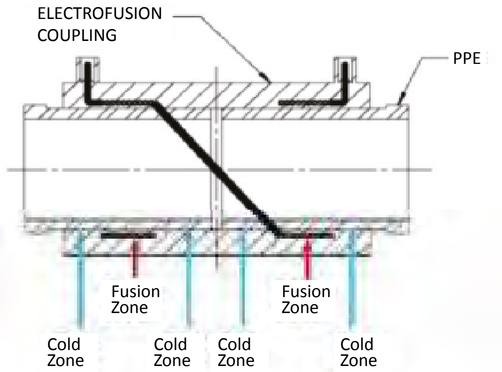


Fig. 2.2.4 Heating coil inside coupler ID & Fusion zones

Figure 2.2.5 explains the coil position. The zone under coil is fusion zone and both sides are "cold zone". The heat zone is shown in fig 2.2.4 and 2.2.5, where heat is generated and coupling and pipe surface melts. The cold zone protects the flow of melts not flowing out of coupling. In fig 2.2.4 and 2.2.5, see the fusion zone,where the wire is impregnated inside the surface of coupling such that it is placed in the inner most point of ID. When energized, it heats the ID of coupling and also the pipe surface such that the coupling and pipe melts and fusion is obtained.

3. Temperature, time and pressure control

Electrofusion fittings generate significant pressure from thermal expansion during the melt phase of the fusion process. This melt pressure is an integral part of the fusion process and a designed function of the fitting and fusion parameter. Large temperature gradients exist in the electrofusion joint during the fusion cycle. The low thermal conductivity of polymers is the main cause of these large gradients. Refer fig 2.2.6 for the time versus temperature heating cycle graph. The temperature is selected based on the manufacturers recommendations from their catalogue or welding procedure specification.

The temperature, holding time, cooling time are set in the control unit and the process is automatically controlled**.** Continued heating causes the pipe surface to melt and then mix with the molten plastic of the fitting. This mixing is vital to produce a good weld. At the end of the heating cycle, the fitting and pipe are left to cool and the molten material solidifies to create a solid and sound joint. During this cooling phase, the joint must be completely standstill stationary as any movement may disturb the joint and can crack at the interface and cause a leak path.

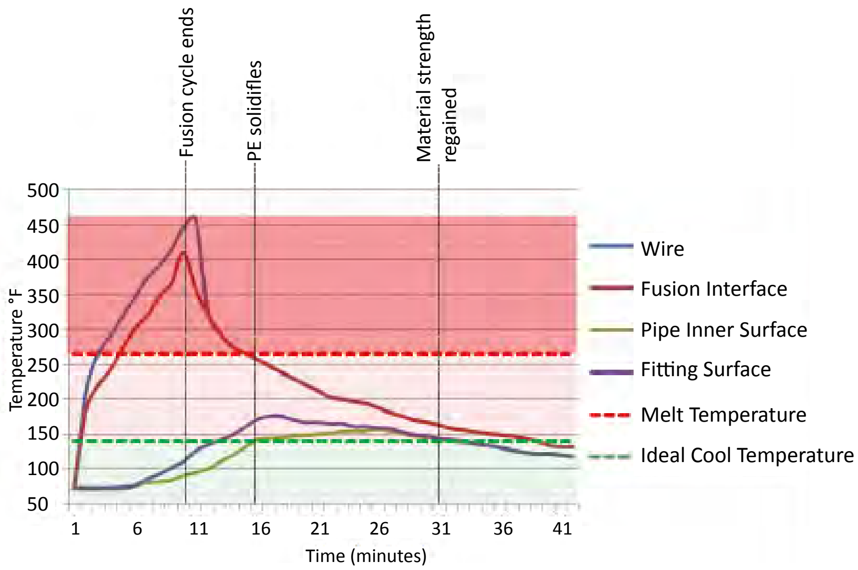


Fig. 2.2.5 The heating cycle graph

Electrofusion Control Units

1. Control unit description

The electrofusion control unit supplies electricity to this coil, heating it up and causing the plastic to melt. When this cools, a gas-tight joint is formed. The Electrofusion control box / unit that applies current to the fitting also controls and monitors the critical parameters of fusion, (time, temperature and pressure). The control box / unit is a microprocessor capable of storing the specific fusion data for each joint. The supply power from input current is converted to “high current at low voltage” as per electrofusion coupler requirements by a control unit, which is has cycle timer control as shown in fig 2.2.6. It has:

- input current cable
- output connector to the coupler (electro fusion)
- digital display of input parameter like voltage, current, timing and joint number
- IP 55 protection for outdoor welding operations.

2. Electrofusion control unit function

The Control Unit is plugged into a standard electric outlet and converts 110/120 VAC power to DC power. Then transforms the DC power into an RF signal that travels to the Fuser. The RF (Radio Frequency) signal is transferred to the jaws of the Fuser and concentrated into a high frequency electromagnetic field that reacts with ferrous materials in the fitting to create heat. The heat in turn melts the plastic, creating a hermetic weld.

Exercise

I. Answer the following questions.

1. Differentiate heat fusion and electrofusion.

---

2. Explain electrofusion principle and processes.

---

3. Describe electrofusion control units duly addressing their functions.

---

4. Write expansions of HDPE, PE, BTU and RF.

II. State whether the following statements are True or False.

1. Electrofusion Technology is a pipe joining technique by heat fusion, where heat is produced by heating tool.
   True ☐ False ☐
2. 1kW (KiloWatt) = 3414 BTU/hr.
   True ☐ False ☐
3. Resistivity is defined as resistance of unit length per unit area of a conductor.
   True ☐ False ☐
4. Electrofusion fittings generate significant pressure from thermal expansion during the melt phase of the fusion process.
   True ☐ False ☐

Notes

2.2.2 Requirements to Achieve Good Quality Fusion Joints

At the end of this topic, you will be able to:

1. explain the necessity for keeping heating coils close to joint surfaces
2. describe the importance of accurately controlling wire positioning during manufacture and fusion processes
3. justify the requirements of uniform heat distribution requirement
4. maintain accurate control of melt pressure and temperature.

Coupling sleeves / fittings with implanted metal coils are placed around two ends of pipes to be joined, and current is passed through the coils. Resistive heating of the coils, melts small amounts of the pipe and fitting, and upon solidification, a joint is formed. The development of the joint strength is affected by the influence of several process parameters. Hence,consistent, qualified and demonstrated joining procedures with detailed parameters and control measures requirements, are necessary for the creation of strong joints.

2.2.2.1 Necessity for keeping heating coils close to joint surfaces

Coil / Wire Position: Refer Fig 2.2.7. The black lines are heating coil position, which is factory made and coils are very accurately positioned along the circumference and for a particular length from edge such that the melts do not flow through edge. The coil is precisely interconnected and forms resistance to create heat.

Since it is factory made, and the coils are very close to ID surface during joining and handling, the operator shall understand that any scratch inside will expose the coils and may create a discontinuity, which will result in "no melt or improper melt" and failure of joints. One of the most critical functions of the electrofusion process is to close the gap between the pipe and the fitting and to build up interfacial pressures for the fusion process to take place. If this gap is not closed, the interfacial pressures cannot be built up. Then, there is no way for the electrofusion joint to effectively achieve high level of fusion integrity for which it was designed.

If a pipe has out-of-roundness, the initial concern is that the surface area of the pipe may not adequately come in contact with the fusion zone of the electrofusion fitting. This could result in the electrofusion fitting's cold zones, that are designed to contain the material generated in the melt pool, to simply allow the molten material to escape out of the fusion area without producing any melt penetration. Heating coils are to be kept as close to the joint surfaces as possible so as to ensure effective heat transfer and joint surface fusion. The following requirements shall be met to ensure the heating coil position as close as possible with joint surfaces

- ovality of pipe if any, shall be rectified
- joint misalignment shall be avoided
- effective clamping shall be performed
- undersize pipe shall not be used
- improper pipe preparation and overscraping of pipe surface shall be avoided

Fig. 2.2.6 -Typical pipe coupler with heating coil

Fig. 2.2.7 Ffitting sticker showing manufacturer marking

Tips

See fig 2.2.8 and Read - Weld 200 sec 40V;   Cool 17 min.

2.2.2.2 Importance of accurately controlling wire positioning during manufacture and fusion processes

The connecting surfaces, the pipe surface and the inside of the socket, are heated to welding temperature by electricity with the aid of resistance wires embedded in the socket (heating coil). Then they are welded by fusion process. Wire position is to be accurately controlled during manufacture and during the subsequent fusion process so as to avoid wire movement, overheating and nonuniform heating / temperature gradient. If wire pitch and positioning of the coil in relation to the inner surface of the socket is not accurately controlled, uniform heat distribution cannot be obtained. This may result in defective / inadequate strength joints with voids.

2.2.2.3 Importance of uniform heat distribution over the length of the hot zone

It is important that heat distribution shall be uniform over the length of the hot zone. If heat distribution is not uniform, it might lead to poor fusion interface, voids, over / under-flush welding / fusion, structural deformity, cold welding with poor fusion, etc. Good fusion joint is highly dependent on heating uniformity. Cold weld, generally, is caused due to insufficient time of heating / lack of uniformity is heat distribution.

2.2.2.4 Melt Pressure, Time and Temperature Accurate Control Requirement

Heating, holding and cooling cycle control is important similar to butt weld. Every coupling manufacturer provides recommended cycle time by marking on the coupling. Joining instructions and parameters specified for the joints, shall be followed.

As the polyethylene surfaces melt, they also expand in volume to close allowable gaps between the pipe and fitting. Then after the gaps are closed, the continuing melt expansion generates pressure within the heated zones. The expanding melt reaches “cold zones” within the fitting where the melt flow fronts cool and solidify. This block any further melt movement or material escape. Hence, to synchronise the fusion heat zone, fusion zone pressure and temperature, the prescribed and manufacturer required optimum time and temperature ranges control shall be strictly adhered to in order to produce strong and defect - free fusion joints.

2.2.2.5 Importance of protecting coils from damage prior to, during and after fusion

The heating coils are to be protected from damage prior to, during and after joining and fusion to ensure uniform and effective heating enable fusion and avoid overheating. Damaged leads, loose terminal tips, poor connections could result in over heating or electrical faults/overheating during welding. Each wire terminal is to be protected with shrouds to ensure fittings / coupling do not arrive damaged.

Inner surface protection: It is important that the joining part which has the wire connection shall be kept in original cover, against any damage to the inner surface as it may cause the resistance wire to be cut or exposed, which will result in bad weld joint.

Exercise

I. Answer the following questions.

1. What are all the requirements shall be met to ensure the heating coil position as close as possible with joint surfaces?

----

2. Explain the need for accurately controlling wire positioning during manufacture and fusion processes..

----

3. Why is it essential to ensure uniform heat distribution over the length of the hot zone while joining PE pipes?

----

4. Explain the importance of protecting coils from damage prior to, during and after fusion.

II. State whether the following statements are True or False.

1. If heat distribution is uniform along the circumference of PE pipe, then the heat distribution need not be uniform over the length of the hot zone.
   True ☐ False ☐
2. Large temperature gradients will exist in the electrofusion joint during the fusion cycle.
   True ☐ False ☐
3. The molten polymer in the PE piping fusion zone exerts inward force on the surrounding solid polymer material.
   True ☐ False ☐

Notes

2.3 Physical Properties

Unit Objectives

At the end of this unit, you will able to:

1. gain knowledge on different PE piping material properties and compatibility
2. explain the importance of Standard Dimensional Ratio
3. describe the effects of expansion and contraction
4. perform pipe bending.

2.3.1 Different PE Material Properties & Compatibility

At the end of this topic, you will be able to:

1. identify different type of plastics, PE pipes and its classifications
2. gain knowledge on different PE piping material properties
3. identify the PE pipes based on numbering code identification and colour coding.

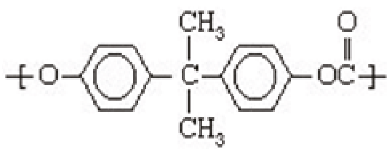
2.3.1.1 Plastics and PE Pipe Basics and Types

1. Plastic – Basics

Plastic is a chemical chain link formation of Carbon, Hydrogen, Oxygen and few additives like chloride, etc., formed in controlled chemical process. (Refer Fig 2.3.1). There are many varieties of plastic available in the market. It is classified as thermoset and thermoplastic. Thermoplastics are weldable. Thermoplastics are at two types based on their internal structure. They are: amorphous and crystalline.

a. Amorphous structure is a random structure and it is opposite of crystalline. This structure gives flexibility to plastic. refer Fig 2.3.2.

Fig. 2.3.1 Plastic chain link



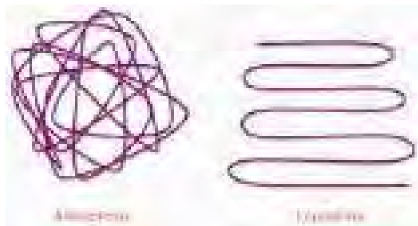


Fig. 2.3.2 Amorphous and Crystalline Structures

b. Crystalline structure has a molecular structure that is very orderly. This plastic is strong and rigid. It will brake instead of bending when maximum load is applied.

2. Types of Plastics

ABS – Acrylonitrile Butadiene Styrene – pipes and sheets .

PVC – Polyvinyl Chloride – used mostly in drain pipe in house, industries and farming, etc.

UPVC – Unplasticized Polyvinyl Chloride – used in windows, roof sheet , pipes, etc.

PP – polypropylene – used in package , injection molds parts, etc.

PE – Polyethylene.

3. PE Piping

PE pipes are available in different types – Light density, Medium density & High density and being used in many applications like water lines, industrial piping, gas distribution piping, etc. Pipes are supplied in 6M random length with size above 125mm OD. Coils are supplied up to 110 mm OD.

Tips

Refer Individual manufacturer catalog for supply specification, handling and storage instructions.

a. Two types of PE the pipes are used for Gas lines. There are MDPE and HDPE.

Fig. 2.3.3 MDPE Pipes

Fig. 2.3.4 HDPE Pipes

2.3.1.2 Physical Properties

MDPE – Medium Density Polyethylene – yellow coloured pipes. HDPE – High density polyethylene – Black coloured pipe with yellow strip marking. HDPE – is semi crystalline structure plastic of “crystalline + amorphous” having good strength, wear and chemical resistance. HDPE has more percentage of crystalline structure than LDPE or MDPE. Density – varies from 0.985 to 2.55 gram/ cm3 (low density to high density student to understand that 0.925 low density will float in water and high density pipe will go down into water, also note the weight to handle while erection of pipe).

Strength – PE pipe strength varies from 7.6 to 43 Mpa. Whereas, steel pipe strength is in the range of 400-1000 Mpa. From this, we can have an idea of PE strength which is around 40 times lower than steel. Hence, safe handling, storage and installation of PE pipes are mandatory. Melting point – ranges from 130˚C to 280 ˚C. This is an important parameter to be considered. The HDPE supplier / manufacturer will give us the melting temperature and pipe fitter must note. (Amorphous polymer temperature is called Glass transition temperature).

Service temperature – This is also represent ‘working or operating’ temperature. Look at the supplier catalogue for the permissible service / operating/ working temperature. Ultraviolet Exposure: The ultraviolet component in sunlight can produce a deleterious effect on the polyethylene unless the material is sufficiently protected.

2.3.1.3 Material Classification

PE piping material specification includes:

IS 14885 – Polyethylene Pipes for the Supply ofGaseous Fuels

ISO 4437 – Buried Polyethylene Pipes for the supply of gaseous fuels.

ASTM D 2513 – Standard Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings

ASTM D 3350 – Standard Specification for Polyethylene Plastics Pipe and Fittings Materials.

Polyethylene pipes are classified based on material used for various pressure rating (SDR). The pipe size is selected by the designer and as indicated in the drawing.

In general, Polyethylene pipes are classified as:

i. PE 32 – low pressure piping systems

ii. PE 40 – low pressure piping systems

iii. PE 63 – medium pressure piping systems – irrigation system – drinking water connections

iv. PE 80 – gas pipe for natural gas distribution network with pressure rate up to 4 bars – drinking water pipe with pressure rate up to 16 bar – sewers, outfall pipes, industrial pipes.

v. PE 100 - high perfomance/ high pressure PE piping applications used in gas transmission and distribution.

PE100 is a higher performance material than PE80 and demonstrates exceptional resistance to rapid crack propagation as well as to longterm stress cracking. Moreover, the higher strength of PE100 permits thinner pipe walls than PE80 for the same operating pressure. PE100 uses less polymer and provides for a larger bore and increased flow capacity for a given nominal pipe size. This can result in significant cost savings at certain sizes and pressure ratings. The Minimum Required Strength – MRS – according ISO 4427 for the different materials are as tabulated in Table 1.

Table 1

Designation of material	**MRS at 50 years and 20oC MPa (bar)**
PE 100	10 (100)
PE 80	8 (80)
PE 63	6.3 (63)
PE 40	4 (40)
PE 32	3.2 (32)

2.3.1.4 PE Piping Identification – Numerical Code identification (marking on pipe) and Colour Coding

PE Materials are identified by 6 digit number as per ASTM 3350 in accordance with density, melt index, flexural modulus, tensile strength at yield, environmental crack resistance and hydrostatic design stress basis. But in practice, a simpler code of 4 digit code as per ASTM F 412 is followed by all manufacturers.

a. Four Digit Identification As Per ASTM F 412

PE – PolyEthelyne

1st digit – resin character “density range” as per ASTM D 3350 (Resin is mixer of chemicals used to make pipe)

2nd digit – slowing / resisting crack growthASTM D 3350 (this is property of pipe based on how it develop cracking during usage to determine service life). That is, material’s capacity for safe resisting of localized stress intensifications and hence resisting crack growth.

Last two digit – Max Hydro static design pressure / stress in Psi.

For example, PE 3708 – in which, 1st digit ‘3’ is based on pipe material density, 2nd digit ‘7’ is indicating the level of resistance to crack growth and 3rd and 4th digits together “08” (last two digits) stands for hydrostatic design stress 800 Psi (if the last two digits are 10, will mean ‘100 Psi’).

b. Pipe identification as per IS 14885 gas fuel pipeline

PE pipes are marked as per IS 14885 as below:

PE- XX DN XXX * XX SDR XXX GAS

For example, designation “PE-80 DN200X11.4SDR 17.6 GAS” states that

i. “this pipe made off PE 80 material outside diameter 200 mm

ii. minimum wall thickness 11.4 mm having SDR 17.6 for gas application.

c. Color Code Identification

Common colors are used to classify the PE pipes as stated below:

- completely black pipe means, it is meant for industrial applications
- completely blue pipe or black with blue stripes means it is for potable water

- completely yellow, or black with yellow stripes means, it is meant for gas pipes.
- As per IS 14885, yellow colour for PE80 and Orange for PE100 for gaseous fuel pipeline.

Exercise

I. Answer the following questions.

1. Explain PE piping, types and its classification based on strength.

----

2. What are the physical properties of PE piping?

----

3. Describe PE pipe numerical code identification system and identification by colour coding.?

II. State whether the following statements are True or False.

1. Based on internal structure, thermoset plastics are classified in to two types –"amorphous and crystalline".

   True ☐ False ☐

2. Crystalline structure gives a flexibility to plastic and hence has an easily bending characteristic.

   True ☐ False ☐

3. As per pipe colour, completely black pipe means, it is meant for industrial applications.

   True ☐ False ☐

4. Last two digit of four digit identification of PE piping, indicates Max Hydro static design pressure / stress in Psi.

   True ☐ False ☐

Notes

2.3.2 PE Piping, Standard Dimensional Ratio and Pipe Bending

At the end of this topic, you will be able to:

1. explain the importance / significance of Standard Dimensional Ratio
2. identify various electrofusion fittings
3. describe the process of welding pipes having different wall thicknesses using electrofusion fittings
4. perform pipe bending.

2.3.2.1 Pipe Dimensions

The pipes have different diameter, thickness based on material types, grades and ratings are selected by the designer suitable for different flow rate and pressure. The pipe fitter shall be able to understand the required dimension / sizes from drawing and check actual pipe and fitting dimensions such as OD and ID as per drawing / specification.

Ovality or out of roundness: The difference between maximum and minimum diameter is called ovality. This is very important for PE pipe electrofusion joining, as it will cause mismatch, improper joining, nonuniform fusion, etc., and you will be studying how to correct ovality. Ovality tolerance of is tabulated in the table 1.

Fig. 2.3.5 MDPE pipe

Table 1

Type	Nominal Outside Diameter (dn) mm	Maximum Ovality mm
Straight Pipe	< 75 >75 to <250 >250	1+0.008 d 0.02 d 0.035 d
Coiled Pipe	<180	0.6 d for SDR 11 0.15 d for SDR 17.6

2.3.2.2 SDR Standard Dimensional Ratio

One of the items of information stated on both pipe and fittings is the standard dimensional ratio. SDR is the term, mostly, used by industries to define method of rating pressure piping. It is the ratio of outer diameter to the minimum thickness of the pipe.

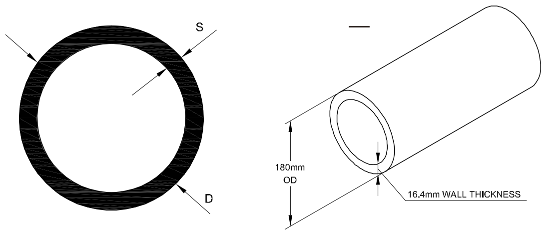


Fig. 2.3.6 Pipe OD and thickness notation / relationship

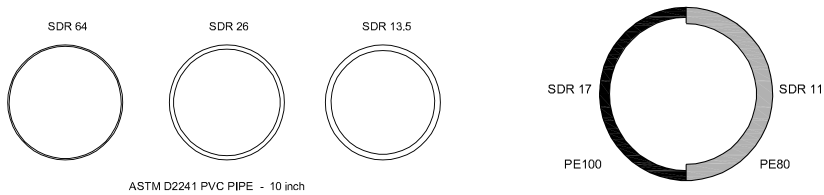


Fig. 2.3.7 Depicting SDR Differentiation

Refer to fig 2.3.6, SDR relationship can be expressed as a formula SDR = D/ s, where 'D' is Outer diameter and 's' is thickness of pipe.

For Example, referring to fig 2.3.6, if OD is 180 mm and thickness is 16.4 mm, then SDR = 180 /16.4 = SDR11.

If SDR is a lower, pipe wall is thicker; in other means "Lower the SDR, higher the wall thickness". Refer fig 2.3.7 for more clarity. Trainees have to understand the SDR vs pipe OD vs thickness. Refer table 3 for dimensions of common HDPE pipes.

Table 3

Nominal Pipe Size	Outside Diam-eter	SDR 21		SDR 12		SDR 13.5		SDR 11		SDR 9	
		PRESSURE CLASS 80		PRESSURE CLASS 100		PRESSURE CLASS 128		PRESSURE CLASS 160		PRESSURE CLASS 200	
		INSIDE DIAMETER	WALL THICKNESS	INSIDE DIAMETER	WALL THICKNESS	INSIDE DIAMETER	WALL THICKNESS	INSIDE DIAMETER	WALL THICKNESS	INSIDE DIAMETER	WALL THICKNESS
3”	3.50	3.167	0.167	3.088	0.206	2.981	0.259	2.864	0.318	2.722	0.389
4”	4.50 4.80	4.071 4.343	0.214 0.229	3.971 4.235	0.265 0.282	3.833 4.089	0.333 0.356	3.682 3.927	0.409 0.436	3.500 3.733	0.500 0.533
5”	5.56	5.033	0.265	4.909	0.327	4.739	0.412	4.552	0.506	4.327	0.618
6”	6.63 6.90	5.994 6.243	0.315 0.329	5.846 6.088	0.390 0.405	5.644 5.878	0.491 0.511	5.420 5.645	0.602 0.627	5.153 5.367	0.736 0.767
8”	863 905	7.804 8.188	0.411 0.431	7.610 7.985	0.507 0.532	7.347 7.709	0.639 0.670	7.057 7.405	0.784 0.823	6.708 7.039	0.958 1.006
10”	10.75 11.10	9.726 10.043	0.512 0.529	9.485 9.794	0.632 0.653	9.157 9.456	0.796 0.822	8.795 9.082	0.977 1.009	8.361 8.633	1.194 1.233
12”	12.75 13.20	11.536 11.943	0.607 0.629	11.250 11.647	0.750 0.776	10.861 11.244	0.944 0.978	10.432 10.800	1.159 1.200	9.917 10.267	1.417 1.467
14”	14.00	12.667	0.667	12.353	0.824	11.926	1.037	11.455	1.273	10.889	1.556
16”	16.00	14.476	0.762	14.118	0.941	13.630	1.185	13.091	1.455	12.444	1.778
18”	18.00	16.286	0.857	15.662	1.059	15.333	1.333	14.727	1.636	14.000	2.000
20”	20.00	18.095	0.952	17.647	1.176	17.037	1.481	16.364	1.818	15.556	2.222
22”	22.00	19.905	1.048	19.412	1.294	18.741	1.630	18.000	2.000	17.111	2.444
24”	24.00	21.714	1.143	21.176	1.412	20.444	1.778	19.636	2.182	18.667	2.667

Electrofusion piping fittings and ability to weld different wall thickness pipes

1. Electrofusion PE pipe fittings

A range of universal fittings suitable for gas pipeline, manufactured from high strength polyethylene are available in the market. PE fittings must have a bar code affixed to them. Common fittings used in gas piping, are discussed below:

a. **Saddle Connections:** This is used to make branch (taping) connection from main pipeline.
b. **Elbows:** Elbows are used to divert the flow direction. Pipe elbows are, generally, available in 90 and 45 degree. Other angles may be on specific request. Operator shall be able to select right elbow as per drawing. (Refer Fig 2.3.9.)
c. **Coupling:** Coupling is used for electrofusion joining, instead of butt welding joints.
d. **Tees:** This is to make branch connection from running pipe. (Refer fig 2.3.11.)
e. **Reducer:** Reducers are used to connect pipe having change in / different diameter. (Refer fig 2.3.12.)

Tips

AWWA means- American Water Works Association.

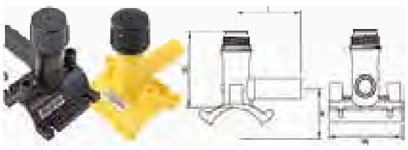


Fig. 2.3.8 PE Saddle connections

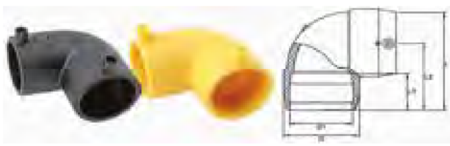


Fig. 2.3.9 PE Elbow connections

Fig. 2.3.10 PE piping couplings

Fig. 2.3.11 PE piping tees

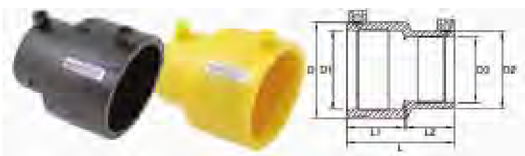


Fig. 2.3.12 PE piping reducers

2. Welding pipes having different wall thickness using electrofusion fittings

Electrofusion fittings are able to weld pipes of the same OD but can be of different wall thicknesses (SDRs). They are available in a choice of 10 bar or 16 bar (water) and 5.5 bar or 7 bar (gas) rating. Care should be taken to ensure that the pressure rating of the fittings is equal toor greater than that of the pipe. Dissimilar materials and dissimilar wall thicknesses can be jointed by electrofusion. (Refer Fig 2.3.13.)

Tips

The maximum working pressure should not exceed the lower value for the two pipes.

Similar materials and/or wall thicknesses may be jointed by butt fusion or electrofusion.

2.3.2.4 Perform Pipe Bending

PE pipes may be bent during pipe laying to allow a pipeline to follow through a curved path. Electrofusion or mechanical joints and fittings should not normally be incorporated in sections of pipework which are to be bent. Instead, a formed bend or elbow should be welded into the pipeline in order to prevent excessive stress. For curves of smaller radius, post-formed bends, moulded fittings or purpose-made sockets shall be used.

For profiling pipes to the actual site installation condition / profile, reference should be made to the manufacturer for bending requirements.

Generally, a pressure pipeline can be bent without difficulty in the vertical plane to follow changes in the ground surface. Where it is not possible to bend the pipe by hand, preformed bends or moulded fittings shall be installed. The form of the trench floor provides support for the pipes and bending occurs more or less uniformly along the length of the pipes involved.

Bending in the horizontal plane is more difficult as pipes tend to move in the trench and the deflection tends to be concentrated in a few places. There is a tendency for excessive loads. Highly localized stresses may cause premature failure of the pipeline.

1. Bending Characteristics and Radius

Bending characteristic depends on the plastic material structure. All PE pipes installed on a curved alignment must be drawn evenly over the entire curve length, and not over a short section. This can lead to kinking in small diameter, and/or thin wall pipes. Pegs or stakes are not permitted to achieve the pipeline curvature as these can result in highly localised stresses.

The semi crystalline HDPE pipes can be bend to radius based on bend ratio specified in the table 4 for field application. Instead, the pipe should be progressively supported with backfill material as the curve is formed. The bigger the bending radius, the smaller the possibility for cracks or wrinkles to occur. For all pipes, there is a minimum–bending radius. The bending radius depends on the material, the pipe diameter, wall thickness and heating temperature. The allowable radius of curvature depends on the temperature of the pipe and the SDR. The 4 table gives recommended minimum bending ratio for pipes at 20°C, for long – term application.

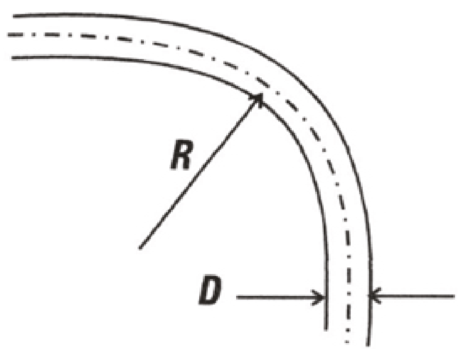


Fig. 2.3.13 Piping Bending Radius

Bend Radius R = α x OD, where R is the minimum bend radius,

OD is the pipe's outside diameter, α is the minimum bend ratio.

The minimum bend ratios shown below are for a long term application.

Table 4

Dimension Ratio, SDR	Minimum Bend Ratio, α
7	20
7.3	20
9	20
11	25
13.5	25
17	27
21	27
26	34
32.5	42
41	52

Generally as a thumb rule, cold bending of 20-30 times OD is permitted for field application. In general, more typical safe bending radius for SDR11 and SDR17 pipes is 25 times, increasing to 35 times the pipe OD in cold weather. For thin–walled SDR26 and SDR33 pipes, these values should be increased by 50%. In the case of pipe supplied in coils or drums, the above bend radius values apply only if pipe is bent in the same direction as it was previously coiled.

Exercise

I. Answer the following questions.

1. Explain the importance and significance of SDR.

----

2. Write short notes on various PE pipe fittings with its applications.

----

3. Explain PE pipes dimension, ovality and tolerances.

II. State whether the following statements are True or False.

1. SDR is the ratio of PE pipe inner diameter to the minimum pipe thickness.

   True ☐ False ☐

2. The difference between maximum and minimum diameter is called ovality.

   True ☐ False ☐

3. Electrofusion fittings are able to join pipes having different wall thicknesses (SDRs).

   True ☐ False ☐

4. Pressure rating of the PE pipe fittings is to be equal to or greater than that of the pipe.

   True ☐ False ☐

5. If dimension ratio – SDR increase, minimum bend ratio will also increase.

   True ☐   False ☐

Notes

2.3.3 Effect of Expansion and Contraction

At the end of this topic, you will be able to:

1. describe the effects of PE pipes expansion and contraction
2. calculate possible change in length due to change in temperature
3. mitigate the effects of expansion / contraction.

2.3.3.1 PE Pipe Thermal Expansion And Contraction

Understanding of thermal expansion / contraction during PE pipes installation / erection is must for PE Pipe / City Gas Distribution pipe fitter. The average coefficients of linear thermal expansion between 20°C and 60°C for PE80 (MDPE) (1.3x10- 4°C-1) and PE100 (1.5x10-4°C1) are approximately ten times greater than for metal. Allowance must be made for this when designing and performing polyethylene pipeline installations where significant temperature variation is expected. Thermal expansion / contraction will induce longitudinal stress in the pipeline; and if restrained, lateral strain and bending moment too. An expansion joint shall be able to permit an axial movement of the connecting pipe of not less than 10 mm in either direction. When heated, the metal expands. This expannsion will not be visible as it is in microns, (1mm/1000 =1 micron), when longer length of metal or plastic is heated and it expands significantly .

The expansion(change in length) $\Delta L = L \times \alpha \times \Delta T$

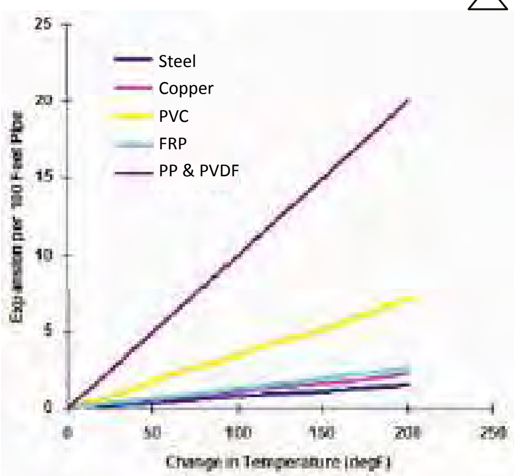


Fig. 2.3.14 Temperature Vs Expansion Effect

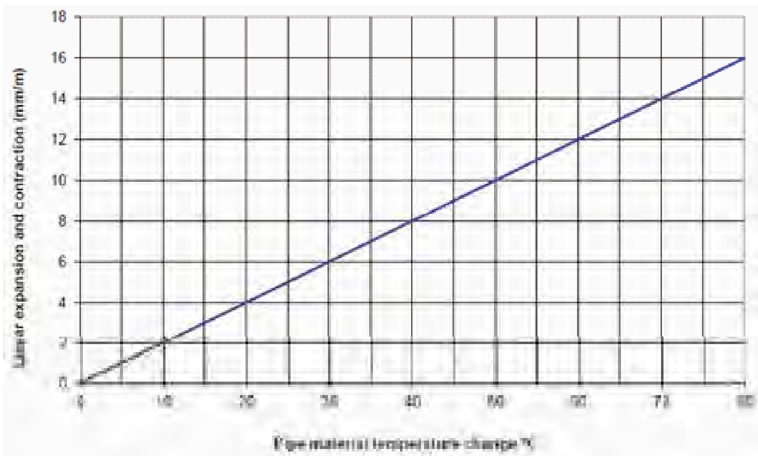


Fig. 2.3.15 Thermal Expansion and Contraction of PE

The expansion of HDPE pipe is approximately 10 times more than a steel pipe. Fig 2.3.17 depicts various material expansion / contraction with respect to change in temperature. Fig 2.3.18 conveys the relationship / proportionality between change in pipe material temperature and linear expansion / contraction.

For example,

For normal operation day time temperature max 45 ˚C, Night temperature 15 ˚ C, Change in temperature, T = 45-15 = 30˚C, PE pipeline length, L = 300 meter, Contraction length LC= 30 X 300 X 120 1000000 = 1.08 M (1080 mm)

As shown in above example, the change in pipe length for PE pipe is significant. However, this calculated change in length assumes both an unrestrained movement of the pipe and an instantaneous drop in temperature.

2.3.3.2 Means of Mitigating / Componsating the effects of expansion / contraction

In above ground installations, the natural flexibility of the pipe, coupled with judicious sitting of anchor and support brackets, will conveniently accommodate expansion and contraction at changes of direction, etc. In installations where fully end-load bearing joints are used, the compressive or tensile forces set up in the pipeline due to constraint of thermal movement will not detract from long-term performance. But the effect of these forces on pipe support, ancillary equipment and so on, must be considered and allowance must be made.

The potential for thermal movement is a particular issue where a (fully end-load bearing) PE system is connected to any non end-load bearing mechanically jointed system. It is essential that such transitions are securely anchored, to obviate the risk of any joints in the mechanically jointed system separating. It is also prudent to allow a newly installed pipeline sufficient time to conform to ambient temperature before end connections are made.

Introducing expansion joints / expansion loops

i. Provision shall be made for thermal movement by fitting expansion joints or loops, unless the movement can be accommodated by other means, such as if the stack is free to move through a weatherproofed sleeve through the roof, or at a junction, bend or expansion loop in a graded pipeline where the thermal movement in the pipeline can be accommodated by deflection of the offset leg without affecting the grade of the pipeline.

ii. Pipes are anchored in interval sufficient to take care of expansion (refer fig 2.3.19). Expansion joints shall be supported at the socket section of the fitting by a fixed support.

iii. Care shall be taken to ensure that expansion fittings are correctly installed in accordance with the manufacturer's instruction and that the pipe is not bottomed in the expansion socket.

iv. Final connection / tie-in shall be done after the buried pipes temperature is stabilized.

v. As PE 100 pipe expansion coefficient is higher than other materials, PE 100 Pipes that will be exposed to a certain increase in temperature, will make snake like movements or will put pressure on the fixed point. Creating a lateral expansion loops / forming S –Curves (snaking) has been illustrated in Fig 2.3.20.

vi. Allowing controlled expansion/contraction to take place in one part of a piping system is an accepted means to prevent added stresses to rise to levels in other parts of the system that could compromise the performance of, or cause damage to the structural integrity of a piping component, or to the structure which supports the piping.

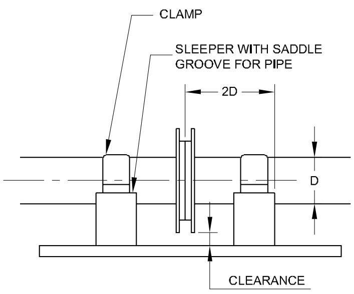


Fig. 2.3.16 Pipeline- supporting and clamping

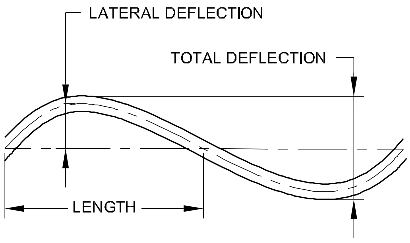


Fig. 2.3.17 Pipe forming S curve

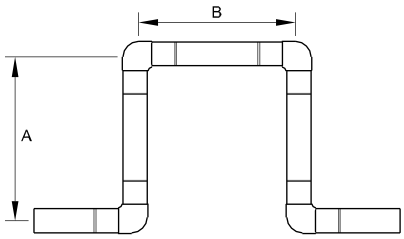


Fig. 2.3.18 Expansion loop

vii. Expansion joints are to be considered as permitted to take care of expansion.

viii. Everyone is familiar with the typical expansion loops (Refer Fig 2.3.21) that are periodically placed in long pipelines subject to wide temperature changes. These loops absorb cha nges in pipe length. They mute and redistribute the large stresses that would result if pipe thermal movements had been physically restrained. Similar measures for safely absorbing thermal expansion/contraction reactions need to be taken with thermoplastic piping systems.

Exercise

I. Answer the following questions.

1. Describe the effects of PE pipes expansion and contraction.

----

2. What are your recommendations to mitigate the effects of PE pipes expansions.

----

3. A 400 meter long pipeline section of 50 NB diameter HDPE pipe is left unrestrained overnight. If theinitial temperature was 42˚C, determine the change in length of the pipe section after a night time temperature of 28˚C.

II. State whether the following statements are True or False.

1. If PE pipe installed at 42˚C, and length measured again when the temperature is 25˚C, the pipe length will get decreased.

   True ☐ False ☐

2. Linear expansion of PE pipe will be approximately ten times greater than that of carbon steel pipe.

   True ☐ False ☐

3. Purpose of expansion loop in pipeline is to absorb change in pipe length, if any.

   True ☐ False ☐

4. In general, expansion loop will increase / induce stress in the pipeline, if not rigidly clamped or movement restrained.

   True ☐ False ☐

Notes

Unit 2.4 Preparing the Pipe

Unit Objectives

At the end of this Unit, you will be able to:

1. check and visually examine the PE pipe for any abrasions or damages
2. mark and cut the pipe in professional manner
3. check the scraper blade for its good condition and use safely
4. mark the pipe end insertion depth and perform preliminary scraping
5. preform mechanical scraping of PE pipe joining surface and hand scraping of leading edge and remaining line markings
6. safely handle and protect the PE pipe prepared fusion surfaces and edges.

2.4.1 Visual Examination, Marking and Cutting of PE Pipe

At the end of this topic, you will be able to:

1. check and visually examine the PE pipe for any abrasions or damages
2. mark and cut the pipe in professional manner
3. ensure cut end and edge squareness.

2.4.1.1 Examination of PE pipe material

PE Piping materials such as coupling / sleeve, pipe , saddle, socket, elbow, etc., shall be visually examined prior to surface preparation and cutting. The effectiveness of fusion joint depends on the preparation of joint for welding. Presence of abrasion, scratches, deep marks, dents, damages, etc., on joining faces / surfaces, may provide detrimental effects to the performance of the coupler and pipe fusion. To achieve perfect and sound joint, the following examination and verification are essential:

1 **PE pipe examination on receipt:** The selected pipe is to be dimensionally checked prior to surface preparation to ensure that correct pipe has been supplied. This verification shall include material, grade, diameter, thickness, ovality, identification and traceability, etc.

2 **Visual examination**

- All PE pipes shall be visually inspected for abrasions, damages or defects prior to installation.
- Prior to visual examination, mud and dirt, etc., shall be cleaned with water and wipe with lint free cloth.
- The pipe surfaces have to be visually checked within the fusion zone for unacceptable defects like severe toe-in (pipe end reverse), flattening, scratches or damage that will not be eliminated during mechanical scraping.
- Visually examine the pipe surface for any embedded debris that may cause damage to scraping tools, and once more make sure that the outer pipe surface is clean and free of any dirt or mud that could recontaminate the scraped pipe surfaces.
- The edge of pipe to be welded are visually inspected for damages, defects, dents, etc. The following are common surface damage at the edge of pipes.

i. Pipe edge bulged – This is caused due to improper handling, dropping of any weight on pipe edge. Cut the necessary length and remove damaged portion.

ii. Pipe edge scratch or abrasion mark – This is caused by dragging of edge on sand surface, poor handling during loading and unloading or storage, etc. Trainee must learn about careful handling of both edge and not to drag while handling at site. If the scratch is deep, cut the necessary length and remove the damaged portion.

Fig. 2.4.1 Pipe cleaning

Fig. 2.4.2 Pipe end without damage

Fig. 2.4.3 Damaged Pipe ends

2.4.1.2 Marking PE pipe to required length

If any unacceptable defect or damage is apparent in pipe ends, the pipe ends should be cut to remove the defective portion, at right angles with appropriate pipe cutter and if necessary, edge shave to be deburred.

If the full pipe length is to be used, the squareness shall be checked and cutting line shall be marked accordingly. The required length shall be marked on the pipe before cutting using permanent visible marker. Marks should be visible on the pipe colour being used. Caution should be taken to assure that a non-petroleum marker is used. For black pipe, a silver coloured or equivalent, permanent marker works well. The marker dries fast and contains no oils or other ingredients that could accidentally contaminate a prepared pipe surface.

Tips

Markers that are slow-drying or contain oils that could be spread onto fusion surfaces should not be used.

2.4.1.3 Cutting the pipe and ensuring pipe edge squareness

For the pipe cutting, a suitable cutter for plastics must be used. An improper cut can lead to the pipe ends being outside the cold zone in the coupler, which will result in excessive melt of the coupler.

For smaller pipes cutting, use a blade type pipe cutter or cutting saw. In general, pipe cutters like ratchet type-snap cutters, rotary cutters & eclipse saw can be used as per different ranges of diameters.

When using any pipe cutting equipment, care should be taken to follow the manufacturer's instructions and to wear the appropriate protective clothing. Any statutory regulations regarding cutting equipment must be adhered to. Cutting should be performed only by appropriately trained personnel.

Pipes can be cut using various tools, Appropriate / necessary cutting tool depending on pipe size to be cut, shall be used for cutting. (Refer Fig 2.4.5)

It is recommended to use an electric planer to face of the rough ends of the pipe so as to make them flat and smooth.

Mark the pipe with a pipe wrap and mark a square cut with a marker pen before cutting the ends. Failure to cut square ends could result in a "short stab" in which the pipe ends are not together in the cold zone. This would cause exposure of the electrofusion wires and create excessive melt and heat.

Do not allow the use of any lubricant on the cutting tool. Oil on the cutting tool will create a non-fusible barrier between the pipe and coupling which will lead to joint failure.

Make sure that the ends of the pipe are cut with a square or right angle cut. Cut edge shall be 90 degree to the pipe outer surface (right angle to the pipe axis). Check the squareness at various locations and diametrically opposite. The square-ness of the cut can be checked by placing a square at the end of the pipe at its longest point and measuring the resulting gap between the square and shortest point of the cut

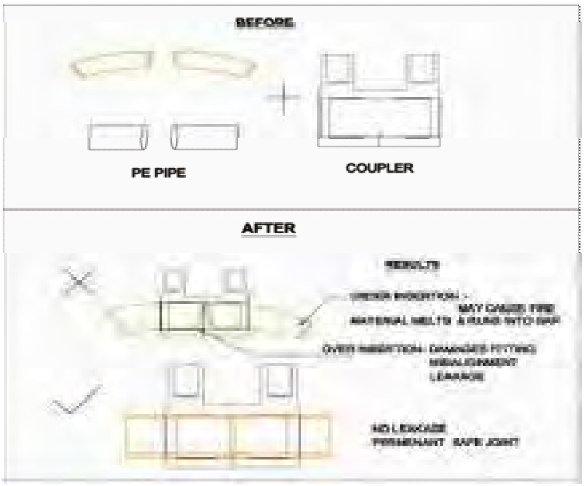


Fig. 2.4.5 Commencing cutting with tool

Fig 2.4.6 Checking squareness

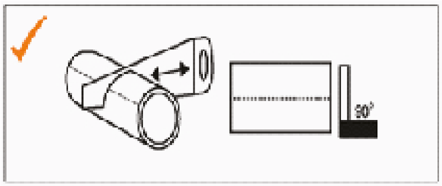


Fig. 2.4.4 Importance of cutting pipe end to square

Fig. 2.4.7 PE pipe cutting with hacksaw

If pipe end is not square cut, it could lead to too great an angle to allow the pipe end to cover the heating coil and cold zone is referred to as a "miscut" / improper fusion assembly as depicted in fig 2.4.8.

Fig. 2.4.8 Mis-cut assembly if pipe not cut to square

Exercise

I. Answer the following questions.

1. Describe all PE pipe examination requirements prior to preparing for installation.

----

2. Explain the process of marking and cutting of PE pipes.

----

3. Why is it important that pipe end / edges are to be cut square? How will you ensure the cut end / edge squareness?

II. State whether the following statements are True or False.

1. The effectiveness of fusion joint depends on the preparation of joint for welding.

   True ☐ False ☐

2. Failure to cut square ends could result in a "short stab".

   True ☐ False ☐

3. If PE pipe ends are not together in the cold zone, it would cause exposure of the electrofusion wires and create excessive melt and heat.

   True ☐ False ☐

Notes

2.4.2 Joining Surfaces, Scrapping and Marking Insertion Depth

At the end of this topic, you will be able to:

1. perform scraping using hand scraping tools and mechanical tools
2. deburr and prepare the joining edges
3. mark the insertion depth.

2.4.2.1 Marking length of scrapping

Proper insertion depth of a pipe end into an electrofusion coupling is required for successful fusion. Marks are needed to locate insertion depths and to use as a guide for pipe scraping effectiveness. Mark the pipe for stab insertion depth of couplings or the proper fusion location of saddles.

If stab depth marks are not indicated on the outside of the coupling, measure the total length of the coupling to be installed and make a mark on both pipe ends equal to ½ the length of the coupling. This mark is used as visual indication by the installer that the pipe ends are correctly inserted to the centre of the coupler.

Measure the coupling length =L. Mark scrapping length L/2 +10mm. Refer Fig 2.4.9.

Mark lines with permanent marker pen to ensure that the entire area is scraping is performed. Mark the entire pipe surface to be scraped with longitudinal and/or circumferential lines with permanent marker in multiple positions around the circumferences of pipe ends.

Fig. 2.4.9 Marking the scraping portion and insertion depth

2.4.2.2 Scraping tools and scraper blade checking

Proper pipe scraping is necessary to obtain proper melt characteristics of the pipe. During scraping, the outer oxidized layer of pipe gets removed and the cleansurface is available for electrofusion joining. It is recommended that a minimum of "0.2 mm to .5 mm" of the pipe's surface material should be removed during the scraping process in order to expose a clean virgin material.

The tools used for surface preparation are those that are specifically designed for electrofusion scraping and peeling. Make sure that the scraper blade is sharp. Unless otherwise specified, it is recommended to use a tungsten carbide blade. Scraper blade shall be checked and ensured that it is in good condition and it is the right blade to be used. Scraper blades should be free of damage such as knicks. Damaged or dull blades that do not peel the pipe properly, should be replaced.

2.4.2.3 Hand scraping with tools

Sand paper, emery cloth, or other abrasives should never be used to prepare a pipe surface for electrofusion. Abrasives have been proven to be ineffective for electrofusion because they do not adequately remove PE pipe surface material. They can redistribute contaminates on the surfaces and because they can leave behind a grit residue that forms another barrier that will also prevent fusion.

For removal of the oxidation layer from the pipe, use either a manual scraper tool with a tungsten carbide steel blade or a mechanical scraper tool. Wood rasps and metal files are not recommended (Fig. 2.4.10) due to inconsistent surface preparation and difficulty in mastering skills required for uniform surface preparation. Use the right hand scraping tool. Handle carefully with sharp edge of tools.

Carefully scrape the whole circumference of the pipe in the axial direction over t length using a hand scraper

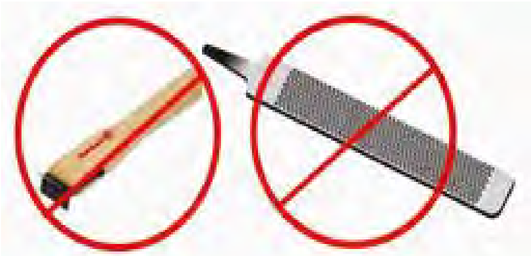


Fig. 2.4.10 Not Recommended hand tools for PE

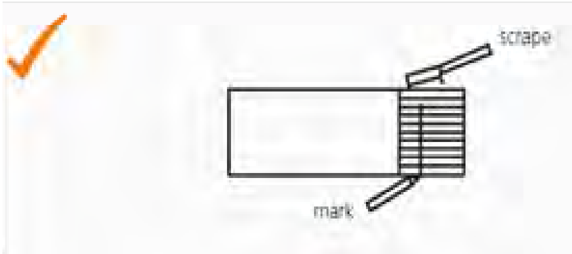


Fig. 2.4.11 Rotary scraping by hand tool

2.4.2.4 Mechanical scraping

Please note that mechanical scraper may take off approximately 0.5 mm of the pipe surface of the pipe diameter. (Refer Fig 2.4.12 & 2.4.13). Use a mirror to inspect while scraping underneath pipe surface. Scrape the pipes with rotary scraping tool until the outer surfaces of the pipes have been removed to expose a clean, virgin pipe material. Inspect the entire circumference of the scraped areas to ensure total scraping coverage. When rotary scraper is used, no second scrapping must be performed. (Refer Fig 2.4.11) Repeated scraping may be necessary, depending on actual pipe diameter till minimum chip removal has to be achieved. However, ensure that minimum allowable pipe diameter is maintained so as to avoidmore gap between the pipe and fitting.

Overscraping can increase the gap between the pipe and the coupler, especially for pipes with small diameters. If the gap is too large (>0.5 mm), there is a risk that no contact at all is formed between coupler and pipe after welding, with catastrophic result. The internal end and edge face of pipe must be deburred. Round off or bevel the outer edges of the pipe with a hand scraper, electric planer, or router. Fig 2.4.14 shows the pipe containing burrs and fig 2.4.15 shows the typical deburring operation.

Fig. 2.4.12 Preparation for scraping

Fig. 2.4.13 Preparation for scraping

Fig. 2.4.14 Preparation for scraping

Fig. 2.4.15 Preparation for scraping

Inspection of PE Pipe After Preparation By Scraping

Check and ensure that, scraping all around surface is complete. A properly scraped pipe may have a thin outer layer at the pipe surface, that is to be removed to expose clean virgin PE material for fusion. Visual indicators can be very helpful to ensure that all of the surface has been scraped, and that an adequate amount of surface material has been removed. Refer fig 2.4.16 for incorrect marking and scraping. Check and ensure that all scraping material has been removed. Check and ensure that pipe edge is chamfered and clean.

Fig. 2.4.16 Incorrect scraping

Marking insertion depth

The previous marking for scrapping shall have been removed, hence, the length L/2shall be marked as STOP point for insertion as discussed above. Refer Fig 2.4.17. Failure to insert the pipe end correctly can result in a loss of melt containment during the fusion process.A pipe end that is not inserted beyond the innermost heating wire is commonly referred to as being “short-stabbed” and is the result of an assembly error. If proper insertion depth is not marked, it could lead to

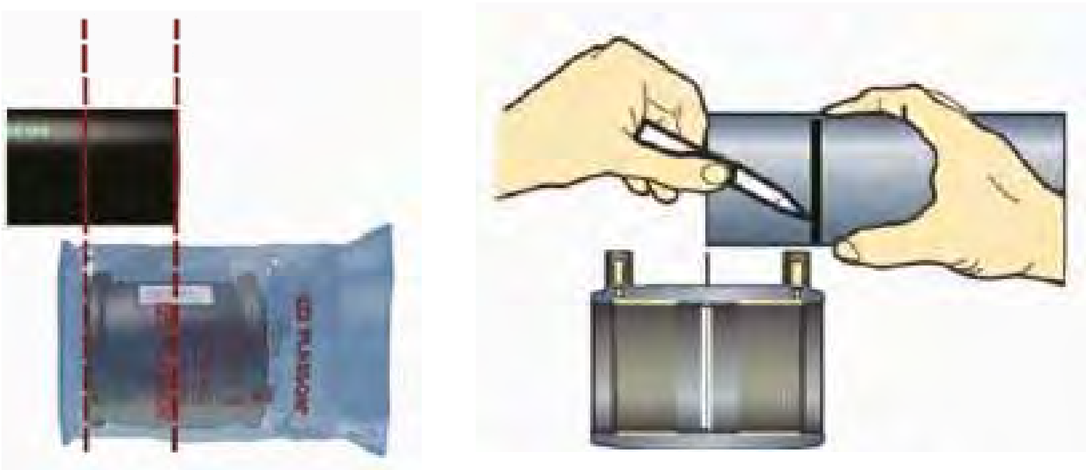


Fig. 2.4.17 Marking Insertion Depth

i. **Short Stab – Incorrect Assembly:** Assembly errors that can occur include “short-stab” conditions where the one or both of the pipe ends are not centred in the coupling (Refer Fig 2.4.18). This condition is avoidable by measuring and marking the stab depth on the pipe ends before inserting them into the coupling. If the pipe ends are not properly inserted, the melt generated during the fusion cycle will expand and flow over the end of the exposed pipe inside the fusion zone.

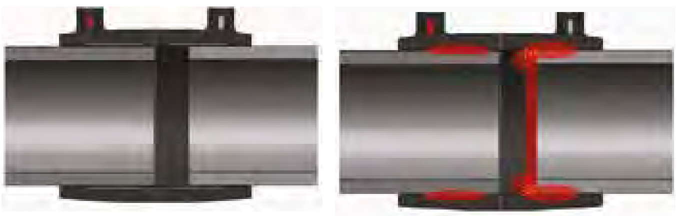


Fig. 2.4.18 Short stab – Incorrect assembly

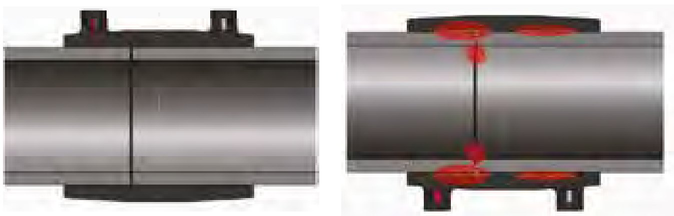


Fig. 2.4.19 Mis-stab – Incorrect assembly

ii. **Mis-Stab – Incorrect Assembly:** A mis-stab is another avoidable assembly error where the pipes are not located in the centre cold zone of the coupling. In this case, one pipe end is over-inserted into the coupling, while the other is under-inserted (Refer Fig 2.4.19). Melt again is allowed to escape between the pipe ends and the potential for heating coil shorting is likely.

2.4.3 Identify the Type of Flanges

At the end of this exercise, you will be able to:

1. mark, cut and prepare the PE pipe for electrofusion joining.

Practical

Requirements			
Tools/Instruments		**Materials/Components**	
Measuring Tape	– 1 No.	Electrofusion coupler – 2" Ø,	– 1 No.
Scale,Try-Square	– 1 No.	MDPE/HDPE pipe –2" Ø, 200 mm Long	– 2 Nos.
Vernier Caliper			
Marking Pin			
Marker	– 1 Set.		
Equipment/Machines			
Plastic tube cutter	– 1 No.		
Hacksaw			
Manual scraper			
Mechanical scraper			

Work instructions

1. Select the raw material MDPE / HDPE pipe according to the requirement and ensure that there is no damage / defect.
2. Check the diameter of MDPE / HDPE pipe using Vernier calliper.
3. Choose the electrofusion unit (EFU) and check whether it is working properly.
4. Cut the HDPE pipe with the help of plastic tube cutter or hacksaw as appropriate.
5. Deburr the sides / cutting edges of the pipe.
6. Cut edge shall be 90 degree to the pipe outer surface (right angle to the pipe axis) . Check the squareness at various locations and diametrically opposite.
7. If necessary, use an electric planer to face of the rough ends of the pipe so as to make them flat and smooth.
8. Do not allow the use of any lubricant on the cutting tool.
9. Check pipe ovality and ensure that difference in diameter does not exceed 3 % of diameter.
10. If ovality exceeds 3% of diameter, correct the ovality as required.
11. Preclean the pipe to avoid coupler contamination and insert the pipe into coupler ID. Mark the insertion depth line using appropriate marking pin.
12. Mark the entire pipe surface to be scraped with longitudinal and/or circumferential lines with permanent marker in multiple positions around the circumference of pipe ends.
13. Carefully scrape the whole circumference of the pipe in axial direction over length using a hand scraper.
14. Scrape the pipe using manual scraper about 10 mm beyond the insertion depth mark. Avoid over scraping.
15. Sand paper, emery cloth, or other abrasives should never be used to prepare a pipe surface for electrofusion.
16. Deburr the prepared surface again to remove the burrs resulted due to scraping.

17. Clean the dust and clean the prepared surface with acetylene. Use lint free cloth to wipe the surface during cleaning to absorb the acetylene.
18. Protect the cleaned surface using a polyethylene cover.

Tips

Safety: Never touch the pipe with hand after cleaning by acetone.

When using any pipe cutting equipment, care should be taken to follow the manufacturer's instructions and to wear the appropriate protective clothing & safety gloves.

Cutting should be performed only by appropriately trained personnel.

Exercise

I. Answer the following questions.

1. Explain the process of marking PE pipe scraping length with illustrations.

----

2. Describe hand scrapping and mechanical scraping of PE pipes for joining by electrofusion

----

3. Address the importance of marking and ensuring correct insertion depth with illustrations.

II. State whether the following statements are True or False.

1. Scraper blade shall not be sharp, as it not good for both pipe fitter and material

   True ☐ False ☐

2. Tungsten carbide blade shall not be used for PE pipe scraping.

   True ☐ False ☐

3. Wood rasps and metal files are recommended due to consistent surface preparation and difficulty in mastering skills required for uniform surface preparation.

   True ☐ False ☐

4. It is recommended to carefully scrape the whole circumference of the pipe in circumferential direction using hand scraper.

   True ☐ False ☐

5. Short stab result from assembly error.

   True ☐ False ☐

2.4.4 Handling Protection of Joining Surfaces and Pipe Ends

At the end of this topic, you will be able to:

1. clean the PE joining surfaces effectively
2. handle PE pipes duly avoiding any fusion surface contamination
3. protect the PE pipe surfaces after scraping.

2.4.3.1 Cleaning and handling of prepared PE pipe surfaces

Pipe surfaces must be dry during joining / fusion process. If contamination is present on the pipe or coupler, it will be very difficult to achieve effective fusion. Hence, cleaning and protection of scraped surface is essential.

Clean the surface with isoproply solution with lint free wipes. The prepared pipe must be degreased with a suitable cleaning agent and a white absorbent and non-fibrous / lint free cloth prior to joining.

Fig. 2.4.20 Avoid finger print

2.4.3.2 Protecting PE pipe cleaned surface

The finished and cleaned surfaces must be protected against ingress of dirt, moisture or water, contamination and unfavourable weather conditions duly covering with dirt free cover. Make sure that any possible moisture, dew or frost is removed prior to covering. Refer fig 2.4.21. Avoid cross-contamination of the pipes from outside of the scraped zone. (refer fig 2.4.20)

Avoid possible recontamination of the prepared surfaces (these should not be touched with bare hands due to body oils) as this could affect the jointing quality. Do not touch the surface as the finger marks will leave sweat mark on surface and cause improper fusion. The operator should wear clean cotton gloves to ensure the cleaned surfaces don't come in contact with bare hands or any equipment/debris. To avoid coupler inside get exposed to dirt, the original cover shall not be removed during handling until insertion takes place. Care is to be given to protect outer and inner sufaces. During installation, protection from rainfall and intense sunlight shall be performed. For example, by installing tent as shown in fig 2.4.22. Use of protective shelters, prevents additional contamination entering the jointing area. If there is ground water, pumping out ground water from the working pit is a necessary precautionary measure. Open pipe ends should be sealed before starting and after completing the installation process, to prevent contamination, entry of any objects and draft through the pipeline.

Fig. 2.4.21 Protecting PE pipe scraping surface

Fig. 2.4.22 Protecting fusion area with tent

Exercise

I. Answer the following questions.

1. Explain the PE pipe handling requirements and cleaning process after scraping completion.

----

2. Describe the protection requirements of scraping surfaces after scraping and during installation.

II. State whether the following statements are True or False.

1. After PE pipe surface scraping with isoproply solution with lint free wipes is permitted.

   True ☐ False ☐

2. The PE coupling / sleeve cover should not be removed during handling until insertion takes place.

   True ☐ False ☐

Notes

2.5 PE Pipe Manual Butt Fusion Welding Procedure

Unit Objectives

At the end of this unit, you will able to:

1. apply correct method of tightening the pipe clamps to grip and reround the pipes
2. perform pipe end shaving and trimming with appropriate tool and techniques
3. check the trimmed face for squareness / single uniform plane
4. perform pipe fitting without or within permissible limits of mismatch by properly and effectively closing the clamps
5. check to ensure no visible gap is there between the trimmed faces
6. perform manual butt fusion welding with heat plate.

2.5.1 Instruments, Tools and Equipment For PE Pipe Butt Welding

At the end of this topic, you will be able to:

1. Identify PE pipe butt- fusion joining
2. recognise various instruments, tools and equipment required for butt-fusion joints fitup and fusion
3. choose the required tools, instruments and equipment for butt-fusion joints fitup and fusion.

2.5.1.1 Introduction to Manual Batt Fusion Welding of PE pipe

This unit describes procedures for making joints with polyethylene (PE) pipe and fittings by means of heat fusion joining. Manual butt fusion welding is a thermo fusion process by simultaneously heating both ends until melting stage is attained at both ends of contact surface. The two surfaces are brought together by controlled pressure for specific cooling time and homogeneous fusion is formed upon cooling.

Butt fusion – welding should be used only for jointing pipes of the same SDR value.

The City Gas Distribution piping installation company is responsible for the joining of polyethylene pipe and fittings. It shall ensure that detailed procedures developed in conjunction with applicable codes and regulations and the manufacturers of the pipe, fittings, and joining equipment involved, including the safety precautions to be followed, are issued before actual joining operations begin. Types of items, which can be joined by butt fusion welding process are – pipe to pipe, pipe to elbow, pipe to fittings.

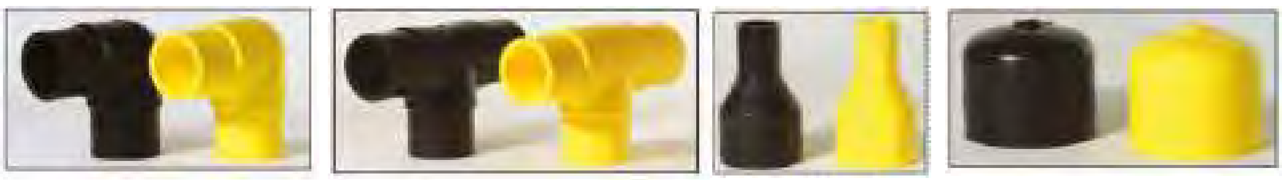


Fig. 2.5.1 Pipe Fittings

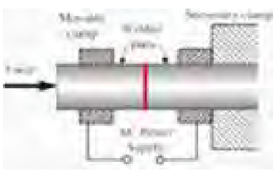


Fig. 2.5.2 Typical Butt Fusion Method

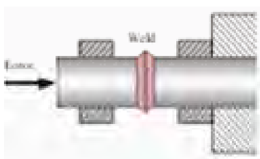


Fig. 2.5.3 Butt Fusion Joining

2.5.1.2 Instruments

Temperature indicator: Heating tools shall be equipped with a thermometer or other built-in temperature indicating device. This device indicates the internal temperature of the heating iron, which is usually higher than temperature of the heating tool surfaces.

Digital thermometer with surface probe.

Pyrometer: Use a pyrometer, or other temperature measuring device, on the first joint of the day and periodically during the day to verify the temperature of the tool face surfaces within the pipe or fitting contact area. Select multiple checkpoints to ensure uniform surface temperature.

2.5.1.3 Tools and equipment required for butt welding

Each fusion procedure requires specific tools and equipment to do the job properly. Using poorly maintained, damaged, or incorrect tools and equipment can cause a poor fusion, and may be hazardous. Use only the correct tools and equipment for the job. Do not use defective or improper tools or equipment. Follow the equipment manufacturer's procedure for equipment maintenance. The fusion operator must be proficient in tool and equipment use and operation, and proficient in fusion procedure.

Fig. 2.5.4 Pipe Support with Movable Clamp

Fig. 2.5.5 Typical Pipe and Clamp

1. Clamps

Types of clamps

i. Hand operated for pipes up to 74 mm OD

ii. Hydraulic operated – lever type or automatic programmed.

The clamp is used to hold one end of fixed pipe edge and other end is moved on guide rod by hand, mechnical lever or by hydraulic.

Tips

Pipe Fitter / operator shall recognise various types to select or request the right clamp for the pipe to be joined.

2. Shaving machine

Shaving machine is used to trim edges. When operated with both edges together, it creates a parallel surface to join. The shaving machine is available invarious sizes to suit the pipe size. They are mostly supplied as a set along with clamping set with locking arrangement.

The tool adapter arrangement allows to change the shaving blade as and when required. Similar to shaving blade changed at saloon, the blade shall be inspected and changed frequently.

Fig. 2.5.6 Shaving Machine

Fig. 2.5.7 Heating Plate

3. Heating plate

Electric heating plates maintain consistent fusion temperatures when provided with an adequate power source.

Heat plate generates necessary heat for fusion when placed in between two edges to be welded. Similar to shaving tools, heating plate is supplied along with clamp to suit clamping machine locking arrangment.

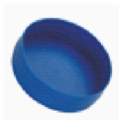
The heater sets are avaiable in different diameters to suit the diameter of the pipe, operator to select right heating plate.

4. **Pipe support rollers / stands:** Pipe support stands or racks are used to support the pipe at both ends of the butt fusion machine to assist with pipe loading and alignment.

5. Generator with proper electrical control panel

The minimum power supply required shall be calculated based on SDR and heater size which is normally, 7.5 KVA single phase supply.

6. Butt fusion machine



Butt fusion machines are operated manually or hydraulically. Some have their own power supply and some require a separate generator. They are available in a variety of sizes to fuse pipe and tubing produced to ASTM and other industry specifications.A Butt fusion machine has three basic parts:

- a stationary clamping fixture and a movable clamping fixture for aligning and holding each of the two parts to be fused. This may or may not include the power supply to operate the machine.
- a facer / trimmer for simultaneously preparing the ends of the parts to be joined.
- appropriate inserts for clamping different pipe sizes or fittingshapes.
- Traditionally for manual machines a data plate, coloured blue for water and yellow for gas are permanently attached to the machine indicating thenecessary fusion parameters.

7. **Facer:** A facer is a rotating cutting device used to square-off the pipe or fitting ends to obtain properly mating fusion surfaces. If so equipped, facing should continue until a positive mechanical stop on the butt fusion machine is reached.
8. Internal and external debeading tool, pipe cutters and bead gauge are also essential.

Exercise

I. Answer the following questions.

1. What are the common tools and accessories required for PE pipe butt–fusion jointing?

----

2. Name any five equipment required for PE pipe butt fusion joining related activities.

----

3. What is the basis for PE pipe clamps selection for butt–fusion weld?

----

4. Describe butt–fusion machine and heater plates.

II. State whether the following statements are True or False.

1. Manual butt fusion welding is a thermo fusion process.

   True ☐ False ☐

2. Butt fusion welding should be used only for jointing pipes of the same SDR value.

   True ☐ False ☐

3. Elbows cannot be joined by butt fusion weld process.

   True ☐ False ☐

4. Shaving machine is used to trim edge.

   True ☐ False ☐

Notes

2.5.2 Butt Fusion Welding Procedure and Personnel Performance Qualification

At the end of this topic, you will be able to:

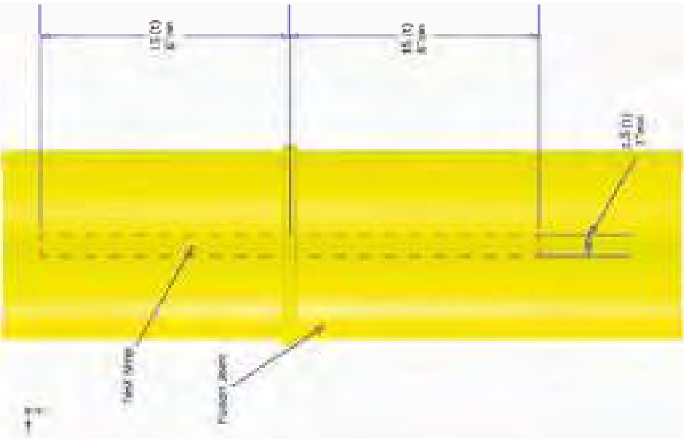
1. determine the requirements for procedure and personnel qualifications and gain knowledge of PE pipe butt fusion procedure and performance qualification
2. prepare yourself for PE pipe butt fusion joining performance qualification and certification
3. get trained in butt fusion joint fitup / assembly and butt – fusion welding
4. describe the procedure for qualification joints preparation and to perform butt – fusion.

2.5.2.1 Butt fusion procedure qualification

Butt fusion joint procedure shall be qualified as per applicable codes / standards / specifications with guidance of manufacturer instructions. Refer the subsequent sections and topics as guideline and prepare and procedure qualification test. The following summarizes the ASTM methods to which the operator and/or user should refer for specific qualification requirements.

- Prepare a sample joint. Pipes on either side of the joint should be at least 6” (150 mm) or 15 times the wall thickness in length.
- Dirty or contaminated, or poorly prepared surfaces that do no mate together properly cannot produce a quality fusion. Clean and prepare the surfaces before joining. If contamination is reintroduced, clean the surfaces again.
- Observe the joining process to determine that the correct procedure is being followed.
- Visually inspect the sample joint for quality.
- Allow the sample to cool completely, for not less than one hour.
- Cut the sample joint lengthwise along the pipe into at least three straps that are at least 1” (25 mm) or 1.5 wall thicknesses wide and prepare the sample. It is recommended that four equally spaced strips be cut, one from each quadrant of the pipe.

- Visually inspect the cut joint for any indications of voids, gaps, misalignment or surfaces that have not been properly bonded. There should be no gaps, voids, misalignment or unbonded areas.
- Bend each sample at the weld with the inside of the pipe facing out until the ends touch. The inside bend radius should be less than the minimum wall thickness of the pipe. In order to successfully complete the bend back, a vice may be needed.
- The sample must be free of cracks, voids and separations within the weld location.
- If failure does occur at the weld in any of the samples, cut another sample adjacent to the position the failed sample came from and retest. If the second sample fails, then the fusion procedure should be rejected, reviewed again and revised.
- After necessary correction and revision, another sample fusion should be made per the new procedure and re-tested and qualified successfully.



Sample EPS Format

<table>
<tr><td colspan="2">Organization: Location:
BPS/QR NO : Rev: Date :</td></tr>
<tr><td colspan="2">BASE MATERIAL:
Pipe1 Manufacturer: Pipe dia & Tk: SDR:
Pipe2 Manufacturer: Pipe dia & Tk: SDR:
Fitting Manufacturer: Fitting dia & Tk: Rating:
Qualified Dia Limit / Range : Qualified SDR Range:</td></tr>
<tr><td>Butt fusion Unit
Make:
Model:
Rating / Range:
Power Supply:
Voltage & Amps:</td><td>Hot Plate
Dimentions:
Type of Contract Surface:
Type of Heating System:
Type of Temperature Control Device:
Type of Temperature Measurement:
Capacity (W/ square cm) :</td></tr>
<tr><td>Pipe Preparation
Pipe cutter used:
Squarenss:
Prelceaning solution:
Scraping tool used:
Ovality:
Final cleaning:</td><td>Pipe & Fitting Assembly
Tools & Equip used:
Re-rounding:
Pipe & Fitting fitup:
Interface Gap:
Clamping:
Type of Pressure device:</td></tr>
</table>

Butt-fusion Operation (Actual Values)	Inspection & Testing
Temerature & Humidity: Joint Position: Plate temperature: Heat up force: Full heating force: Full heating time: Plate withdrawal Time: Changeover time: Pressure raising Time: Welding force: Welding time: Cooling duration:	Operator Name: Operator Number: Visual: Accepted / Rejected Pressure Test: Accepted / Rejected Bend Test Accepted / Rejected

2.5.2.2 Operator training and qualification guidelines

1. Testing knowledge and skill of butt-fusion pipe fitter / operator competence

Skill and knowledge on the part of the operator are required to obtain a good quality joint. This skill and knowledge is obtained by making joints in accordance with proven procedures under the guidance of skilled operators. Evaluate operator proficiency by testing sample joints.

2. Typical and simple butt-fusion performance qualification certificate model:

PE PIPE BUTT-FUSION JOINTING CERTIFICATE

Name Of Fitter / Operator: Certificate Number:

Identification No / Code: Certification Date:

Reference BPS Number:

Employer: Location:

This is to certify that the above mentioned butt-fusion pipe fitter / operator has undergone training and demonstrated his / her ability in the following techniques and deemed competent and qualified as per ASME B31.3 and ASTM D 2657.

Butt-fusion Joints Types:

PE Pipe & Fitting Material:

Diameter and SDR range:

-- --

2.5.2.3 Trial fusion

A trial fusion, preferably at the beginning of the day, is to be performed to verify fusion procedure and equipment settings for the actual jobsite conditions. Normally, during each day of butt fusions to be made, the first fusion shall be a trial fusion in the presence of inspector.

Trial fusion shall be performed as per approved BPS and approved procedure. The following shall apply:

i. Pipe and fitting surfaces must be clean and properly prepared.

ii. Heating plate surfaces shall be inspected for cuts and scrapes and shall be free of dirt and residue. Heater surfaces should be between 400˚F (minimum) to 450˚F (maximum).

iii. Measure the temperature @ 12:00,3:00, 6:00 and 9:00 o'clock positions using a pyrometer of infrared the rmometer at locations where the heating plate will contact the pipe/fitting ends.

iv. The maximum temperature difference between any two points on a single heating surface must not exceed 24˚F. If this temperature is exceeded, the heating plate shall be cleaned per the manufacturer's recommendations.

Allow trial fusions to cool completely before cutting straps and testing by bending straps until the ends touch.

ASTM F2620 specifies test specimen dimensions for bent strap testing for pipes having a wall thickness of 1" (25mm) or less. The full wall side bending is recommended for wall thickness greater than 1". Bent strap test samples may be bent back on themselves or twisted through 180 degrees. If the sample breaks at the location of the fusion, this is an indication that the appropriate conditions were not established to permit satisfactory fusion to occur. It is a 'qualitative measure' only and requires experience on the part of the operator/technician, to properly evaluate the efficacy of a fusion weld.

The fusion or test section shall be cut out for inspection after cooling completely.

The test section shall be 12" or 30 times (minimum) the wall thicknessin length and 1" or 1.5 times the wall thickness in width (minimum).

The joint shall be visually inspected as to continuity of "beads" from the melted material, and for assurance of "cold joint" prevention (joint shall have visible molded material between walls of pipe). Joint spacing between the walls of the two ends shall be a minimum of 1/16" to a maximum 3/16". Pressure test is not required for trial run joint.

Exercise

I. Answer the following questions.

1. Describe the training and examination requirements for qualifying pipe fitting / operating personnel.

----

2. Describe the required test procedure and acceptance criteria for butt fusion procedure qualification.

----

3. How will you perform trial fusion and the required tests?

II. State whether the following statements are True or False.

1. Trial fusion is to be performed to verify fusion procedure and equipment settings for the actual jobsite conditions.

   True ☐ False ☐

2. PE pipe procedure qualification test specimen shall be tested for tensile strength.

   True ☐ False ☐

3. Trial test specimen shall be pressure tested.

   True ☐ False ☐

Notes

2.5.3 PE Pipe Butt Fusion Planning and Preparation

At the end of this topic, you will be able to:

1. plan the PE pipe installation by butt fusion method
2. prepare the site for PE pipe joining by butt fusion welding process
3. control and maintain heating plate / tool properly.

2.5.3.1 Butt-fusion joining planning

Approved procedure shall be in place. Do understand the principles of butt fusion (refer to pipe manufacturers/ machine suppliers guidelines, if necessary). Adequate trained and approved personnel shall be employed for butt fusion process.The Pipe fitter / operator is to be trained and certified as per the applicable standard / code and specification requirements. Read the machine manual and understand its working. Ask supervisor to explain all function, if in doubt. The pipe fitter / operator has to familiarize the SDR, heating temperature, cooling time as per written butt fusion procedure (BPS) and note in record sheet . Pipe with different SDR shall not be joined by butt fusion process.

2.5.3.2 Preparation for PE pipe manual butt welding

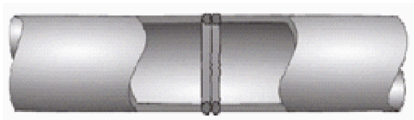


Fig. 2.5.8 Correct Same SDR

Fig. 2.5.9 Incorrect different SDR

As discussed earlier, the butt-fusion procedure in its simplest form consists of heating the squared ends of two pipes, a pipe and a fitting, or two fittings by holding them against a heated plate, removing the heater plate when the proper melt is obtained. This promptly bring the ends together. Allowing the joint to cool while maintaining the appropriate applied force is needeed. An appropriately sized butt fusion machine is used to clamp, align and face the pipe or fitting ends and to apply the specified fusion force.

i. Pre-joining checks

Inspect pipe lengths and fittings for unacceptable cuts, gauges, deep scratches or other deleterious defects. Damaged products should not be used. Remove surface damage at pipe ends that could compromise the joining surfaces or interfere with fusion tools or equipment. Pipe and fitting surfaces where tools and equipment are fitted must be clean and dry. Use clean, dry, non–synthetic (cotton) cloth or paper towels to remove dirt, snow, water and other contaminants. Pipes must be correctly aligned before making connections.

ii. Preparation of Butt Fusion

Use equipment that is clean, in good condition and regularly maintained. Ensure that the correct jointing parameters for the machine type and pipe are known. Check if the heater plate is clean and dry. Check that the trimmer is clean and that the blades are not damaged and are in the correct position for the required pipe size. Ensure clamp liners and securing screws are of the correct size. Ensure the generator is in good condition and has sufficient fuel.

iii. Cleaning

Clean inside, outside and the ends of components (pipe to pipe or pipe to fitting) to be joined and welded using water for mud and dirt. Wipe out gently using clean lint free non-synthetic cloth such as cotton and dry it. Remove all foreign matter from the piping component surfaces where they will be clamped in the butt fusion machine.

If the contamination cannot be removed this way, wash the pipe with water and a clean cloth or paper towel to remove the contamination. Rinse the pipe with water and dry thoroughly with a clean, dry, lint-free, non-synthetic cloth such as cotton or paper towel.

iv. Clamping and supporting

All piping shall be supported, guided, and anchored in such a manner to prevent damage to the piping. Point loads and narrow areas of contact between piping and supports shall be avoided. Suitable padding shall be placed between piping and supports where damage to piping may occur.

- Take measurements and check OD/Thickness on both ends and measure ovality.
- Select correct size of clamp suitable to OD of pipe.
- Check the correct size of clamp or replace with correct size and see the clamp area is clean, the clamp which is pressing the OD of pipe shall match.

Clamp ID = OD of pipe

- Place the clamping device on level surface.
- Place pipe support stands at both ends of the butt fusion machine and adjust the support stands to align the pipe with the fusion machines centerline.
- Install the pipes or fittings being joined in the stationary and movable clamps of the butt fusion machine.
- Leave enough pipe protruding through the clamps to allow for facing and clamp the pipe or fitting in the machine.
- Connect all electrical wires as per scheme with control panels. Follow and check safety precautions.
- Tent or closure is required if wind is more.
- Load the pipe on pipe support on both side levels to clamping device. If the pipe has any branch connection, ensure the marking direction is followed.
- Clean around the pipe edge using lint free cloths Before clamping, ensure no foreign material is in clamp and pipe.

Method of tightening pipe on clamps:

i. Load the pipe on clamp projecting around 10-15 mm away from clamp face from welding edge.

Fig. 2.5.10 Pipe Clamping

ii. Take care when placing pipe or fittings in the butt fusion machine. Pipes shall be aligned before the alignment clamp is closed.

iii. Do not force the pipe into alignment by pushing it against the side of an open butt fusion machine clamp.

iv. Heating plate / tool control and maintenance

Heating tool faces have non-stick coatings for quick, complete release from melted polyethylene. Dirty or contaminated heating tool faces can cause poor fusion, and damaged coatings may not release properly from the melt. Use a pyrometer or infrared thermometer to check for uniform temperature across both of the component contact surfaces. (Temperature indication crayons are not preferred. If used, temperature-indicating crayons must never be applied to a surface that contacts a pipe or fitting.) Uneven temperature may indicate a faulty heater. The heater thermometer measures the internal temperature, which is usually higher than surface temperature. However, heating tool temperature can be verified by checking the thermometer to ensure that the heating tool is maintains the temperature.

Exercise

I. Answer the following questions.

1. Describe the planning and prepration requirements for PE pipe butt fusion joining requirements.

----

2. List out the pre-joining requirements of PE pipe butt fusion welding.

----

3. How will you control and maintain heat plate / heating tool?

II. State whether the following statements are True or False.

1. Non-stick coatings in heating plate faces shall be removed prior to commencing assembly and heating.

   True ☐ False ☐

2. The heater thermometer measures the internal temperature, which is usually lower than the surface temperature.

   True ☐ False ☐

Notes

2.5.4 Trimming and Aligning

At the end of this topic, you will be able to:

1. cut the PE pipe and prepare for butt fusion
2. perform pipe face trimming / facing
3. correct joint mismatch if any.

2.5.4.1 Out of roundness correction / pipe re-rounding

Check the pipe ends for high-low alignment and out-of-roundness. Correct out off roundness.

After clamping, if adjustment is needed, adjust the high side down by tightening the high side clamp. Do not loosen the low side clamp as slippage may occur during fusion. The clamp is to be tightned so that it is seated properly inside the clamp ID. This will make the pipe round.

2.5.4.2 Trimming / facing

To perform effective and efficient trimming, pipes shall be placed in the correct postion and orientaiton with ends against trimming tool with uniform paralallity and aligned in the axis without lateral or angular offset. This will help to ensure uniform trimming without any surface wearness / ireegularities.

Cut the end of the PE pipe to square. Chamfer the pipe end for sizes 1¼” inch diameter and larger. (Chamfering of smaller pipe sizes is acceptable and sometimes specified in the instructions.)

Face the piping component ends until the facer bottoms out on the stops and is locked between the jaws to establish clean, parallel mating surfaces between the pipe/ fitting ends.

Place the trimmer into the gap between pipe. Hold the guide rod of the machine and lock.

Ensure that trimmer is not touching the face of pipe. Then switch on the trimmer and close the clamps.

Slowly move the mechanical handle or hydraulic lever towards trimmer and apply slight pressure such that pipe ends are moved against the trimming tool. The trimmer start shaving the pipe edge.

Trim / face both edges to establish smooth, clean, parallel mating surfaces.

Move the carriage to separate the pipe ends from the facer, remove the facer and all shavings and debris from the facing operation by brushing away with a clean, dry, lint-free, non-synthetic cloth such as cotton. Bring the pipe/fitting ends together at facing pressure.

Remove scraps, burrs, shavings, oil or dirt from the surfaces to be joined. Ensure to remove loose shavings from the machine and component ends.

Clamp the cold ring on the pipe the proper position, using the integral depth gauge pins or a separate (thimble type) depth gauge. The cold ring will assist in re- rounding the pipe and provide a stopping point for proper insertion of the pipe into the heating tool and coupling during the fusion process.

If the trimmer is struggling, loosen the pressure and apply pressure again and repeat this sequence until both ends are trimmed to perfect square. Slowly release the pressure before switching OFF to keep trimming tool turning while opening.

Ensure to keep the trimming tool turning whilst opening the clamps to avoid steps on the trimmed surfaces.

Method of trimmer removal

i. Alternatively, once the trimmer completely is stopped, open the cage and remove the trimmer with care without touching the trimmed end.

ii. While removing, make sure the shaving blade (tool’s face) does not touch the cut edge and trimmed face. Mishandling or forced removal will make mark on cut edge.

Fig. 2.5.11 Stopping the Trimming

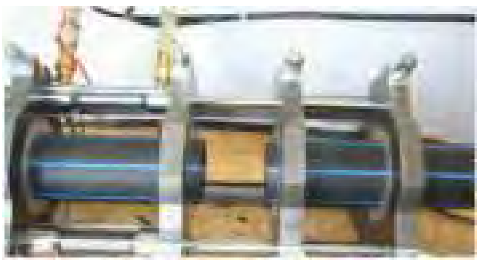


Fig. 2.5.12 Moving PE pipe side way

2.5.4.3 Cleaning the edge burrs

Clear the shaved burrs / loose shaving materials around the cut edge. Be careful and use proper gloves. Do not touch the cut edge with bare hands as it will leave the finger sweat on edges. After the pipe ends are faced and aligned, bring the pipe ends together to prevent dirt and other contaminates from blowing onto the fusion surfaces. Keep the pipe ends together until you are ready to install the heater for the butt fusion process.

2.5.4.4 Gap in joint

Ensure to close the clamps and check that there are no visible gaps between the trimmed faces. Bring the moving clamp to the edge of the pipe and check any visual gap. The gap shall not exceed 0.5 mm for pipe diameter up to 355 mm and 1.00 for pipe diameter above 400 mm. If any visible gap is seen, repeat the trimming operation.

2.5.4.5 Mismatch correction and final re-rounding

Check any mismatch of PE butt fusion joining pipe, using gauge. The maximum permitted mismatch is 10% of pipe thickness.

i. Thickness x0.1 = max permissible mismatch.

ii. Maximum mismatch 1mm for pipe diameter size 90 to 315 mm and 2mm for pipe diameter sizes 316 mm to 800 mm.

iii. If mismatch is greater than the above values, then the pipe must be realigned and re-trimmed. Adjust the clamp pressure. Re-round the pipe and bring it within tolerance.

iv. During alignment checking, the hydraulic system takes some pressure for movement. The operator make note of initial pressure (called alignment pressure)P1. Operator has to note the initial point and mostly it is based on experience and hand feel of operator.

2.5.4.6 Preventing air flow through PE pipes

Since the cooling rate is critical and decides good homogeneous weld joint soundness and integrity, pipe ends are to be closed with pipe cap to avoid wind flow through pipe.

If pipe ends are open, the outside air will cool the heating plate by internal draughts and create a non- uniform heating. Hence non–uniform joining faces melt duly affecting the butt fusion joint is soundness.

Exercise

I. Answer the following questions.

1. How will you prepare the PE pipe faces by trimming?

----

2. Will you remove the trimmer from PE pipe faces after trimming?

----

3. What are the permissible limits of PE pipe butt fusion joint mismatch and how will you correct the mismatch, if any?

II. State whether the following statements are True or False.

1. Maximum permitted PE butt fusion joining mismatch is 10% of pipe thickness.

   True ☐ False ☐

2. The required gap between the PE pipe joining face is 2 mm to 3 mm.

   True ☐ False ☐

Notes

2.5.5 Butt-fusion Joining Process, Heating and Welding

At the end of this topic, you will be able to:

1. verify the joint preparation
2. perform PE pipe butt-fusion joint fitup.

2.5.5.1 Setup Parameters

1. Heating Tool Surface Temperature

In general, heating tool surface temperature is 425°F ± 25°F (218°C ± 14°C). Heating tool surfaces must be brought up to the required temperature before fusion begins. Prior to starting, all points on both heating tool surfaces where the heating tool surfaces will contact the pipe or fitting ends must be within the prescribed temperature range. The temperature difference between any two points on the heating tool fusion surfaces must not exceed 20°F (11°C) for equipment for pipe smaller than 18 in (450 mm) diameter, or 35°F (19°C) for larger equipment. When the properly heated mating surfaces are brought together, the force required to make the joint is the force that is necessary to roll the fusion melt beads over to the pipe surface. This is visually determined.

2. Interfacial and hydraulic gauge pressure

In general, interfacial pressure range is to be minimum 60 psi and maximum 90 psi. The required interfacial pressure is used as the basis for calculating applied force (measured using a torque wrench) for a manual machine. Interfacial pressures vary based on whether the pipe wall is considered 'heavy' (1.5") or not. The correct hydraulic fusion joining pressure settings are calculated based on the type of butt fusion machine as well as the pipe OD and DR.

Tips

Interfacial pressure and the hydraulic gauge pressure are not the same.

Interfacial pressure is used to calculate fusion joining gauge pressure value for hydraulic butt fusion machines or manual machines equipped with force reading capability.

The interfacial pressure is constant for all pipe sizes and all butt fusion machines. However, fusion joining gauge pressure settings are calculated for each butt fusion machine, which is dependent upon the outside diameter (OD) and dimension ratio (DR) and the piston area of the fusion machine.

For manual machines without force reading capability, the correct fusion joining force is the force required toroll the melt beads over until they contact the pipe surface as required by the joining procedure.

When joining pipes with different melt properties, such as bimodal MDPE to unimodal MDPE, apply sufficient force to make the bimodal pipe fusion bead roll back and contact the pipe surface. Bimodal MDPE has a lower melt flow ratio than unimodal pipe.

2.5.5.2 Setup / alignment

Clean the inside and outside of the pipe or fitting (components) ends by wiping with a clean, dry, lint–free cloth or paper towel. Remove all foreign matter. An interfacial pressure (IFP) of 60 to 90 psi (0.41 to 0.62 MPa) is used to determine the force required to butt fuse the pipe components. For manually operated fusion machines, enough force should be applied to roll the bead back to the pipe surface. Align the components in the machine using support rollers, place them in the clamps, and then close the clamps. Do not force pipes into alignment against open fusion clamps. The pipes shall be levelled using sprit level.

Ensure to open and then close the clamps and note the drag pressure needed to move the pipes together using hydraulic system. This will help to quicken the process and to minimise the changeover timing. Bring the ends together and check alignment and check for slippage against fusion pressure. Look for complete contact around both ends with no detectable gaps, and outside diameters in correct alignment or within permissible limit of misalignment.

If necessary, adjust the high side by tightening the high side clamp. Do not loosen the low side clamp because components may slip during fusion. Re-face, if high low alignment is adjusted.

2.5.5.3 Heating

Heating of both surfaces to be joined and assembly of these surfaces shall produce a continuous homogeneous bond between them. It shall produce a small fillet of fusedmaterial at the outer limits of the joint.

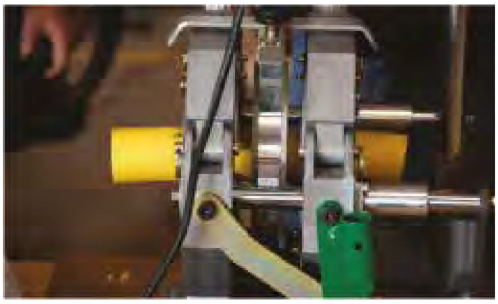


Fig. 2.5.13 PE pipe and hot plate arrangement

Table 1: Melt bead sizes for corresponding pipe sizes

Pipe (OD) [Outside Diameter, in. (mm)] heater plate.	"A" Minimum Bead Size, in. (mm). Measured from the
<2.37 (60) 1/32 (1)	
≥ 2.37 (60) ≤ 3.5 (89)	1/16 (1.5)
> 3.5 (89) ≤ 8.62 (219)	3/16 (5)
> 8.62 (219) ≤ 12.75 (324)	1/4 (6)
> 12.75 (324) ≤ 24 (610)	3/8 (10)
> 24 (610) ≤ 36 (900)	7/16 (11)
> 36 (900) ≤ 65 (1625)	9/16 (14)

Briefly ensure full contact between piping component ends and the heating tool. Then reduce the pressure to drag pressure but without breaking contact between the piping component ends and the heating tool. (On larger pipe sizes, (14 in. and larger) hold fusion pressure until a slight melt is observed around the circumference of the pipe or fitting before reducing the pressure.This normally varies from about 10 s on 14 in. pipe to greater than 2 min on 36 and larger pipe sizes.)

The hraph in Fig. 2.5.14 explains the process of heating, holding and pressurizing with respective durations.

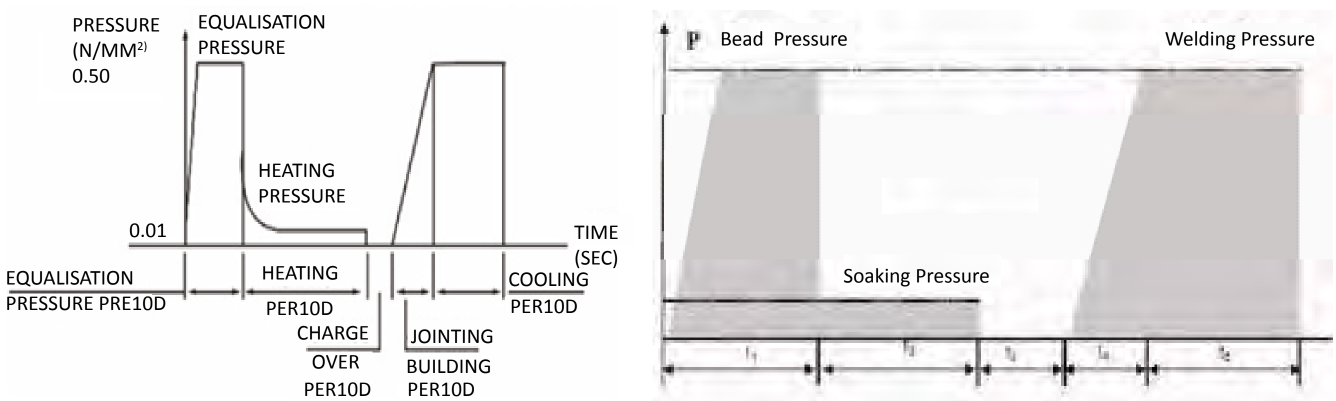


Fig. 2.5.14 PE pipe butt fusion process of heating joining and cooling pressure Vs Time

Bead pressure / equalisation pressure – when the pipe is pressured against heater plate, the pressure built up in system, the limiting time (T1) is called BEAD pressure equalisation period. During pressing with bead pressure, the fusion bleeds out of pipe edge. This bleeding is limiting value to stop bead pressure. The correct fusion pressure rolls both melt beads so that they touch the piping component OD surfaces.

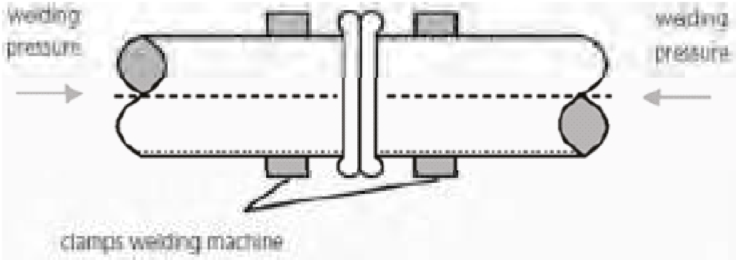


Fig 2.5.15 PE pipe butt fusion melting and bead formation

2.5.5.4 Melting

Verify that the contact surface of the heating tool is maintaining the correct temperature. Place the heating tool between the component ends, and move the ends sagainst the heating tool. Bring the component endstogether under pressure to ensure full contact. The initial contact pressure should be held very briefly and released without breaking contact. Pressure should be reduced when evidence of melt appears on the circumference of the pipe. Beads of melted PE will form against the heating tool at the component ends. When the proper melt bead size is formed, quickly separate the ends and remove the heating tool. The proper bead size is dependent upon the size of the component. Approximate values are shown in Table I. During heating, the melt bead will expand out flush to the heating tool surface, or may curl slightly away from the surface. If the melt bead curls significantly away from the heating tool surface, unacceptable pressure during heating may have occurred. Once the indication of melt is observed around the circumference of the pipe, begin the heat soak by reducing the pressure to maintain contact, without force, while a bead of molten polyethylene develops between the heater and the pipe or fitting ends. Continue heating the pipe ends until the melt bead size has developed against the heater face per Table 3.

When the proper bead size is observed, quickly move the piping component ends away from the heating tool. Remove the heating tool and quickly inspect the pipe ends.

Acceptable melt appears flat and smooth with no unmelted areas. Unacceptable melt appearance is any combination of a concave surface, unmelted areas, a bubbly pockmarked sand paper-like surface or melted material sticking to heating tool surfaces. Low strength joints result from unacceptable melt appearance.

Once the bead outside formation is achieved to the desired height, release the pressure to aligning pressure (P1). It is atmospheric pressure for the pipe joint(soaking pressure). Just hold the temperature for the recommended time period as per BPS.

4) Changeover time –T3 (release the lever and removing the heater plate and bringing the edge of pipe together): This shall be as minimum as possible –The maximum time permitted shall not exceed the tables recommended by manufacturer and approved BPS. Table 1

1	2	3	4	5	
Nominal wall Thickness (mm)	Alignment Bead height on heating tool at the end of the alignment time (alignment with 0.15 N/mm²) (mm) minimum values	Heating-up (T2) Heating-up time =10 x wall thickness (heating-up with < 0.02 N/mm²) (second)	Changeover (T3) (second) maximum time	Joining	
				(T4) Joining Pressure build-up time (second)	(T5) Cooling time under joining pressure P=0.15 N/mm² + 0.01 (minute) minimum values

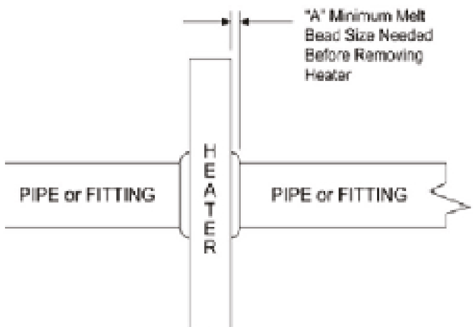


Fig. 2.5.16 Bead Formation

≤4.5	0.5	45	5	5	6
4.5...7	1.0	45..70	5..6	5..6	6..10
7 ... 12	1.5	70..120	6..8	6..8	10..16
12 ... 19	2.0	120..190	8..10	8..11	16..24
19 ..26	2.5	190..260	10..12	11..14	24..32
26 ... 37	3.0	260..370	12..16	14..19	32..45
37 ... 50	3.5	370..500	16..20	19..25	45..60
50 ... 70	4.0	500..700	20..25	25..35	60..80

Fig. 2.5.17 Non uniform fusion of PE pipe butt fusion joint

2.5.5.5 Joining PE pipe

Immediately after heating tool removal, quickly inspect the melted ends, which should be flat, smooth and completely melted. If the melt surfaces are acceptable, immediately and in a continuous motion, bring the ends together and apply the correct joining pressure. Apply enough joining pressure to roll both melt beads over to the pipe surface. The correct joining pressure will form a double bead that is rolled over to the surface on both ends.

2.5.5.6 Holding and Cooling

Welding Pressure: Slowly increase the pressure within time (T4) and hold the pressure as per BPS for period T5 minimum cooling time (see table given by manufacturer for recommended time).

Hold / maintain joining pressure against the ends until the joint is cool. The joint is cool enough for gentle handling when the double bead is cool to the touch.

Cool for about 30- 90 seconds per inch of pipe diameter or cool for a minimum 11 minutes per inch of pipe wall thickness, whichever is greater. Do not try to shorten cooling time by applying water, wet cloth.

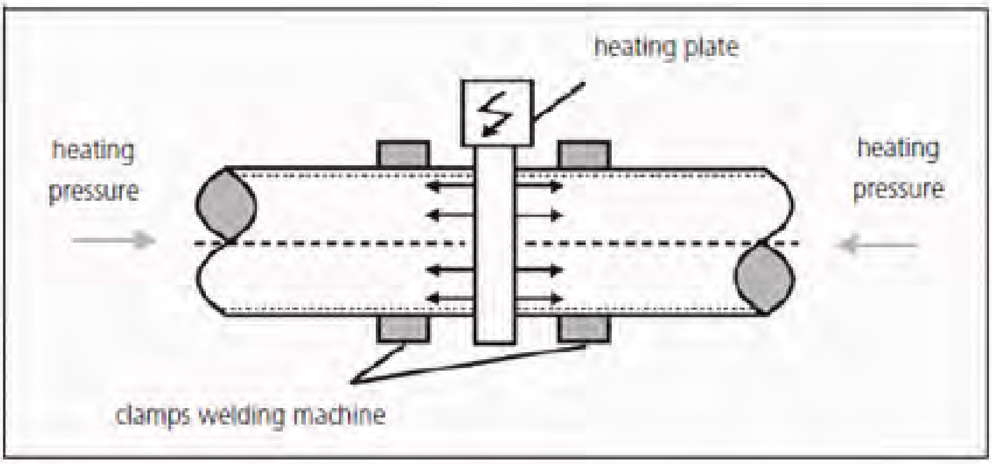


Fig. 2.5.18 PE pipe faces heating and melting system

Avoid pulling, installation, pressure testing and rough handling for at least an additional 30 minutes. Visually inspect and compare the joint against the butt fusion bead visual inspection acceptance guidelines. The v-groove between the beads should not be deeper than half the bead height above the pipe surface. When butt fusing to molded fittings, the fitting-side bead may display shape irregularities such as minor indentations, deflections and nonuniform bead rollover from molded part cooling and knit lines.

2.5.5.7 PE Pipe butt fusion process summary

Having clear understanding of the above processes dealt about bead pressure / equalization pressure, bead width, heating / soaking time, heating / soaking pressure, changeover time, welding pressure / jointing building period and performing necessary operations for the joint to be butt fusion welded, the pipe fitter / operator shall start performing the fusion process as summarized below:

1. Clean the heating plate with lint–free cloth just before inserting.
2. Clean the joint with lint–free cloth just before inserting heating plate.
3. Heating plate is to be heated at a recommended temperature as per BPS and temperature reading is to be checked with thermometer and recorded in the worksheet.
4. Insert the heating plate in between gap of the pipe ends and hold on guide bracket of machine and lock.
5. Move the pipe ends to heating plate and apply pressure as per table (Bead pressure). Look for the melt to come out of edge once bead size is reached (T1) as per table and release pressure lever.
6. Move the clamp away and quickly release the heater in one hand and operate the lever on other hand to bring pipe together (can be performed by two operator also)
7. The change over time (T3) shall not exceed recommend time as per table /BPS. This quick operation skill shall be gained by the operator and to do so enough practice is required.
8. Increase pressure within (T4) to recommended pressure slowly, Too much pressure will lead to over bleeding of melts and too slow pressure will lead to cooling of melt and hold (T5) cooling time. An experienced operator with clear understanding on how to apply correct pressure can achieve a proper weld.
9. Release from clamp and avoid pulling, pressure testing and any rough activity for minimum 30 minutes.

Exercise

I. Answer the following questions.

1. Describe the PE pipe alignment and parameters set up requirements.

----

2. Explain the PE pipe butt fusion heating, melting and bead formation procedure.

----

3. Describe PE pipe butt fusion joining, holding / cooling process.

----

4. Summarize the PE pipe butt fusion joining process.

II. State whether the following statements are True or False.

1. In butt fusion, pipe edges are heated to plastic at the melting temperature and the melted surface is pressed against each other by proper pressure to join together.

   True ☐ False ☐

2. The v-groove between PE pipe joint butt fusion beads should not be deeper than half the bead height above the pipe surface.

   True ☐ False ☐

3. During PE pipe butt fusion, required interfacial pressure is the basis for calculating applied force.

   True ☐ False ☐

Notes

2.5.6 Inspection, Testing and Analysis

At the end of this topic, you will be able to

1. identify the PE pipe butt joints, faulty fusions with root causes of joint faults
2. perform PE pipe butt fusion joints inspections
3. analyze the possible causes of PE pipe butt fusion joints and poor workmanship.

2.5.6.1 Faulty Fusion

Faulty fusion is caused by improper or defective equipment, omitting steps or doing things out of sequence. Faulty fusion may be hazardous. Fig 2.5.20 shows acceptable butt-fusion. Fig 2.5.21 shows unacceptable butt fusion.

Fig 2.5.22 shows misalignment / improper "high-low" pipe alignment.

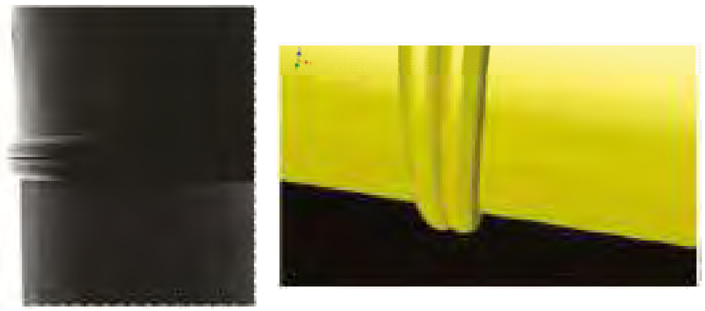


Fig. 2.5.19 Acceptable butt fusion

Fig. 2.5.20 Unacceptable butt fusion

Fig 2.5.23 indicates unacceptable fusion due to excessive heat time or too much applied pressure (melt bead too large).

Fig. 2.5.21 Unacceptable mis alignment

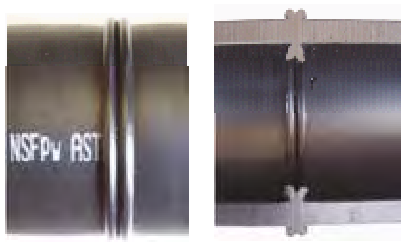


Fig. 2.5.22 Melt bead too large

2.5.6.2 Inspection and testing of butt-fusion joints

All butt fusion joints shall be progressively inspected during joining and melting. Final inspection shall be carried out visually and dimensionally.

In butt fusion joints, the following defects are unacceptable:

i. cracks of any length
ii. unfilled joints are not acceptable
iii. unbonded areas.

Tips

Unless otherwise specified / limited in contracts, applicable codes, standards or specifications, protrusion of fused metal inside the pipe bore shall not exceed 25% of wall thickness to a maximum 4 mm.

1. Rotate the pipe on pipe roller or move around and check weld bead is uniform. Butt fusion beed proportions need s per ASTM F2620.

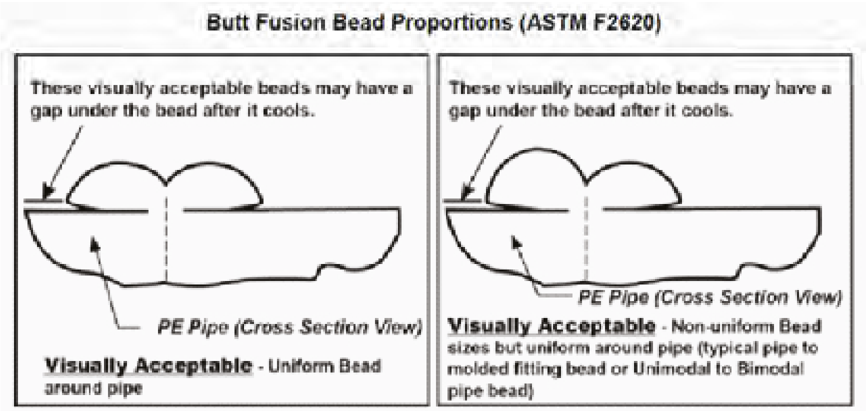


Fig. 2.5.23 Butt fusion bead proportions

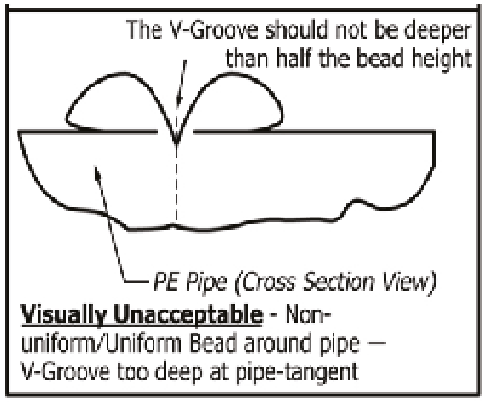


Fig. 2.5.24 Butt fusion bead proportions

2. V–groove deeper than ½ the bead height in the fusion bead is not acceptable.
3. The shape of weld bead is indication of proper weld and both bead shall have uniform look. Refer Fig 2.5.26.
4. Misalignment up to 10% of thickness (e) is acceptable.
5. The joint bead is too big, but a good visual inspection shows the bead has full penetration weld. This is acceptable. Refer Fig 2.5.28.
6. Unacceptable butt fusion weld joints are as depicted below

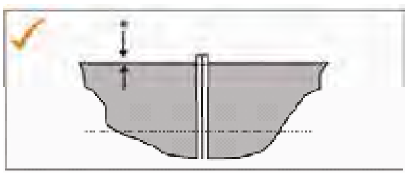


Fig. 2.5.25 Good fusion bead

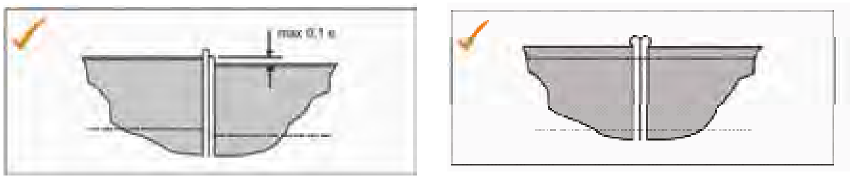


Fig. 2.5.26 Max Misalignment 10% of wall thickness

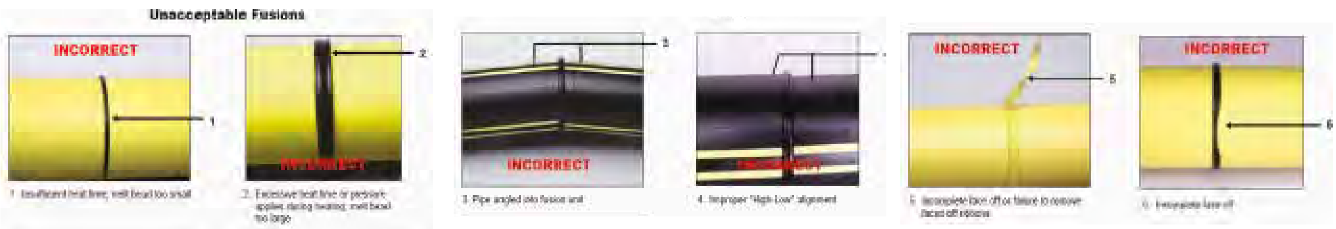


Fig. 2.5.27 Unacceptable butt fusion joints

2.5.6.3 Butt fusion Joints Failure Reasons / Causes

PE pipe butt fusion joints / beads poor workmanship conditions with possible causes are tabulated as below. PE pipe fitter shall have thorough understanding of these poor workmanship causes and eliminates during PE pipe installation and joining by butt fusion process.

2.5.6.4 Pressure Testing

Pressure testing shall be performed as required and pressure test records shall be prepared and compiled for each piping system during the testing, including

- date of test
- identification of piping system tested
- test fluid
- test pressure
- certification of results by examiner.

Table 3 Fusion beads workmanship condition and possible causes

Observed Workmanship Condition Of Fusion Beeds	Possible Cause
Excessive double bead width	Overheating; Excessive joining force
Double bead v-groove too deep	Excessive joining force; Insufficient heating; Pressure during heating
Flat top on bead	Excessive joining force; Overheating
Non-uniform bead size around pipe	Misalignment;Defective heating tool; Worn equipment; Incomplete facing
One bead larger than the other	Misalignment Component slipped in clamp; worn equipment Defective heating tool; Incomplete facing dissimilar material – see note above.
Beads too small	Insufficient heating; Insufficient joining force
Beads not rolled over to surface	Shallow v-groove – Insufficient heating & insufficient joining force Deep v-groove – Insufficient heating & excessive joining force
Beads too large	Excessive heating time
Square like outer bead edge	Pressure during heating
Rough, sandpaper-like, bubbly, or pockmarked melt bead surface	Hydrocarbon contamination

Exercise

I. Answer the following questions.

1. Write down any five faulty PE pipe butt fusions with root causes and propose required remedies.

----

2. Tabulate the observed poor workmanship conditions of PE pipe fusion joints with the possible causes.

----

3. Illustrate any four incorrect butt fusion joints with free hand sketches duly identifying the defects.

----

4. What are the visual inspection acceptance criteria of heatfusion butt joints?

II. State whether the following statements are True or False.

1. PE pipe fusion excessive double bead width is due to overheating and excessive joining force.

   True ☐ False ☐

2. Concave melt appearance after heating, is due to over-pressurization during the heat cycle.

   True ☐ False ☐

3. Protrusion of fused metal inside the PE pipe bore shall not exceed 25% of wall thickness to a maximum 4 mm.

   True ☐ False ☐

Notes

2.6 Electrofusion Welding Technique and Procedure

Unit Objectives

At the end of this unit, you will able to:

1. verify the scraping prior to installation
2. clean pipe end and coupling joining surfaces prior to joining
3. insert the pipe into the coupling and complete the fitup
4. connect the electrofusion weld unit to the terminal shrouds / fitting terminals and power supply
5. operate the electrofusion welding unit and perform electrofusion joining
6. perform electrofusion pipe to pipe or pipe to fittings–joints fitup / assembly and fusion welding
7. perform pipe saddles fitup / assembly and fusion welding.

2.6.1 Instruments, Tools and Equipment For Electrofusion Joining

At the end of this topic, you will able to:

1. identify various instruments, tools and equipment required for electrofusion joints fitup and fusion
2. choose the required tools, instruments and equipment for electrofusion joints fitup and fusion.

2.6.1.1 Electrofusion joining introduction

Electrofusion is a heat fusion joining process where heat source is an integral part of the fitting. When electric current is applied, heat is produced, melting interface and the components are joined. Fusion occurs when the joint cools below the melt temperature of the material. PE pipe joining procedure and performance qualifications, fitting / joining and electrofusion shall be made only in accordance with a written electrofusion procedure specification (EPS) that has been qualified in accordance with applicable codes / standards, manufacturers recommendations of piping materials, pipe and fitting materials.

Electrofusion joining involves various instruments, tools and equipment

2.6.1.2 Measuring Item / Instrument

Required measuring item / instruments for PE pipe fitting and fusion welding include measuring tape, steel rule, depth gauge, level gauge, thermometer, laser gun, etc.

Thermo meter laser gun type or thermo stick and other type of sensors may be used for temperature measurement. Laser gun is best suitable to check temperature up to a certain distance.

Tips

Trainees need to practice temperature measurement with laser gun and thermo stick and compare the readings.

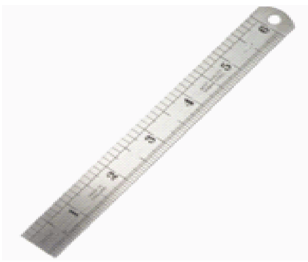


Fig. 2.6.1Measuring Scale

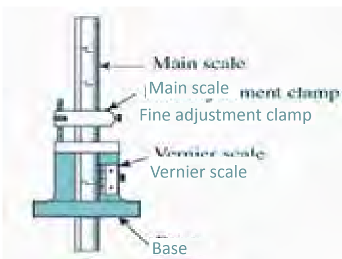


Fig. 2.6.2 Depth gauge

Fig. 2.6.3 Level Gauge

Fig. 2.6.4 Laser gun

2.6.1.3 Tools and Accessories

Required tools and accessories include:

i. Spanner set, marker, sharpened scraper, etc. A surface cleaning tool is required for certain fitting designs to remove the outer layer or skin of material on the pipe or fitting spigot surface prior to fusion. Tools used for these purposes are commonly called scrapers.

i. Sharpened scraper which is a hand operating manual tool, used for scraping pipe surface and also to clean the sharp edge in ID and OD.

ii. Quick clamps are made by different manufacturers length / range and with different number of clamps. Based on field application, operator has to choose right clamp.

Tips

Sharp edges may cause injury! Handle with care!

Fig 2.6.5 Spanner set

Fig. 2.6.6 Permanent marker

Fig. 2.6.7 Sharpened scraper

Fig. 2.6.8 Quick clamps

2.6.1.4 Re-round tools

i. Re-round Tool (with clamp):

Various types of re-round tool and equipment are available. Re-rounding equipment is equipment used to bring the pipe into /within the out of round limitation requirements of the applicable pipe standard or the limitations established by the electrofusion fitting manufacturer. Pipe fitter / fitting operator shall select the right tool / equipment based on OD of pipe, SDR and amount of ovality in pipe. Refer fig 2.6.9, 2.6.10 and 2.6.11 for various pipe re-rounding tools.

Fig. 2.6.9 Typical pipe clamp

Fig. 2.6.10 Hydraulic re-rounding equipment

Fig. 2.6.11 Various pipe re-rounding tools

2.6.1.5 Equipment for electrofusion joints Fitup and fusion

i. Pipe cutter- Different pipe cutters are available in the market. The roller type is best suited to make square cut for smaller pipes. For bigger pipes, it is preferred to use chain mounted autocutters for manual cutting and shaving tools. Typical pipe cutters are shown in Fig. 2.6.12, 2.6.13 & 2.6.14.

Fig. 2.6.12 Rotational pipe cutter

Fig. 2.6.13 Simple Pipe cutter

Fig. 2.6.14 S type-rotational pipe cutter

ii. Mechanical Scraper: Typical mechanical scraper for large diameter pipe is shown in Fig. 2.6.15.

iii. Rotary scrapper is used to scrap the OD of pipe by rotating over outer surface. The tool moves smoothly towards the end and making controlled scraping with smooth surface. Refer Fig. 2.6.16.

iv. Debeader: The purpose of debeader is to remove the part of excess bead or to trim the beads after welding / fusion as required / permitted by applicable standards / specifications. Refer Fig. 2.6.17.

v. Special Cleaning Solution and Wipes

Cleaning solution is 90% or more concentrated Isopropyl alcohol. (Refer fig 2.6.18).

Wiping Cloth: A clean, dry, non-synthetic, lint-free cloth or absorbent paper towel used for removing surface preparation residue from the joining surfaces. Considerations of the hazards of static electricity should be applied in selection of a wiping cloth material.

Fig. 2.6.15 Mechanical Scraper

Fig. 2.6.16 Rotary scraper

Fig. 2.6.17 Debeader

Fig. 2.6.18 Special cleaning solution

vi. Electrofusion Control Unit (ECU)

Selection of electrofusion control unit is based on duty cycle and required working range (watts). This unit supplies required electrical energy / current at set voltage (power), that controls the heating time cycle and auto compensation of welding current during heating . This unit read selectrofusion material / fitting bar code and keep memory of joints numbers and joining parameters. ECU is also called control box, as it controls and regulates electrical energy input to the fitting.

Fig. 2.6.19 Typical Electrofusion Control Unit

Parts of Electrofusion Control Unit

1. Welding terminal Cable – connection to coupling plug
2. USB Memory Drive Bar Code Scanner (Optional) to scan the sticker which read the timing and input automatically to the machine
3. Bar Code Pen and Cord (Standard)
4. USB Socket
5. Welding Cable Socket
6. Protective Lid
7. Display
8. Buttons
9. Protective Frame
10. Ratings Plate
11. Supply Cable
12. Fuse Holder

Sample Specification of ECU machine for trainee pipe fitter / operator understanding is shown in 2.6.19.

This is only a demo machine for learning. Each manufacturer has own equipment specification. Typical specification is as stated below:

Power supply : 220 V single phase 50/60 HZ or 110 V /220 V 50/60 HZ

- Output current :100 A, At60 % duty cyle -- 60 A
- IP protection : IP55
- Voltage : 8 to 48 volts
- Sugessted power supppy : Power supply units are designed to operate by 3 to 7.5 KVA Generator
- Name plate reading

TECHNICAL SPECIFICATION	
Single-phase power supply	230 V 50/60 Hz
Output voltage	8 ÷ 48 V
Max output current	120 Amp.
60% duty cycle output	80 Amp.
max input power	4.8 kVA
Working range	20 ÷ 800 mm
Working temperature range -	10°C - +45°C
Operating mode	Barcode / manual

Tips

Catalogue of ECU machines shall be made available during classroom and practical training for more understanding and to familiarize student about various welding machines.

ECU equipment must comply with all safety trainees regulations CE marking or IS marking and IP 55 for outdoor application (protection against rain).

ECU shall have valid calibration certificate.

The operator shall understand / determine:

power supply requirment to controller unit

selection of controlling parameters for the work to be carried out

parts name and it is purpose

safety features.

setting and operating control unit.

vii. Power source (Generator) Either direct power from EB or suitable capacity generator is used. The minimum power supply required shall be calculated based on SDR and heater size–Normally, 7.5 KVA single phase supply is sufficient. The values and ranges given in the table 1 is for example only. codes / standards, will precede this table.

viii. Supports / Alignment devices

Fig. 2.6.20 Generator with proper control panel

Various types of supports / alignment devices are available and may be required for a particular fitting. The alignment device should prevent movement of the components. Refer Fig 2.6.21. Pipe supports / roller supports are used for a simple and damage-free movement of pipes to keep the pipeline straight , which will prevent any stress on joint during welding. They will help to improve pipe alignment and pipe movement with lower forces to achieve a stress-free installation.

Table 1-ECU-KVA & fitting range

Minimum KVA	Fitting Range
5.0 KVA	Will fuse all Central Plastics fittings including 24" DIPS / 630 mm couplings
3.5 KVA	Will fuse Couplings up to 8"/ 225 mm and all Tapping Tees, High Volume Tapping Tees, Branch Saddles and Reducers
2.0 KVA	Will fuse Couplings up to 1 1/4", and all Tapping Tees, High Volume Tapping Tees, Branch Saddles and Reducers

Fig. 2.6.21 Typical pipe supports / alignment devices

Exercise

I. Answer the following questions.

1. What are the common tools and accessories required for PE pipe jointing?

---

2. Name any five equipment required for PE pipe fitting related activities.

---

3. Explain the application of re-rounding tools.

---

4. Describe electrofusion control units.

---

5. Write short notes on pipe supports / alignment devices used during PE pipe fitting and weld fusion activities.

II. State whether the following statements are True or False.

1. Laser gun is suitable to check temperature upto a certain distance.

   True ☐ False ☐

2. Selection of electrofusion control unit is based on duty cycle and required working range.

   True ☐ False ☐

3. Rotary scrapper is used to scrap the ID of pipe by rotating over the inner surface.

   True ☐ False ☐

4. Re-round tool / equipment is used to perform re-round scraping to get pipe roundness.

   True ☐ False ☐

5. Debeader is a pipe cutting tool.

   True ☐ False ☐

Notes

2.6.2 PE Pipe Joining Procedure, Personnel Qualification and Certification

At the end of this topic, you will be able to:

1. determine the requirements for electrofusion procedure and personnel qualifications
2. prepare yourself for PE pipe joining performance qualification and certification
3. practice electrofusion joint fitup / assembly and electrofusion welding.

2.6.2.1 Procedure and performance qualification requirements

Each employer is responsible for the electrofusion done by personnel of his organization and shall conduct the required performance qualification tests to qualify electrofusion procedure specifications and pipe fitters/ operators. Fusion Procedure / EPS and fusion fitter / operating personnel shall be qualified as per ASME B31.3

Chapter VII or AWS B 2.4. Refer respective codes / standards / specifications for all qualification tests and acceptance criteria.

Procedure qualification: Each organization shall prepare a written electrofusion procedure specification and qualify to demonstrate the electrofusion joint integrity of PE pipe and pipe fittings. Manufacturer recommendations and applicable specifications shall be the basis for qualification. It shall provide direction for making electrofusion welds duly listing on essential variables. Changes in Pipe or Coupling / Fitting material and outside the range of specified diameter and SDR range, change in electrofusion units make / model, are essential variable and require new qualification of EPS.

The employer shall maintain a self-certified record, available to the owner or owner's agent and to the inspector, of the Electrofusion Procedure Specification (EPS) used and the pipe fitters / operators employed by him/her duly showing the dates and results of EPS qualifications and electrofusion performance qualifications.

Performance Qualification:

Skill and knowledge of the operator, are required to obtain a good quality joint. All personnel to be involved is electrofusion welding need to be trained, qualified and certified by competent and approved authority / employer in accordance with approved procedures. In general, training and certification by respective manufacturers or approved certifying authority are considered acceptable. Employer is responsible for engaging qualified and certified pipe fitter / operator for city gas distribution piping installation.

i. Each qualified pipe fitter / operator shall be assigned an identification symbol.

ii. Each pressure containing fusion joint or adjacent area shall be stenciled or suitably marked with the identification symbol of the pipe fitter / operator.

iii. Identification hard stamping shall not be performed and any marking paint or ink shall not be detrimental to the piping material. In lieu of marking the electrofusion joint on the city gas distribution piping, appropriate records may be filled and maintained.

iv. Qualification in one EPS does not qualify a pipe fitter / operator for any other electrofusion EPS procedure.

2.6.2.2 Procedure specification and qualification

To qualify a Electrofusion Procedure Specification (EPS), all tests and examinations specified therein and in applicable codes / standards / specifications shall be successfully completed.

1. In addition to the procedure for making the electrofusion, EPS should specify the following:

i. all materials and supplies with identification and traceability

ii. material manufacturer , pipe / fitting size and rating

iii. tools, equipment, supports and fixtures (including proper care and handling)

iv. identification of Electrofusion Unit (Model, make, rating, etc)

v. identification of pipe fitter / operating personnel performing the assembly and electrofusion

vi. environmental requirements (temperature,humidity, and methods of measurement)

vii. joint preparation and scraping including the tools and equipment used

viii. cleaning method and cleaning medium

ix. dimensional requirements and tolerances

x. pipe and fittings assembly requirements and details including joint position / orientation

xi. amperage and voltage application limits

xii. fusion and cool / cure time

xiii. tests and examination details as required by respective codes / standards

xiv. acceptance criteria for the completed test assembly. (reference code / standard can be cross referenced).

2. Test assembly

The assembly shall be prepared and fitting performed in one pipe size in accordance with the EPS and shall contain at least one of each different types of joints identified in the EPS. More than one test assembly may be prepared, if necessary, to accommodate all the fitting types or to assure that at least one of each joint types is loaded in both circumferential and longitudinal directions. The size of pipe and fittings in the assembly shall be as follows:

i. When the largest size to be qualified is DN 100 (NPS 4) or smaller, the test assembly shall be the largest size qualified.

ii. When the largest size to be qualified is greater than DN 100 (NPS 4), the size of the test assembly shall

be between 25% and 100% of the largest piping size qualified, but shall be a minimum of DN 100 (NPS 4).

Materials. Pipe joining materials that have deteriorated by exposure to air or prolonged storage, or will not spread smoothly, shall not be used in making joints.

Tools and equipment: Fixtures and tools used in making joints shall be in such condition as to perform their functions satisfactorily.

Preparation for Electrofusion Jointing

Preparation shall be addressed in the EPS and shall specify requirements such as

cutting, cleaning (Surfaces to be heat fused together shall be cleaned of all foreign material), preheat / warming,

end preparation and surface preparation / scraping, fitup.

Electrofusion welding

Joints preparation, fitup and assembly shall be performed following the procedures and instructions in accordance with manufacturer instructions and applicable codes / standards.

Electrofusion Control Unit (ECU) output leads shall be plugged into the fittings. Power supply shall be connected with ECU. Joining parameters shall be scanned or uploaded manually. ECU shall be operated as per manufacturer instructions. Required current and voltage shall be applied for the specified duration and joint shall be cooled and cured for the specified period without any disturbance to the joint. All these parameters shall be documented in EPS.

3. Electrofusion procedure specification & qualification tests

i. Non–destructive Tests are performed.

ii. Pressure Tests

The test assembly shall be subjected to specified hydrostatic / air pressure for not less than 1 hour with no leakage or separation of joints. If joint failure is detected during pressure tests or connection bubble tests, the joint is to be rejected.

iii. Destructive Tests

Crush Test Method: The test assembly shall be subjected to a crush test in accordance with the applicable specifications. The test is not to be rejected and considered successful if failure initiates outside of any electrofusion joint.

4. Typical EPS format

PE PIPING ELECTROFUSION WELDING PROCEDURE SPECIFICATION & QUALIFICATION RECORD

Organization: **Location:** **EPS/QR NO :** **Rev:** **Date :** BASE MATERIAL : Pipe1 Manufacturer: Pipe dia & Tk: SDR: Pipe2 Manufacturer: Pipe dia & Tk: SDR: Fitting Manufacturer: Fitting dia & Tk : Rating: Qualified Dia Limit / Range : Qualified SDR Range:	
Electrofusion Unit Make : Model : Rating / Range : Power Supply: Voltage & Amps:	Electrofusion Unit Make : Model : Rating / Range : Power Supply: Voltage & Amps:
Pipe Preparation Pipe cutter used: Squarenss: Prelceaning solution : Scraping tool used: Ovality: Final cleaning:	Pipe &Fitting Assembly Tools & Equip used: Re-rounding: Insertion depth : Pipe & Fitting fit-up: Interface Gap: Clamping:
ElectrofusionOperation (Actual Values) Temerature & Humidity: Joint Position: Power Supply : Applied Current : Applied Voltage : Heating Duration : Cooling Duration :	Inspection &Testing Operator Name : Operator Number : Visual : Accepted / Rejected Pressure Test: Accepted / Rejected Peel Test: Accepted / Rejected Bend Test Accepted / Rejected Crush Tests : Accepted Rejected

2.6.2.3 Operator training and qualification guidelines

1. Testing knowledge and skill of electrofusion pipe fitter / operator (general exam)

Wherever, it has been specified as "pipe fitter" it is also to be considered applicable for "operator" and vice versa.

This section applies to the generic electrofusion procedure for field joining of polyethylene (PE) pipe and specifies the method of testing the knowledge and skill of a pipe fitter / operator who is authorized to perform electrofusion joining of polyethylene pipe up to 12" in diameter. The general examination of an operator is essential for the assurance of the operator's skills, competence and quality of electrofusion work. The application of this section is intended to ensure that the examination is carried out according to a uniform and standard test method.

2. Training and qualification of PE pipe fitter / operator (practical aspects oriented examination)

Any pipe fitter / operator who performs or inspects electrofusion joints on polyethylene (PE) pipe should successfully complete an initial electrofusion training program. Subsequent training frequency will be decided based on the duration of the project and competency of the pipe fitter / operator. During the test, the operator shall demonstrate practical skill and knowledge of electrofusion joints on PE pipe. The test will be carried out in two parts under the direction of the utility or operator qualifying organization.

The operator will answer questions relevant to electrofusion qualification testing. The questions will be presented to the operator in the written form. The written test will be a True/False and/or multiple choice type. The operator must answer all questions correctly.

The operator will perform a minimum of two electrofusion joints adhering to the generic electrofusion procedure. A 2 inch\"diameter or larger coupling and 2 inch or larger main size saddle type fitting are recommended. This will qualify the operator for electrofusion joining upto and including 12 inch diameter. The utility or operator qualifying organization will provide a suitable environment for qualification and testing of the operator. The utility or operator qualifying organization will supply the operator with all necessary fittings and tools for electrofusion joining and testing. Contractors should supply all tooling, power supplies, fittings and pipe, similar to actual field conditions.

Certifying authority shall witness the entire fusion procedure and all required sequential processes / steps to perform electrofusion. If anything is skipped or inadequately performed including observing cooling time, the operator is to be rejected and the prepared fitting will not be tested further. If and only if all the required joining steps are conducted / performed and complied with, all the required tooling is used and in good working order and proper cooling time observed, necessary qualification tests shall be performed. Individuals who successfully complete both sections of the testing will bequalified to perform electrofusion joints on polyethylene piping upto and including 12 inch diameter.

Pipe Fitters / Operators must be requalified annually, or more frequently if any failures are encountered since the last qualification. Renewal of a electrofusion performance qualification is required when a pipe fitter / operator has not used the specific electrofusion process for a period of 6 months or more, or there is specific reason to question the individual's ability to make electrofusion weld that meet the EPS. Electrofusion failed connections are not allowed to be put into service.

3. Inspection and testing of qualification joints

a. Non – Destructive tests

All joints shall be visually observed for compliance during fitting and fusion welding process. Final visual inspection shall be performed prior to pressure test. It is desirable to perform radiography (x-ray or Gamma ray) of the fitting before dissection to check the fusion uniformity. But "X ray" alone shall not be considered for acceptance purpose as it is difficult to check the fusion integrity of contact interfaces as X ray / Gamma ray will not detect defects perpendicular to X rays / Gamma rays direction.

b. Pressure Test

Electrofusion joint shall pass air pressure test or hydrotest. If joint failure is detected during pressure tests or connection bubble tests, the joint is to be rejected. The client / certifying authority may elect to perform additional testing or require the electrofusion joint (saddle only) to be abandoned in place or cut out at its discretion.

c. Destructive tests

Destructive tests shall be performed as required by governing code and contract specifications. These destructive tests are based on requirements from ASTM F1055 standard specification for electrofusion type polyethylene fittings for outside diameter controlled polyethylene pipe and tubing fusion evaluation test section. The Bend tests, peel tests, and crush test methods are useful / helpful in locating fusion weakness and as an evaluation of bonding strength and fusion quality between the pipe and fitting.

As these methods are destructive, they are only useful in determining joint quality of a fitting that was fused for the purpose of testing. They and cannot be used for testing of fusions intended for service. After all relevant information is gathered, the fitting should be cut and subject to joint evaluation tests.

To prepare a specimen for crush testing, it is necessary to cut the pipe and coupling longitudinally in half as near to the center line of the pipe and coupling as possible. It is desirable to leave at least 3 (75mm) to 5 (125mm) of pipe length at each end of the coupler.

d. Crush test procedure

Place a specimen half in a vice so that the outermost wire of the fusion zone is approximately 1 1/4" (32mm) from the vice jaws. Close the vice jaws until the pipe walls meet. Repeat this process for each end of both halves of the coupling.

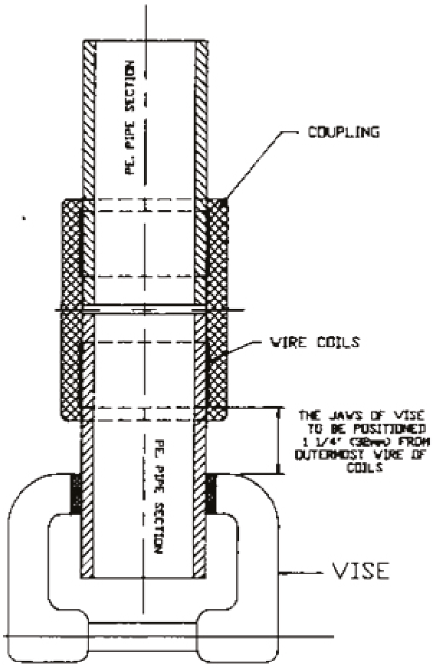


Fig. 2.6.22 Positioning the specimen in vise

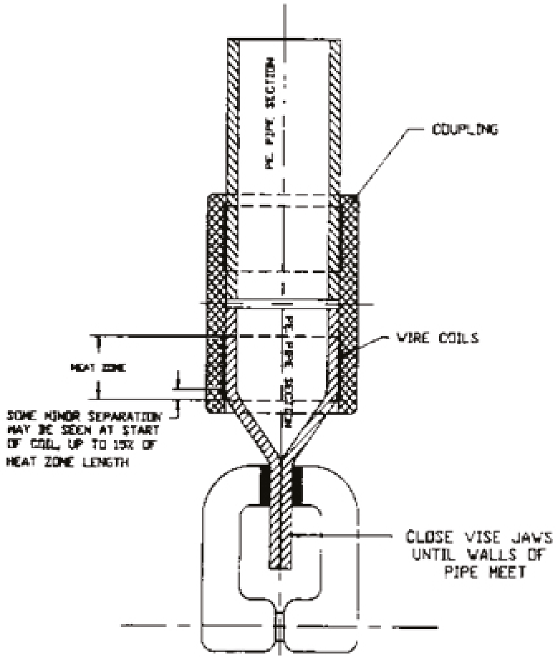


Fig. 2.6.23 Performing the test by closing the jaws

Inspect the crushed specimens for separation of the pipe and fitting in the fusion zone. Some minor separation (up to 15% measured) may be seen at the outermost region of the fusion zone. This does not constitute failure. Ductile failure of the pipe, fitting or PE insulation around the wires is acceptable. There should be no separation at the fusion interface of the pipe and fitting. Refer Fig. 2.6.24 for passing and Fig. 2.6.25 for failing results.

Fig. 2.6.24 Testpass image

Fig. 2.6.25 Test fail image

4. Typical and simple Electrofusion Performance Qualification Certificate model

PE PIPE ELECTROFUSION JOINTING CERTIFICATE

Name Of Fitter / Operator: Certificate Number:

Identification No / Code: Certification Date:

Reference EPS Number:

Employer: Location:

This is to certify that the above mentioned electrofusion pipe fitter / operator has undergone training and demonstrated his / her ability in the following techniques and deemed competent and qualified as per ASME B31.3 and ASTM F 1290.

Electrofusion Joints Types:

PE Pipe & Fitting Material:

Diameter and SDR range:

--- ---

Manufacturer / Qualifying Agency Employer

(Name, sign, date and Organization) (Name, sign, date & Organization)

Exercise

I. Answer the following questions.

1. What are the requirements for procedure and performance qualification of PE pipe electrofusion fitting and weld fusion?

----

2. Describe the training and examination requirements for qualifying pipe fitting / operating personnel.

----

3. What are the typical contents of a Electrofusion Specification?

----

4. What are all the tests to be performed to qualify in Electrofusion Specification?

II. State whether the following statements are True or False.

1. Qualification in one EPS does not qualify a pipe fitter / operator for any other electrofusion EPS procedure.

   True ☐ False ☐

2. Testing knowledge and skill of electrofusion pipe fitter / operator "General Exam" will be conducted in two parts.

   True ☐ False ☐

3. The pipe fitter / operator will perform a minimum of two electrofusion joints to get qualified.

   True ☐ False ☐

4. Individuals who successfully complete both sections of the 2 inch diameter pipe electrofusion joint testing will be qualified on PE piping upto and including 12 inch diameter.

   True ☐ False ☐

2.6.3 PE Pipe Installation Planning and Preparation

At the end of this topic, you will be able to:

1. plan the PE pipe installation
2. prepare the site for PE pipe joining
3. comply to safety requirements.

2.6.3.1 City Gas Pipeline Installation Planning

Installation manuals and additional information accompanying the product must be complied with. Technical information, for example, data sheets, installation manuals for fittings and operation instructions for fusion boxes and tools are to be made available at the worksite. Approved procedure shall be in place.

There shall be approved drawing in place for pipeline installation routes, location and position. If the work is to be performed in any public occupying / utility area, necessary permits shall be obtained and appropriate safety displays shall be kept.

2.6.3.2 Verifying and completing the preparation for PE pipe joining

1. Socket / Coupling / Fittings check

Manufacturer's recommendations shall be referred and verified for compatibility of the electrofusion fitting with the specific pipe or fitting material to be joined. Pipe fitter shall check for size and marking for correct socket / fitting on receipt. The pipe coupling contains an internal heat source. Socket information shall be read and understood by elecrofusion unit operator / pipe fitter. See below the typical manufacturer marking - Size /SDR is in fig 2.6.26. Bar code for direct scan to feed information to control unit is also depicted.

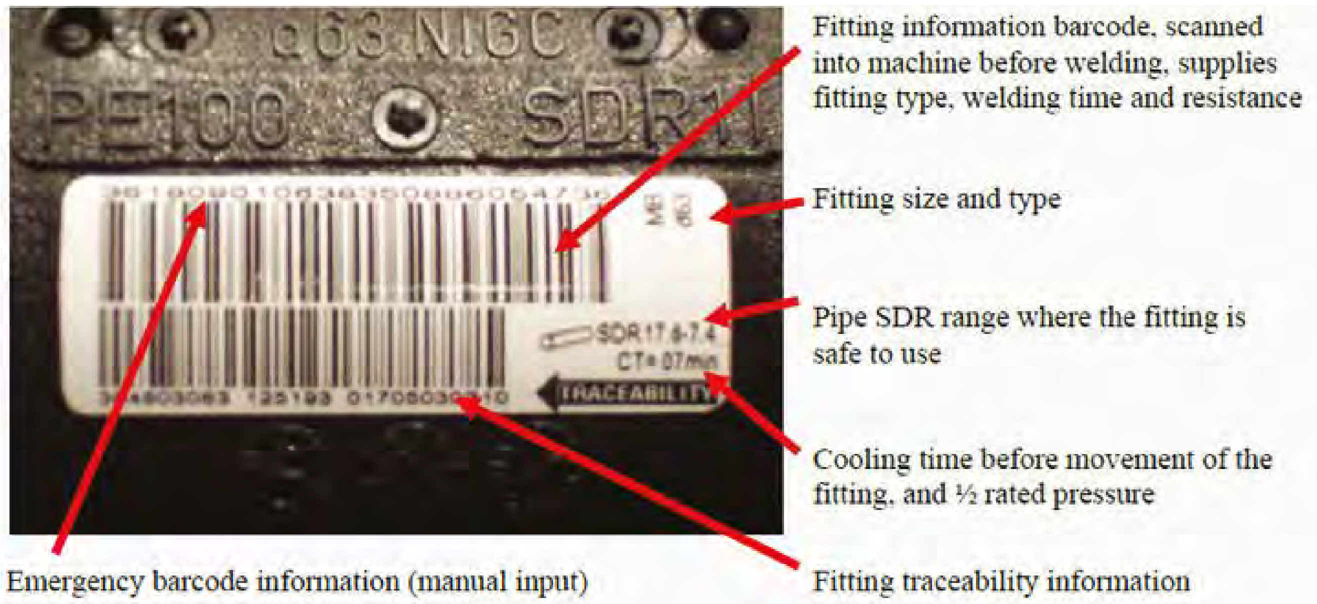


Fig. 2.6.26 Typical fitting with necessary marking

2. PE pipe fitup Readiness

In previous units, we learnt about properties of plastic ,PE type, its semi-crystalline structure, etc., along with principles of electro fusion , heating, cooling and surface preparation. It shall be once gain verified for conformance, compliance and fitness for joining by electrofusion process. Verify and ensure that all items have been inspected and released for fitup and welding by Quality Control. Ensure that adequate pipes, fittings, sockets, saddle materials are available. Verify and ensure the operator / welder qualification certificates validity and approval. Ensure that approved procedures and plans / ITPs are in place.

Refer the respective manufacturer's instructions and recommendations of PE pipes and fittings and understand properly. If in doubt, contact supervisor or manufacturer through proper channel.

Go through the Electrofusion equipment manufacturer manual and equipment operating instructions and become familiar with it.

Prior to commencing PE pipe electrofusion joint fitting, regular check shall include the following:

i. Generator is in working order. Sufficient fuel is available.

ii. Fusion box / ECU is suitable for the job / joint.

iii. Adequate length of external cables are available.

iv. Scraper tools have valid calibration.

v. Specific and appropriate installation tools, re-rounding tools, clamps, rollers, cleaning solvent, lint–free cloth, marker pen, measuring tape, scale, and handling devices are available.

vi. Installation site is clean, dry and free from grease or any other sources of contamination.

3. Preparing working space

Prepare necessary machines, tools and components for the installation (See checklist in last page, SDR compatibility, etc.) Ensure sufficient clearance and cleanliness around the pipe in the working area.

The jobs are mostly carried out in trench which may have water and mud. Prepare the worksite with proper care such that there is no water spill during fusion process. Keeping the area dry is a better wayof carrying out the work safely.

If weather condition is windy, prepare a closer shield (tent) to prevent heat loss during fusion. No work shall be continued if unfavorable weather condition prevail during the joint to be fusion welded (Fig. 2.6.27.) Close the ends of pipes with covers to avoid wind flowing / blowing / draught inside pipe. Manufacturer recommendation shall be the basis for atmospheric / surrounding temperature condition. In general, electrofusion process should be carried out at temperatures between 16˚ C to 49˚

Fig. 2.6.27 typical tent during PE pipe joining

Fig. 2.6.28 Stringed PE pipe ready for lowering

Exercise

I. Answer the following questions.

1. How will you plan PE city gas distribution pipe installation?

----

2. What are the checks to be performed on coupling / fitting prior to commencing pipe fitting / assembly?

----

3. Briefly describe the PE pipe installation worksite and workspace preparation.

----

4. What are the regular checks to be performed prior to commencing PE pipe fitting fusion / assembly?

II. State whether the following statements are True or False.

1. Socket information label will contain / display fitting time.

   True ☐ False ☐

2. Manufacturer recommendation shall be the basis for atmospheric / surrounding temperature condition.

   True ☐ False ☐

3. During installation, PE pipe ends shall not be closed with suitable covers as it may built pressure and explode.

   True ☐ False ☐

Notes

2.6.4 Out of Roundness Correction

At the end of this topic, you will be able to:

1. use appropriate tools and equipment for out off roundness correction
2. correct out off roundness and ensure the pipe is ready for fitup.

2.6.4.1 Pipe out-off roundness

It is important for the installer to confirm that the polyethylene pipe meets all dimensional requirements of applicable specification and that the pipe does not exceed 3 % ovality. If ovality is greater than 3% the pipe fitter must take steps to re-round the pipe. The permitted offset (misalignment) is 10% thickness after setting both ends of pipes . Hence, operator shall achieve ovality as close as possible within 10% thickness to a maximum of 1 mm. Measure for the pipe ovality and determine if the area is out of tolerance. Mark the areas that are outside the standard tolerance for the OD of the pipe with a white marker.

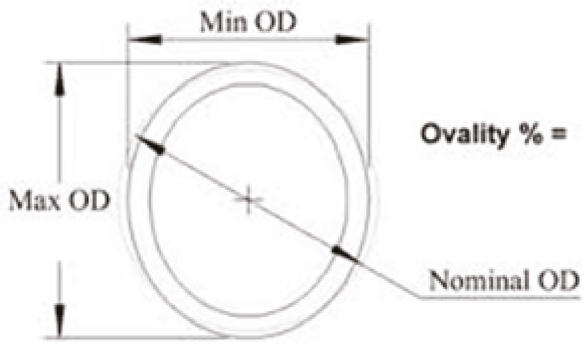


Fig. 2.6.29 Pipe ovality measurement

2.6.4.2 causes of PE pipe out of roundness include the following:

Polyethylene is a flexible material. Pipe roundness can be affected by a number of conditions that include manufacturing process conditions, coiling, storage/stacking, handling and soil load, if buried. Polyethylene pipe that is warehoused for a period of time or stacked on top of each other can experience ovality related issues (this is more pronounced with large diameter pipe).

Large diameter polyethylene pipe will tend to relax a little during storage due to a combination of its weight and its natural flexibility. Mechanical forces experienced during some trenchless installation techniques such as "Directional Drilling" can temporarily leave the polyethylene pipe elongated and out-of-round. Polyethylene pipe that has been underground for a while is subject to earth loads. These earth loads can cause the pipe to sag and/ or become out-of-round.

2.6.4.3 Importance of out of roundness correction

i. One of the most critical functions of the electrofusion process is to close the gap between the pipe and the fitting and to build up interfacial pressures for the fusion process to take place.

ii. If this gap is not closed and the interfacial pressures are be built up, there is no way for the electrofusion joint to effectively achieve the high level of fusion integrity for which it was designed.

iii. If a pipe is out-of-round, the initial concern is that the surface area of the pipe may not adequately come in contact with the fusion zone of the electrofusion fitting. This could result in the electrofusion fittings cold zones, that are designed to contain the material generated in the melt pool, to simply allow the molten material to escape out of the fusion area without producing any melt penetration. This is a particularly important concern when installing tapping tees and branch saddles they do not fully encircle the pipe as an electrofusion coupling dose.

iv. If severe enough, pipe out-of-roundness can have a negative effect on electrofusion joint quality. If the pipe is out-of-round, and is not corrected, the amount of gap between the pipe and fitting can be too large for the melt expansion to close and increase the difficulty of sliding the fitting onto the pipe.

2.6.4.4 Correcting flat spots

If a flat spot is present, you must take care of the flat spot before you start the fusion. In order to correct the flat spot on the pipe, the pipe fitter can use appropriate jack on the inside of the pipe to close the gap. You may also need to use an infrared heater to help close up the gaps. Refer to the maximum allowable gap chart to see if the gaps are in tolerance. If the flat spot is not eliminated, there is a high chance of leakage.

2.6.4.5 Correcting out-off roundness by re-rounding

The pipe which is not round shaped or oval shall be clamped with re-round device (clamp of matching diameter) 20mm away from the stop mark to make it perfect circle.

If it is determined that some of the areas have an OD that is too large, then you will need to use pipe rerounding clamps as shown in figure 2.6.30 to install the coupler. When re-rounding tools/ clamps are used, damage to the pipe surface and any contamination of the fusion zone have to be avoided.

Apply re-rounding tool/ place re-rounding clamp on the pipes immediately outside the proposed fitting position. Re-check out of roundness of the pipes and re-position the tool, if required. (Refer fig 2.6.31).

Do not over scrape to remove high sides of oval pipes. It will reduce the pipe thickness.

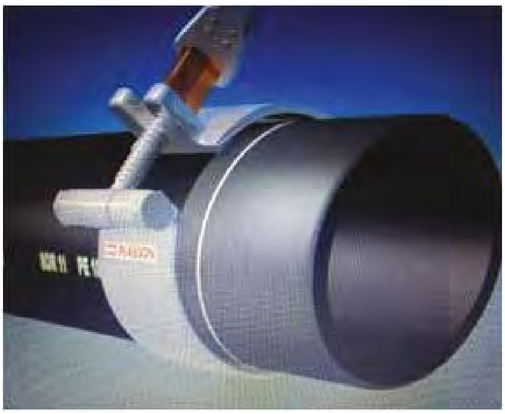


Fig. 2.6.30 Tightening to correct ovality

Fig. 2.6.31 Perfect circle after ovality correction

After tightening the pipe ends, pipes has to form perfect circle or within permissible tolerance limits. . Check the dimension to confirm that the circle is perfect / within permissible limit.

2.6.4.6 Large diameter re-rounding

Large diameter pipes having ovality, can be corrected using various tools and equipment.

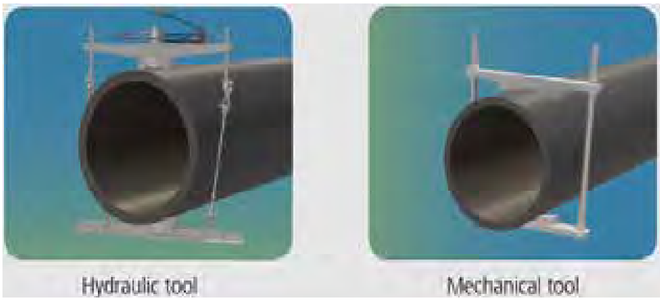


Fig. 2.6.32 Large dia re-rounding

Exercise

I. Answer the following questions.

1. What are the possible causes of PE Pipe out-of-roundness?

---

2. What is the need for out of roundness correction?

---

3. Explain the process / procedure of correcting out-of-roundness

---

II. State whether the following statements are True or False.

1. In general, the permitted offset (misalignment) is 10% thickness after setting both ends of pipes.

   True ☐ False ☐

2. PE Pipe out-of-roundness can have a negative effect on electrofusion joint quality.

   True ☐ False ☐

3. If the PE pipe flat spot is not eliminated, there is chance leakage.

   True ☐ False ☐

Notes

2.6.5 Electrofusion Joining Process

At the end of this topic, you will be able to:

1. verify the joint preparation
2. perform PE pipe electrofusion joint fitup
3. setup the equipment ECU and Power source
4. operate ECU and perform joint electrofusion.

2.6.5.1 Preparation for Joining PE Pipe

Clean the pipe end.

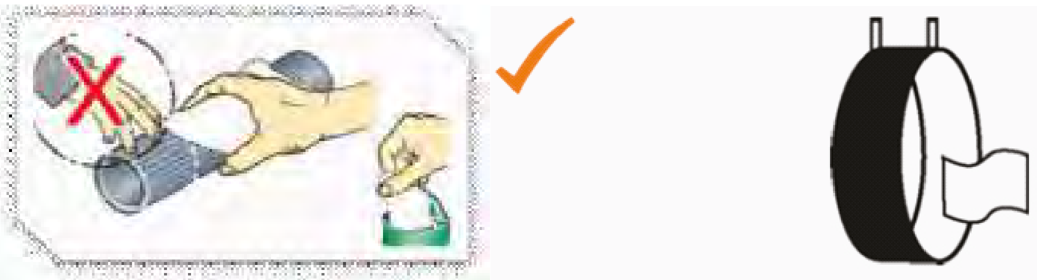


Fig. 2.6.33 Final cleaning

Remove the coupling fitting from its packaging and check the bore of the fitting is clean and dry. This should be performed visually with adequate light level, normally, at light intensity 1000 lux at the surface being checked.

Clean the coupling fitting inside using special solution and wipes (side to be inserted is cleaned covering with original package on other side).

Electrofusion sockets are able to weld same OD, but may be with different SDR pipes. Pipe fitter shall follow the drawing pipe size and the socket pressure rating and ensure that sockets / coupling pressure rating shall be equal or exceed the higher than that of pipe.

2.6.5.2 PE PipeFitup are and assembly

1. Fusion cycle

Four stages of electrofusion cycle are:

i. Warm-up: Pre-heating stage– The coupler receives power from the control box / control unit.

ii. Soak: Non-power stage–Heat is transferred through the coupler and into the connecting pipe.

iii. Weld (fuse): Main fusion stage – The coupler receives power from the electrofusion control box / unit and fusing the coupler to the pipe.

iv. Cooling: The alignment clamps must be left in place during the full duration of the cooling cycle.

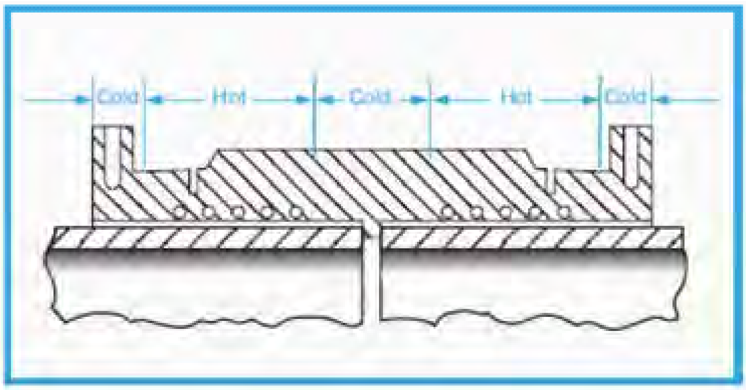


Fig. 2.6.34 PE pipe joint indicating cold and hot zones

2. Safety measures during fitting and fusion

Scraping/peeling tools can have sharp edges. Use with care to avoid injury. Tools should be in good working order and inspected before use for wear and/or damage. Damaged or worn tools should not be used until repaired.

Prepare electrical connections as per procedure duly following safety instructions.

During the heat fusion process, equipment and products can reach temperatures in the range of 231˚C. Caution should be taken to prevent burns. Do not bend pipes while into alignment, as the pipe may spring out and cause injury or damage.

Coiled PE pipe is restrained with strapping to contain the spring like energy retained within the coil. Cutting or breaking strapping can result in an uncontrolled release. Take necessary safety precautions and use appropriate equipment. Always follow safe handling instructions provided by the manufacturer.

The weight of the electrofusion coupler is detailed on the packaging label. Please follow published safety practices when handling couplers.

The surface of the fitting will become hot during the electrofusion process. Do not touch the fitting until it has fully cooled. Before carrying out an electrofusion joint, check and ensure that inside and outside of the pipe is completely dry.

Do not use the electrofusion fitting if the electrical terminal connections are damaged.

Thoroughly read and understand the Electrofusion Control Unit (ECU) and generator manufacturer operating and maintenance instructions prior to any welding operations. If necessary, discuss with supervisor or manufacturers representative or a competent person to have proper understanding of the equipment. operate the equipment with doubt.

Always keep in mind that the joint must be left in the clamps for the specified cooling time mentioned on the fitting, without any disturbance.

3. Pipe and Socket Coupling fitup / assembly

Open one side of the sealed bag containing the electrofusion fitting and slide it on to the pipe after ensuring that fitting bore is clean and dry. Electrofusion fitting may be coupler, reducer, elbow or Tees.

Insert pipe or spigot end into the electrofusion fitting up to the stopping mark. Ensure that pipe ends are in contact with the centre stop. Leave plastic bag over the other fitting end (refer fig 2.6.36) to prevent contamination and debris from entering the open end while working.

Assembly can be assisted by tapping around the face with a plastic hammer at the same time. Care should be taken for a low stress installation and do not tilt. Secure pipe and fitting against dislocation.

Check that full insertion has been achieved up to the markings. Some coupler have removable stopper which act as stopper. Ensure that the pipe cannot be inserted behind the center point.

Repeat process on second pipe end duly following all procedure for assembling other end of pipe. Remove the protection cover partially. Clean and insert the other end of pipe. Check that the insertion stop point marking is touching. Correctly position and fit the restraining clamp to the assembly.

Check the correct end position of the fitting between the marks on both pipe ends. Clamps should always be used to secure an electrofusion assembly during the fusion cycle.Appropriate clamps shall be used based on the profiles / position of fittings (coupler, reducer, elbow, tees etc).

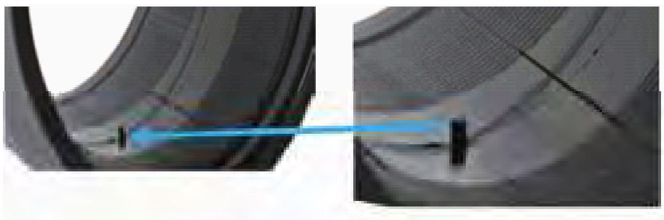


Fig. 2.6.35 coupler having removable stopper

Fig. 2.6.36 pipe and socket 1st assembly

Fig. 2.6.37 Pipe and socket full assembly

Fig. 2.6.38 Check the fitting for gaps

Check the gaps between pipe and coupling / socket (Refer fig 2.6.38) and ensure zero gap or within the permissible limit. All joints prepared for fusion must be stress-free (no bending, self-loading or misalignment stresses). If required, use alignment tools or similar measures, to guarantee a stress-free installation. Set the assembly on clamps and check level along using water pass / sprit level to avoid any stress during fusion heating. This helps to keep the pipe aligned during electrofusion and no load will be transferred to joint.

2.6.5.3 Electrofusion process and sequence

1. Electrofusion process requirements

Before starting the fusion process, ensure that both the pipe and the coupler are adequately supported to stop / prevent any 'sagging' during the fusion process and avoid any tension on the coupler. Ensure that no abnormal load is applied to the assembled joint. Any load on joint due to pipe tension or other disruption may cause incomplete exchange of melt. Eliminate or at least minimize potential short-stab, mis-stab or binding defect situations by

i. Ensuring proper cold-zone contact with the prepared fusion area so that sufficient interfacial pressure is built up.

Fig. 2.6.39 Electrofusion arrangement

Fig. 2.6.40 Correct support placement

Fig. 2.6.41 Incorrect support placement

ii. Eliminate unwanted loss of molten material from the fusion zone (resulting loss of interfacial pressure can be a source of voiding or adefective and unsatisfactory joint).

iii. A properly prepared and assembled joint (refer fig 2.6.39) that is kept stationary and freefrom stresses and strains during the fusion process and recommendedcooling time should have good joint integrity.

Supports: If cribbing or pipe stands are used to support the pipeline while an electrofusion joint is being made, ensure that the supports are placed on both sides so that no weight is being supported by the electrofusion fitting and that no bending stress is exerted on the joint area. For correct and incorrect support placement refer fig 2.6.40 and 2.6.41 respectively.

All welding electrical equipment should be checked to ensure it is in good operating condition due to the long weld times in large bore fittings. Check and ensure that there is sufficient fuel in the generator to complete the joint. Damaged leads, loose terminal tips, poor connections could result in over heating or electrical faults/ overheating during welding.

Remove the terminal protection caps from the terminal shrouds. Connect the ECU output leads to the fitting terminals(refer Fig 2.6.42) and set the controller timing as recommended by the manufacturer (marked on coupling or see written procedure).

Fusion parameters are given by a bar code label (Refer fig 2.6.44) on the fitting. They are automatically converted by the reader wand or scanner of the fusion box (Refer fig 2.6.43). It is recommended to use automatic fusion process documentation and traceability function, which have to be activated at the fusion box / control unit.

Keep a distance of one meter to the fusion siteduring the fusion process for general safety reasons and control and supervise the fusion process.

The above fitting label indicates the requirement to fusion weld for 200 sec at 40V and cool for minimum 17 minutes without disturbance.

Fig. 2.6.42 Connecting leads to fitting

Fig. 2.6.43 Scanning the fusion bar code

Fig. 2.6.44 Fitting label indicating electrofusion parameters

If automatic information feeding is not possible, manual entry of fusion time and voltage entry as printed on the fitting label, will be possible. The fusion time is typically preceded by the word “WELD” or “FUSE” and displayed in seconds. The voltage is displayed and followed by “V”. It is always preferable to use the bar code method.Switch on the supply current and keep watch on timer. The controller automatically stops when the set timing reached. The heating and fusion process should be performed as per manufacturer recommendation and approved procedure.

2. Electrofusion process sequential procedure

When current is applied to the fitting, the plastic in the fitting and on the pipe surface begins to melt and form a melt pool. With continued application of current, the melt pool deepens at the pipe and fitting interface which in turn forces internal pressure to build up.

The whole cycle of electrofusion joining is electronically monitored by the ECU. Electrofusion jointing sequence from energising the coil until completion of fusion are depicted.

Fig 2.6.45 shows the completed pipe and fitting assembly readiness for electrofusioning.

Fig 2.6.46 indicates that coils energization has commenced. Observe that white dot in fig 2.6.45 turned into blue dot in fig 2.6.46.

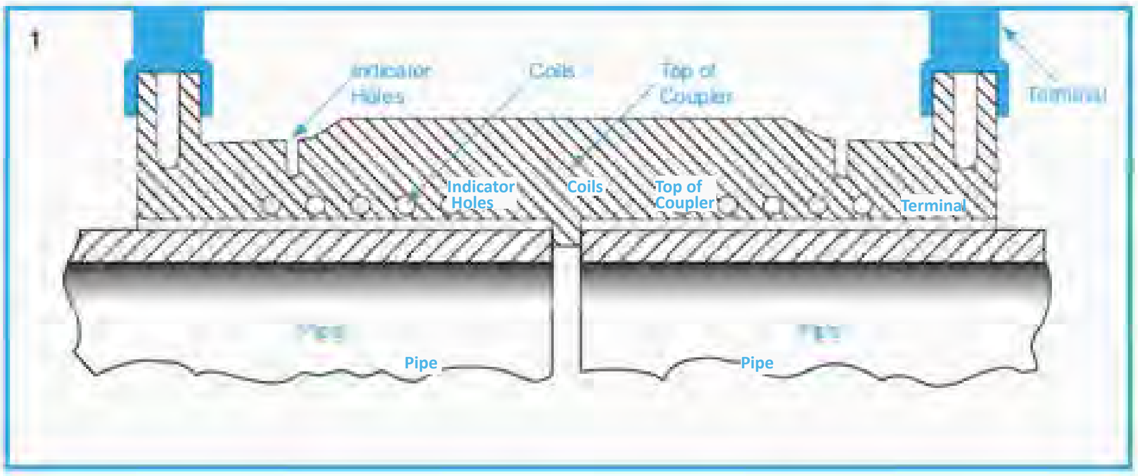


Fig. 2.6.45Pipe and coupling fit-up

Subsequently, material surrounding the coils commence to melt as shown in fig 2.6.47. Fig 2.6.48 depicts that area of material surface melting extends, leading to expansion towards pipe surface.

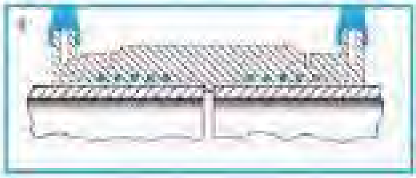


Fig. 2.6.46 Coil energisingFig

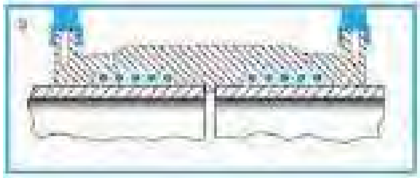


Fig. 2.6.47 Melting commences

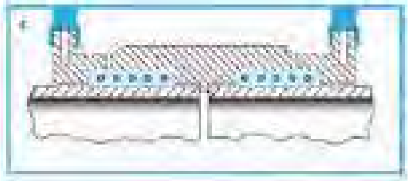


Fig. 2.6.48 Melting spreads to pipe

Fig 2.6.49 shows that heat is transferred to pipe wall and pipe material and melting continues both in coupling and pipe surfaces / interface.

Fig 2.6.50 illustrates that melts commences to solidify and thereby, sealing the melt zone. In the mean time, further input of heat energy causes increase in melt pressure.

Melt pressure reaches the optimum value, means that is to be the end of energising cycle.Figure 2.6.51 exhibiting the emerging of the melts through indicator holes, conveys that melting and fusion has been completed /

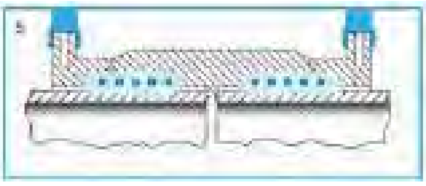


Fig. 2.6.49 Pipe material melting

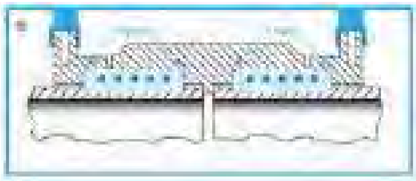


Fig. 2.6.50 Melt fuse and solidify

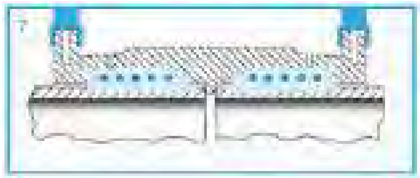


Fig. 2.6.51 Melt & fusion completion

accomplished. That is, pressure created by molten PE during heating process inside the joining surface force out the indicator lugs. This is visible sign that sufficient weld pressure is created.

Allow the electrofused side to warm (heat soak) for a minimum of 15 minutes and a maximum of 20 minutes. this will allow the pipe enough time to expand inside the coupler. It may be necessary topreheat more than once, if recommended, by the manufacturer.

3. Interaction of fusion process

In order to help understanding the importance of this stage, we shall look at the full fusion cycle and follow its phases:

The Polyethylene on the fitting side begins to melt and its volume increases.

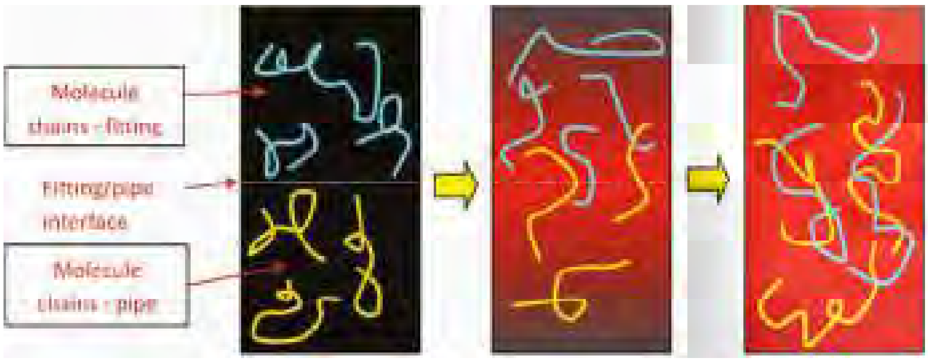


Fig. 2.6.52 Intermingling of PE chains of pipe and fitting during heating

The melt begins to flow and fill the gap between the fitting and the pipe, and once the pipe surface comes in contact with the hot flowing melt, it starts to melt as well and a "melt pool" starts to build up between fitting and pipe as the current continues to be applied.

If melts through the indicator holes are not visible, the operator / supervisor shall check the following so as to determine whether the joint fusion satisfactorily completed or not:

i. Dimensional check and compliance of pipe OD and ovality. The pipe dimension within fusion zone should be compliant with standards.

ii. Input power supply to the ECU is stable without disruption and does not show any error message on the display panel.

iii. Heat fusion parameters are correct.

iv. The pipe to fitting alignment is correct and no visible plastic is extruded out from the fitting.

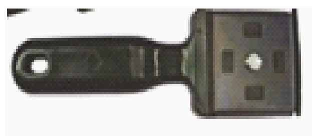
It is possible that a good weld fusion might have been achieved even if the melt indicator does not rise. If above parameters have been checked and "no problem" is detected, the weld need not be rejected, provided it passes the visual inspection and pressure test.

2.6.6 Identify the Type of Flanges

At the end of this exercise, you will be able to:

1. perform PE piping joining and electrofusion welding.

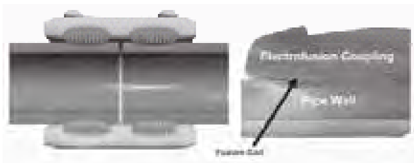
Practical

Requirements	
Tools/Instruments Measuring Tape – 1 No. Scale,Try-Square –EA – 1 No. Vernier Caliper –EA – 1 No. Marking Pin –EA feeler gauge –EA – 1 Set **Equipment/Machines** Electrofusion Welding Unit with scanner and power source. – 1 No.	**Materials/Components** Electrofusion coupler – 2" Ø, – 1 No. HDPE pipe –2" Ø, 200 mm Long – 2 Nos. MDPE pipe-2" Ø 200mm long – 2 Nos.   

Work Instructions

1. Ensure that electrofusion procedure has been qualified and fitter / operator has been trained and certified.
2. Select suitable coupler according to the diameter of pipe and SDR ratio. Check the coupler for any damage / defect.
3. Check proper scraping of pipe. Mark the insertion depth again as it might have been cleaned during scraping and cleaning activities.
4. Insert 1st pipe into the coupler with mild force up to insertion depth.
5. Insert the second pipe to be joined, in the other side of the coupler without contaminating the surface preparation, up to insertion depth.
6. Using feeler gauge, check the gap between the pipe and coupler and ensure that gap does not exceed more than 0.1 mm anywhere.
7. Before starting the fusion process, ensure that both pipe and coupler are adequately supported to stop / prevent any 'sagging'.
8. Ensure that no abnormal load is applied to the assembled joint.
9. Remove terminal protection caps from the terminal shroud.
10. Connect the ECU output leads to the fitting terminals.

11. Connect ECU to the appropriate power source.
12. Start EFU, scan the barcode with the help of barcode scanner.
13. After the barcode scanning, the machine will ask “have you completed scraping?”.
14. Press “ok” button. Again push the “ok” button to start the welding.
15. According to the barcode data, the welding will be completed as per the time indicated on the coupling.
16. Watch the indictor hole. The emerging of the melts through indicator holes, conveys that melting and fusion has been completed / accomplished.
17. When electrofusion welding is completed, an alarm will be made by the EFU. As soon as alarm heard, stop the machine and remove the leads.
18. If timer has been built-in the EFU, switch on the supply current and keep watch on timer. The controller will automatically stop when set timing is reached .
19. Allow the electrofused side to warm (heat soak) for a minimum of 15 minutes and a maximum of 20 minutes. Do not disturb the joint and leave it for adequate cooling.
20. After cooling, write the operator identification number and other joints identification near the joint and perform visual inspection.




Tips

Safety Precautions Always wear safety gloves at the time of practical.

During the heat fusion process, equipment and products can reach temperatures in excess of 231˚C. Caution should be taken to prevent burns.
Keep a distance of one meter to the fusion site during the fusion process for general safety reasons and control and supervise the fusion process.

Exercise

I. Answer the following questions.

1. What are the safety measures to be followed / taken during PE pipe fitting and fusion?

----

2. What are the four stages of PE pipe electrofusion cycle?

----

3. Write work instruction for “Pipe and Socket Coupling Fitup / Assembly”.

----

4. Describe the requirements for PE pipe electrofusion process.

----

5. How will you eliminate or minimize potential short-stab, mis-stab or binding situations?

----

6. Explain electrofusion process sequence.

----

7. Illustrate with diagrams electrofusion phases.

II. State whether the following statements are True or False.

1. Electrofusion sockets are able to weld same OD with different SDR pipes.
   True ☐ False ☐
2. Sockets pressure rating shall be equal or be the higher than the that of pipe.
   True ☐ False ☐
3. Soaking is a non-power stage.
   True ☐ False ☐
4. PE pipe fitup / assembly can be assisted by tapping around the face with a plastic hammer.
   True ☐ False ☐
5. The alignment clamps must be loosened and left in loosened condition during the full duration of the cooling cycle.
   True ☐ False ☐

Notes

2.6.6 Electrofusion Joint Cooling and Completion

At the end of this unit, you will be able to:

1. explain the importance of electrofusion welding cooling phase
2. describe the electrofusion process fusion cycle with melt pool stages
3. perform fusion and cooling control check
4. determine the electrofusion joint failure reasons.

2.6.6.1 Criticality and importance of cooling phase

1. One of the most misunderstood and often ignored components of the entire electrofusion process is the cooling phase. It is often assumed that if the fitting is cool enough to touch, it must be cool enough to remove the restraint device or even pressure test the connections. This is incorrect.
2. The defined cooling time mentioned on the product barcode is an integral part of the electrofusion process and should be adhered to. It is a critical part of the welding process, and is often overlooked and misunderstood.

3. The cooling phase is critical to the success of the electrofusion process and careful attention should be given to insure that the stated cooling times are properly adhered to (refer to fitting manufacturer for respective / specific fitting cooling times).
4. Fusion strength can be affected, if the joint is not allowed to cool sufficiently.
5. It is important not to disturb the joint during its fusion or cooling period. Any movement or external stresses applied to the fused area during this cooling phase, may result in a compromised fusion joint. Adequate joint strength for field testing is attained when the fitting is not disturbed or moved until the joint material cools.
6. Do not allow pipe and fitting to be moved or exposed to stress before the minimum cooling time has elapsed! Comply with the specific cooling times given by the fitting manufacturer, before conducting any operations which could cause joint movement, for example, removal of clamps, pressurising the system or carrying out pressure tests.
7. Remove the clamps only after the cooling period has elapsed.
8. Note the time at ECU machine. Stop and allow cooling time as recommended. Further working can be carried out after approximately 4 times of cooling time.
9. **Method of ensuring and recording timing**

Time at heating stop	time to cool	time to rework
10.30 am	10.30+ 17 min	10.47 + 4x 17 min
	= 10.47 am	= 11.55 am

10. Only after proper cooling and inspection, further operation like placing on trench may be carried out.

2.6.6.2 Electrofusion joint cooling phase

1. After the heating phase, the melt pool re-solidifies. This process is known as co-crystallization between the melted pipe and fitting material.
2. The cooling phase provides a controlled environment between the pipe and fitting where solidification can effectively take place.
3. This cooling phase begins immediately following the termination of the current being supplied to the fitting. It continues for a period of time beyond the point, where the PE polymer re-solidifies. This allows ample time for the fusion area to regain the strength and flexibility it exhibited prior to fusion.
4. The effectiveness of the cooling phase can be illustrated in the actions of the melt pool (Refer fig 2.6.53). We need to look closer at the melt pool stages created during the electrofusion process.
5. When current is applied to the fitting, the plastic in the fitting and on the pipe surface begins to melt and form a melt pool (A and B).
6. With continued application of current, the melt pool deepens at the pipe and fitting interface which in turn forces internal pressures to build up. This process is known as co-crystallization between the melted pipe and fitting material (C).
7. The cooling phase D combined with the design of the fitting) provides a controlled environment between the pipe and the fitting, where re-solidificationcan effectively takes place. This cooling phase begins immediately following the termination of the current being supplied to the fitting and continues for a period of time beyond the point, where the PE polymer resolidifies (also known as clamping time). This allows ample time for the fusion area to regain the strength and flexibility it exhibited prior to fusion.
8. Any movement or external stresses (binding, pulling, etc.) applied to the fused area, during this cooling phase, may result in a quality compromised fusion joint.

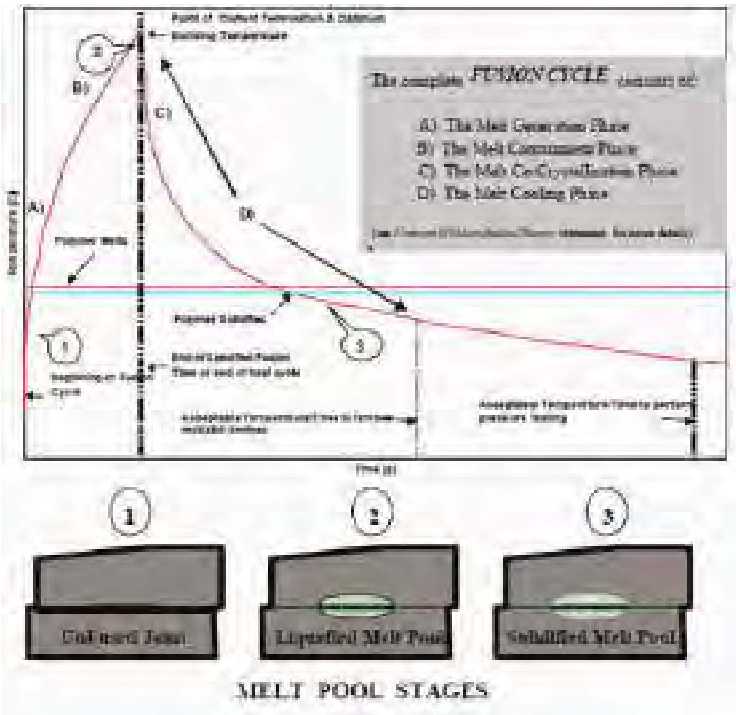


Fig. 2.6.53 Fusion cycle and melt pool stages

2.6.6.3 Fusion and cooling control check

During and after the fusion process, check and ensure the following:

- no error message on the fusion unit
- no melt exudation outside the fitting confines
- no unusual deformations of pipe or fitting
- fusion indicators show correct result
- fitting remains stress-free and avoids islocation until complete cooling time has elapsed.

2.6.6.4 Electrofusion joints failure reasons

Electrofusion has proven to be an extremely reliable joining system. All pipe fitters must aware about the reasons and root causes of failures to be cautious while doing pipe fitting and take appropriate preventive action to avoid any failures of PE pipe joints. The most common reasons for failure account for more than 96% of all fusion failures are:

i. poor pipe preparation and poor scraping

ii. contamination with Dirt, mud, dust, grease, oils, moisture and poor handling

iii. solvents, unsuitable wiping fluids, unclean or unsuitable wiping rags

iv. over scraping

v. geometry – pipe out of round or not cut square

vi. alignment Errors

vii. pipe mis-Stab – pipe not cut to square and pipe ends not being centered in the fitting

viii. short Stab – can result from improper insertion of the pipe or movement during weld due to incorrect restraint.

ix. excessive Gap – between pipe and fitting due to pipe out-of-roundness, undersized pipe or over scraping of pipe surface

x. pipe Movement during fusion cycle – due to external forces or forces induced by the welding process, when the pipes are not clamped properly

xi. movement – pipe not properly restrained during the fusion process

Tips

Unusual conditions - contact fitting manufacturers if smoke or melt flow outside the fitting is observed.

xii. removal of clamping equipment before observance of minimum cooling times.

2.6.6.5 Marking fusion parameters

Mark the relevant fusion parameters such as -date, joint number, fusion, machine identification number, fusion time, cooling time and welder/ operator name or identification number on the fitting / pipe and in the job site documentation. Electronically processed documentation and traceability via fusion box is recommended.

Exercise

I. Answer the following questions.

1. Explain the criticality and importance of cooling phase on PE piping electrofusion process

____

2. Describe the electrofusion process fusion cycle with melt pool stages.

____

3. What are the fusion and cooling control checks that will be performed by a pipe fitter / operator?

____

4. What are the reasons for electrofusion joint failure?

____

II. State whether the following statements are True or False.

1. If the fitting is cool enough to touch, it must be cool enough to remove the restraint device or pressure test the connections.

   True ☐ False ☐

2. Further working on electrofusion joint can be carried out after approximately 4 times of cooling time.

   True ☐ False ☐

3. If heating and soaking of PE pipe electrofusion is stopped at 3.00 PM of a joint needing 16 minutes cooling time, further reworking can be done after 4.20 PM.

   True ☐ False ☐

Notes

2.6.7 Saddle Support Installation and Welding

At the end of this topic, you will be able to:

1. describe and explain general procedure of saddle installation
2. locate, mark, clean and scrape the area of pipe where saddle is to be installed
3. fit / assemble PE pipe saddle properly and effectively clamp
4. fix PE pipe saddle by electrofusion weld.

The installation manual supplied by the specific saddle manufacturer should be strictly complied with as the requirements for clamping/ top loading of the saddles and the clamping techniques and

procedures, as each brand of saddle can vary significantly.

Saddle Specifications:

i. Rating – PN, SDR, etc. See drawing, specification mark on fitting.

ii. Unless otherwise specifically specified, size of saddle is indicated as matching pipe OD x Branch pipe OD.

Example 6x0 means, Matching pipe OD 65 mm, Branch outlet OD is 20mm.

Once received, the pipe fitter shall check and check of the saddle is as per approved drawing.

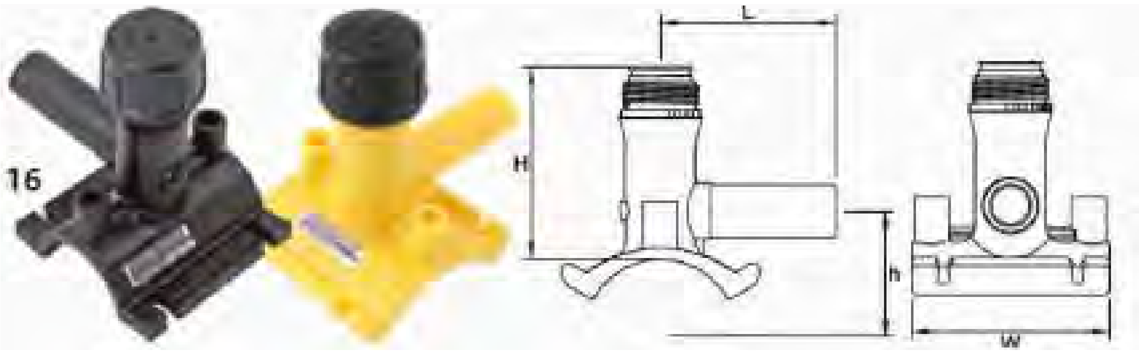


Fig. 2.6.54 Typical pipe saddles

2.6.7.1 Electrofusion saddle installation procedure – general

Saddle installation involves the following activities:

Mark the location and direction as per drawing.

Clean the area of pipe.

Scrap and clean seating area.

Clean the saddle bottom.

Prepare control unit, input parameters (bar code)

Clamp the saddle in location. Place saddle in the correct position and within the prepared pipe area. After clamping check to confirm that the gaps between saddle and pipe are within recommended levels.

Start and perform the fusion process in accordance with the manufacturer manual supplied by the respective / specific manufacturer of the fitting and fusion unit.

1. Locating saddle position, cleaning and marking

Locate the area on the pipe where the saddle will be applied as indicated.

Clean pipe to remove mud, dirt or other foreign material. For this initial cleaning, an area at least three times the width of the electrofusion saddle should be cleaned and marked. Water and a clean cloth can be used for this step as shown in fig 2.6.56.

- Dry the pipe and inspect for any embedded material on the pipe surface. Remove, if any.
- Make a mark on the pipe that is at least 3 times the width of the saddle base, with the intended fusion location centred between the marks. These marks are to indicate a cleaned pipe surface length limit that should not exceed when wiping with alcohol in subsequent steps. This is necessary to prevent the wipe from inadvertently contacting uncleaned pipe surfaces and potentially spreading contaminants onto pipe surfaces that were already cleaned.
- Clean this area with Isopropyl alcohol, wiping in only one direction, and not exceeding the area that has been marked. Allow the pipe to dry. Discard the wiping material and do not re-use.

Fig. 2.6.55 Location Marking

Fig. 2.6.56 Precleaning

Fig. 2.6.57 Area marking.

- Make a second set of marks slightly more than the width of the saddle to be installed. This mark is to indicate the scrape/peel length needed to ensure that at only peeled/scraped pipe will contact the saddle fusion surface (refer fig 2.6.57). It is good practice to scrape/peel a little more length than needed as visual evidence outside of the fusion area that proper preparation has taken place.

2. Scraping saddle area

- Mark the area to be scraped/peeled preferably in a criss-cross pattern.

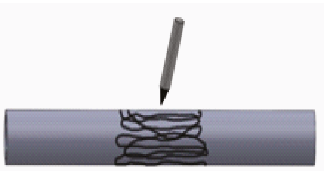


Fig. 2.6.58 Marking scraping area.

Fig. 2.6.59 Hand scraping

Fig. 2.6.60 Mechanical scraper.

- Scrape/peel the pipes as discussed in previous topics, to remove the surface layer and expose clean virgin pipe beneath. (Refer fig 2.6.59)
- Mechanical scraper can be used as shown in fig 2.6.60. Mechanical scrapers are available to facilitate pipe preparation for top loading Tees and branching saddle connections.

3. Cleaning: Clean scraped surface of pipe and saddle bottom with lint–free wipes.

4. **Fitting and Clamping**

- Fit re-round clamps irrespective of pipe ovality as shown in fig 2.6.61.
- Inspect the scraped/peeled pipe surface thoroughly to ensure that all marks are removed and that only virgin pipe surface is exposed.
- Remove the saddle from the bag and place onto the scraped/peeled pipe surface. Secure the pipe and saddle fitting assembly by clamping to the pipe with the appropriate clamping device.

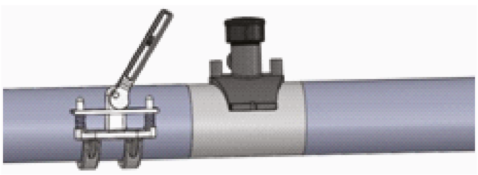


Fig. 2.6.61 Fitting re-round clamps

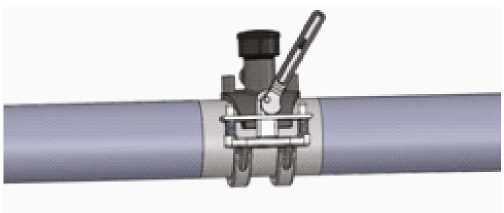


Fig. 2.6.62 Belt clamp type

There are different types of clamps available. Some are typical as is fig 2.6.62 belt clamp type, fig 2.6.63 pedestal type clamps, Fig 2.6.64 standard under clamps. Appropriate clamp type should be used based on diameter and configuration.

Fig. 2.6.63 Pedestal type clamping

Fig. 2.6.64 Standard under clamp

Fig. 2.6.65 Saddle and clamp fixing

- Pressure is applied such that good setting is achieved (Refer fig 2.6.65) Use feeler gauge to check gap between pipe and saddle (insert only few mm).
- Check the position, alignment and verticality of saddle and ensure it is acceptable.

5. Saddle electrofusion process – general

- Connect the terminal cable from control unit and follow all heating.
- Scan the barcode for input parameter to control unit (refer fig 2.6.67).
- Maintain the fusion force for 5 minutes on 42 mm pipe size (1¼ ") and 10 minutes on larger sizes.
- Joint shall be cooled for additional 30 minutes without any disturbance as discussed in previous topic. During cooling, rough handling shall be avoided. Also tapping, connecting to branch outlet or pressure testing are to be avoided.
- After fusion joining force has been applied, never reduce fusion joining force till the end of first cooling period. The saddle fusion machine may be removed after the first cooling period has ended, but without disturbing the joint.

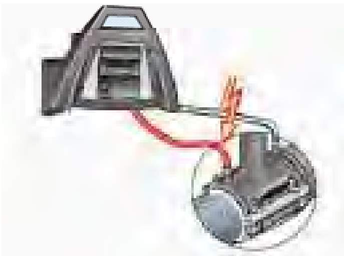


Fig. 2.6.66 Connecting terminal cable

Fig. 2.6.67 Scanning barcode

2.6.7.2 Saddles / saddle fittings installation – 8", 10" & 12" fitting bases

Electrofusion joining procedures for sidewall /saddle fittings for use with Top-Load Clamp on 8", 10" & 12" fitting bases is explained in this section.

1) Equipment needed include :

a. Top load clamp (fig 2.6.67)
b. Top load clamp fitting adapters (fig 2.6.67)
c. Electrofusion processor
d. Sure-form scraper
e. 8", 10" or 12" Electrofusion saddle fitting
f. Permanent Marker
g. Re-rounding clamps (if necessary)

Fig. 2.6.68 Top-load clamp with fitting adapters

Fig. 2.6.69 Pipe with re-round devices

2) Place fitting on pipe and mark area to be scraped. If the pipe is out-of-round, use re-rounding devices on both sides of the area to be fused before proceeding (Refer fig 2.6.68).

3) Using a scraping tool, remove the outer layer of pipe in order to reach virgin material.

4) For installing a "Tapping Tee", remove the cap from fitting.

5) Taking care not to contaminate the scraped pipe surface, attach the "top load clamp" and fitting to the pipe. Hold the fitting in place and lower the cross bar. Then lock in place.

6) Begin applying pressure to the fitting by turning the handle clockwise.

7) Tighten until indicator post located in the centre of the handle is flush with the top of the handle.

8) Attach leads and verify fusion time. Refer fig 2.6.70.

9) Press 'start' button on electrofusion processor.

10) Upon completion of the fusion cycle, allow the fitting to cool for recommended cooling time. DO NOT remove the clamp until the fusion cycle and the cooling cycle are complete.

Fig. 2.6.70 top handle

Fig 2.6.71 Saddle electrofusion arrangement

Tips

CAUTION: Over/Under tightening could result in defective joints.

Clamp weight may need to be supported if fusing to areas other than the 12 o'clock position on the pipe.

Tapping Tees must remain immobile until it has properly cooled. Outlets may be prepared prior to the Tapping Tee installation or at least 10 minutes after the Tapping Tee has been fused to the pipe.

In general, installing 8", 10" and 12" Electrofusion Saddle Fittings can be accomplished at a temperature range of 40˚F to 120 ˚F.

2.6.7.3 Larger diameter saddle installation instructions

1. Scrape and clean the pipe. If manual scraper is used, scraping should be performed twice. Then locate the saddle on the pipe.
2. Place appropriate tightening plate as depicted in fig 2.6.72 according to saddle type and size over the saddle outlet.
3. Fit the jig ring as shown in fig 2.7.73. Place in the appropriate direction of curved area on the spigot diameter used (may be 90mm, 110mm, 125mm or 160mm).
4. Shift the ratchet to its loose position, and attach to the hooks. Both pulling devices should be placed in the same direction.
5. Hooks and straps shall be tightened and fixed firmly as shown in fig 2.6.75. Tighten the strap first by hand and then using the ratchets until the gap in the Tension Force Indicator (TFI which is in red colour) is closed.
6. ECU should be connected and fusion welding can be commenced as depicted in fig 2.6.76. Weld the fitting. Remove the straps only after cooling time has elapsed.
7. Wait 4 x cooling time, then test weld integrity at 1.25 x maximum operating / working pressure.
8. Holes can be drilled in saddle and pipe as indicated.

Fig. 2.6.72 Locating saddle on pipe

Fig. 2.6.73 Placing tightening plate

Fig. 2.6.74 Fitting the Jig

Fig. 2.6.75 Hooking with ratchet

Fig. 2.6.76 Hooks strapping and tightening

Fig. 2.6.77 Performing fusion welding

Fig. 2.6.78 Testing joint integrity

2.6.7.4 Electrofusion joining procedures for branch saddle fittings (for use with T-Clamp)

1) Clean the area to be fused by removing dirt, mud, and other debris from pipe ends (pay close attention to the drill mud residue in trenchless applications). Clean water can be used for initial cleaning prior to scraping and isopropyl alcohol is recommended after scraping, if necessary.

2) Check the pipe for out-of-roundness condition. If the area to be fused is found to be out-of-round, take the appropriate steps to bring the fusion area back within the required tolerances. Use a .015” feeler gauge to check interface gap.

Fig. 2.6.79 Checking interface gap

Fig. 2.6.80 Cutting pilot hole

Fig. 2.6.81 Location marking

3) Before placing the fitting, use a hole saw and cut an entrance / pilot hole that is smaller than the inside diameter of the branch saddle for the T-Clamp to be inserted through. (Refer fig 2.6.81)

4) Identify the location of the fitting to be installed on the pipe and mark the area with a non-greasy marker as depicted in fig 2.6.82.

5) Use your marks to ensure that the alignmentof the fitting is correct.

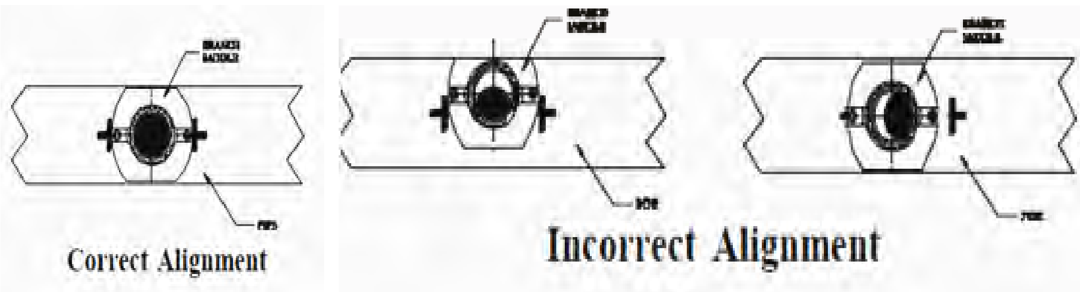


Fig. 2.6.82 showing correct & incorrect alignment

Fig. 2.6 .83 Proper handling

6) Check the pipe surface for any embedded debris that may cause damage to scraping tools ensuring that the outer pipe surface is clean and free of any dirt or mud that could recontaminate the scraped pipe surfaces.

7) Scrape the area to be fused with an approved scraping tool. Make sure that the appropriate amount of material is removed (approx. .007” to.010”).

Simply roughing up the fusion area will not allow an acceptable bond / fusion to take place.

8) Avoid touching the scraped pipe surface or the inside of the fitting as body oils and other contaminates can affect fusion joint performance. (refer fig 2.6.84)

9) If the surfaces become contaminated, clean thoroughly with a clean, lint–free toweland a minimum 70% concentration of isopropylalcohol and allow to dry before assembling.

Do not use alcohol with any additives other than water.

10) Avoid all possible recontamination of the prepared surface.Do not use abrasives, grinding wheels, or other devices that do not cleanly remove the contaminated material.

11) Place the fitting on the area to be fused as depicted and restrain using the T-Clamp.

Fig. 2.6.84 Fitting possitioning

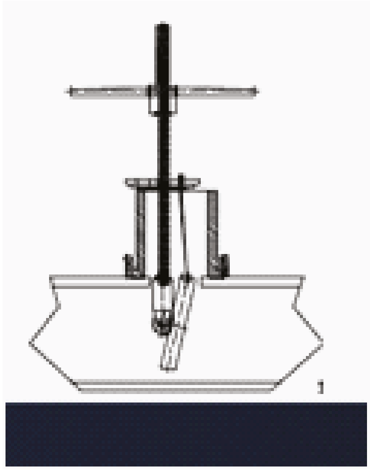


Fig. 2.6.85 Inserting T clamp

12) Insert the T-clamp through the top of the branch saddle and into entrance hole.
13) Tighten T-Clamp down until it is snug on the pipe surface. Then turn handle 1/4 turn more.

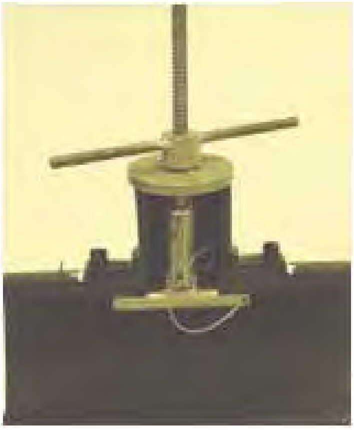


Fig. 2.6.86 Tightening T clamp

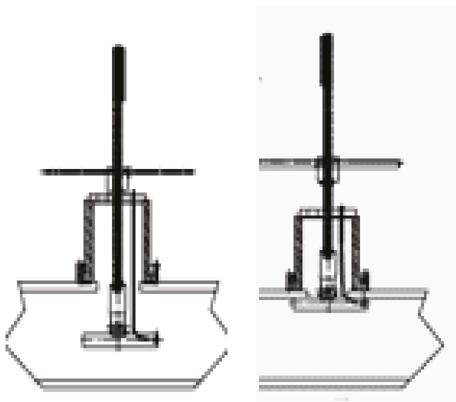


Fig. 2.6.87 Fusion arrangement

14) Check to make sure that there is no excessive gap between the pipe and the fitting. Use a .015" feeler gauge to check interface gap.
15) Attach processor leads to the fitting and proceed with fusion as described for standard joining as depicted in fig 2.6.88.
16) Disconnect and remove the processor leads when the fusion cycle has been completed.
17) Keep the pipe and the fitting restrained until after the fitting has completed the entire fusion cycle and the recommended cooling time. Note the time required before clamp removal and mark it on the fitting, if necessary.
18) Reverse the installation process to remove T-Clamp.

Exercise

I. Answer the following questions.

1. list out the PE pipe saddle installation activities.

----

2. Describe and explain the general procedure of saddle installation.

----

3. How will you locate, mark, clean and scrape the area of pipe where saddle is to be installed?

----

4. Explain the general procedure of saddle fitting / assembly and clamping.

----

5. Write work instruction for general saddle installation by electrofusion welding.

II. State whether the following statements are True or False.

1. If saddle size specified is "168 x 90", it means saddle length is 160 mm and width 90 mm.

   True ☐ False ☐

2. Installing 8", 10" and 12" electrofusion saddle fittings can be accomplished at a temperature range of 10˚F to 120 ˚F.

   True ☐ False ☐

2.6.8 Inspection and Testing of Electrofusion Joints

At the end of this topic, you will be able to:

1. perform in process inspection
2. check and fill electrofusion checklist
3. perform final visual and dimensional inspection of PE pipe electrofusion joint.

2.6.8.1 Progressive visual and dimensional inspection

1. Assembly and erection of piping is to be inspected in accordance with applicable codes / standards / specifications.
2. Visual examination is observation of the portion of components, joints, and other piping elements that are or can be exposed to view before, during, or after manufacture, fabrication, assembly, erection, examination, or testing. This examination includes verification of code and engineering design requirements for materials, components, dimensions, joint preparation, alignment, welding, fusion, bolting, threading or other joining method, supports, assembly and erection.
3. Defective material, joints, and other workmanship that fails to meet the requirements of applicable code / standard and of the engineering design shall be repaired or replaced at client's / owner's discretion.
4. In process Examination: In-process examination comprises examination of the following, as applicable:

- joint preparation, scraping and cleanliness
- preheating / warming
- fitup, joint clearance, and internal alignment prior to joining
- variables specified by the joining procedure, including current and voltage
- appearance of the finished joint.

2.6.8.2 Final inspection prior to pressure test

- Once joint fusion welding has been successfully completed, each joint shall be 100% visually inspected in accordance with applicable codes / standards and records maintained. Inspection and test shall include the examination for all possible defects. Frequently occurring defects with causes of defects are addressed for the pipe fitter to be cautious to eliminate these defects.

1. **Short stub:** Also called short stab / mis-stab is a defect caused by error in inserting. Mis-Stab is an unacceptable fusion (Refer fig 2.6.89 & fig 2.6.90). Pipe fitter has to mark and monitor stab depth correctly. This defect results due to:

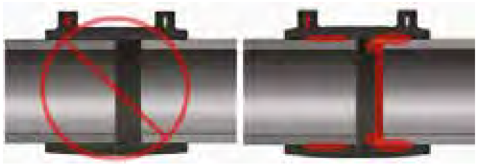
improper insertion of pipe

one or both ends not inserted up to stop mark and leaving centre gap

pipe is not centered into the coupling fitting

movement during weld due to incorrect clamping.

2. **Binding:** Binding (Refer fig 2.6.90) is caused by a severe misalignment or excessive lateral forces on the joint. This will also result in excess flow of molten metal, loss of pressure at fusion interface and poor joint integrity.
3. **Out of Square:** Shifting of both ends out of centre will lead to cause melting slip into pipe inside.



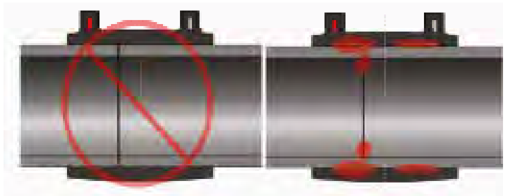


Fig. 2.6.88 Short / Mis Stab – Incorrect assembly *Fig. 2.6.89 Short stab and binding*

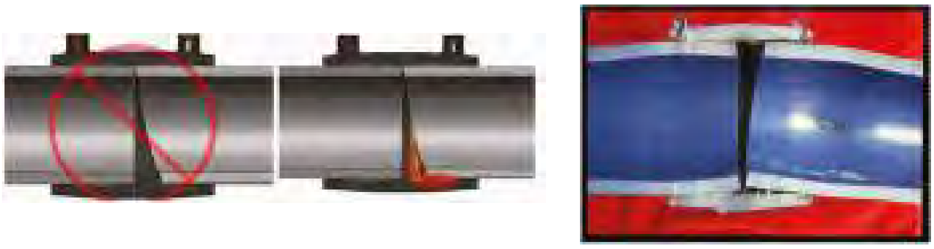


Fig. 2.6.90 Lack of square cut cause melt slip into pipe inside

4. **Improper Scraping and Scratch**

Refer figure 2.6.92. Radial depressions are created by the wire heating element of the fitting and indicate that the fitting has reached the proper temperature for fusion. This pipe section has many grooves and scratches from its insertion into a steel main. Scratches are a damage during transportation or handling of the pipe. These defects along with the dirt that has been melted into the surface make it apparent that no scraping or other pipe preparation was done.

Fig. 2.6.91 Improper scraping Fig 2.6.93 Excessive gap

5. When the gap between the pipe and fitting is excessive, the expansion of molten polyethylene cannot completely fill the space for a successful fusion as indicated in fig 2.6.93. This can be caused by undersized pipe, over scraping or severely out–of–round pipe.
6. Misaligned pipes may cause unacceptable fusion and possible causes are:

   Inadequate clamping or abnormal restraint during fusion. Proper alignment clamps shall be used to avoid misalignment.

   Due to high stresses on the joints, moving wires result in overheating and melt flow at the inner or outer cold zone (refer fig 2.6.94). Overheating can cause voids or pipe/ fitting deformation.

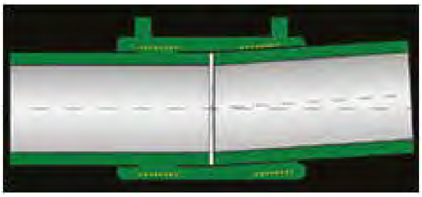


Fig. 2.6.92 PE Pipe Misalignment

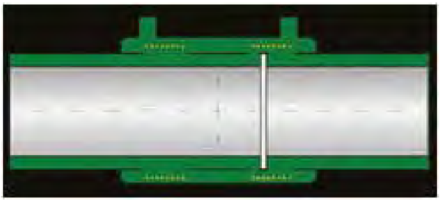


Fig. 2.6.93 Pipe not centered

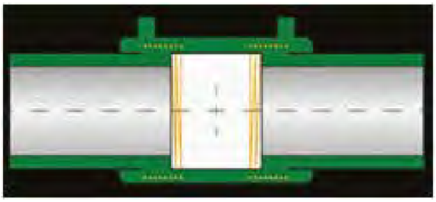


Fig. 2.6.94 Insufficient insertion

7. **Pipe joint not centred:** If the pipe is not centred, not properly cut or not fully inserted into the fitting, melt and wires can cause uncontrolled flow into the pipe gap. (Refer fig 2.6.95) Overheating can cause voids or pipe/ fittingdeformation. Mark insertion depth and control penetration. Use alignment clamp to avoid pipemovement. Fig 2.6.96 indicates insufficient insertion.
8. **Insufficient peeling:** The oxidized surface is not sufficiently removed by mechanical scraping. This will result in insufficient bonding/ fusion as indicated in fig 2.6.97 and leakage may occur.

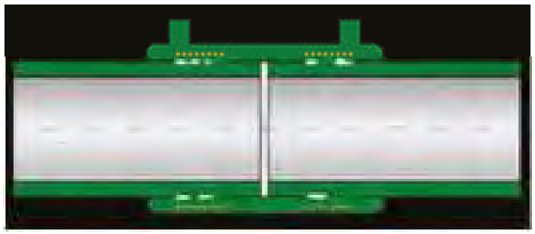


Fig. 2.6.95 Insufficient Peeling / Scraping

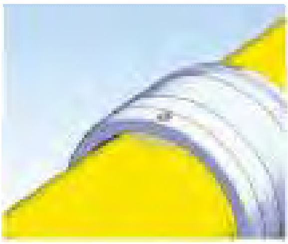


Fig. 2.6.96 Melt out


Fig. 2.6.97 Exposed wire

   Use mechanical scraping tool and control chip removal frequently to create a consistent and reliable scraping result.

9. **Melt out / Exposed wire:** It is an unacceptable fusion and possible causes are, pipe ovality, flat spots, undersized pipe, misalignment etc.

2.6.8.3 Pressure testing

Pressure testing shall be performed as required and pressure test records shall be prepared and compiled of each piping system during the testing, including (a) date of test, identification of piping system tested, test fluid, test pressure, certification of results by examiner.

Typical check List For Electrofusion Welding

Isometric No :	Drawing No :	Sheet No:	Joint No:
Pipe class / spec	Pipe manufacturer:	Pipe dia & thick:	Pipe SDR:
Fitting class / spec:	Fitting manufacturer:	Fitting dia & thick	ECU make &model:

Sl. No.	Activity	Tools	Status	Qc -Clearence
	Visual check in internal and external surfaces of pipe and fitting for contaminations, damages, debris etc	Visual with adequate lighting		
	Cleaning	Pure Water		
	Drying	Wipe cloth/hot air		
	Edge cutting and squareness	Cutter, tri-square,		
	Marking	pen		
	Surface preparation and scraping	Appropriate Scrapers		
	Scrap removal checking	Visual		
	Edge /corner trimming and deburring	Scraper / trimmer		
	Marking	pen		
	Cleaning prior to installation	Iso prophyl solution/wipe		
	Ovality Check and Re rounding	Re round clamp / fixtures and measuring instrument		
	Insert /clamping and checking	Coupler/fitting, check the gap with feeler gauge		
	Alignment and fit-up check	Supports / roller guides, measuring tapes		
	Power supply	Generator		
	Plug connection	Welding terminal from Control Unit		
	Input Data	Control unit		
	Welding/fusion	Control unit ON		
	Heating and cooling	Control unit –programmed		
	Inspection	Visual		
	Pressure Testing	Test manifold with gauge and test medium		

Observed Workmanship Condition Of Fusion Beeds	Possible Cause
Excessive double bead width	Overheating; Excessive joining force
Double bead v-groove too deep	Excessive joining force; Insufficient heating; Pressure during heating
Flat top on bead	Excessive joining force; Overheating
Non-uniform bead size around pipe	Misalignment;Defective heating tool; Worn equipment; Incomplete facing
One bead larger than the other	Misalignment Component slipped in clamp; worn equipment Defective heating tool; Incomplete facing dissimilar material – see note above.
Beads too small	Insufficient heating; Insufficient joining force
Beads not rolled over to surface	Shallow v-groove – Insufficient heating & insufficient joining force Deep v-groove – Insufficient heating & excessive joining force

Beads too large	Excessive heating time
Square like outer bead edge	Pressure during heating
Rough, sandpaper-like, bubbly, or pockmarked melt bead surface	Hydrocarbon contamination

Exercise

I. Answer the following questions.

1. Explain visual inspection and in process inspection requirements.

----

2. List out any six electrofusion joint defects.

----

3. What could be the reasons for short–stab / Mis-stab defects in electrofusion joints?

----

4. What could be the reasons for electrofusion joints misalignment?

II. State whether the following statements are True or False.

1. In PE pipe electrofusion joint, binding is caused by a severe misalignment or excessive lateral forces on the joint.

   True ☐ False ☐

2. Possible causes of melt out / exposed wire in electrofusion joint is pipe ovality, flat spots, undersized pipe, misalignment, etc.

   True ☐ False ☐

3. In electrofusion joint, shifting of both ends out of centre will lead to melting slip into pipe inside.

   True ☐ False ☐

Notes

Notes

Notes

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=rK8Li4a4s9Y&t=58s

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=Vb458tuDY1M

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=Nh5uO6PmHp8

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=cCsVxWwRN90

Skill India

GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

N·S·D·C
National
Skill Development
Corporation
Transforming the skill landscape

HYDROCARBON SECTOR
SKILL COUNCIL

3. Work Effectively in a Team

Unit 3.1. Team Work

HYC/N6103

Key Learning Outcomes

At the end of this module, you will be able to:

1. determine the importance of communication with team members
2. maintain clear communication with colleagues
3. work with colleagues as a team
4. work in ways that show respect to colleagues
5. carryout and meet commitments made to colleagues
6. identify problems in team work and take initiative to resolve them
7. follow the organization's policies and procedures for working with colleagues
8. share resources with other members as per task priorities.

3.1 Team Work

Unit Objectives

At the end of this unit, you will be able to:

1. determine the importance of communication with team members
2. maintain clear communication with colleagues
3. work with colleagues as a team
4. work in ways that show respect to colleagues
5. carryout and meet commitments made to colleagues.

3.1.1 Importance of Teamwork

At the end of this topic, you will be able to:

1. determine the importance of teamwork
2. determine the needs for teamwork
3. find ways to enhance teamwork
4. list out the benefits of teamwork
5. explain the effectiveness of teamwork
6. describe teamwork in city gas distribution facilities.

3.1.1.1 Introduction to Teamwork

- Teamwork is the collaborative effort of a team to achieve a common goal or to complete a task in the most effective and efficient manner.
- Teams are viewed as group (s) of two or more individuals who must interact cooperatively and adaptively in the pursuit of shared objectives.
- Modern organizations have widely adopted team approach as a way of accomplishing tasks that surpass the capabilities of individuals.
- Teamwork originates with and builds relationships among a group of people who share a common interest or purpose.
- Teamwork includes open communication with everyone contributing to improve work efficiency.
- A team that works well together can succeed together and produce great results. Refer the examples in Figs. 3.1.1 and 3.1.2 which display successful teamwork and synergy.

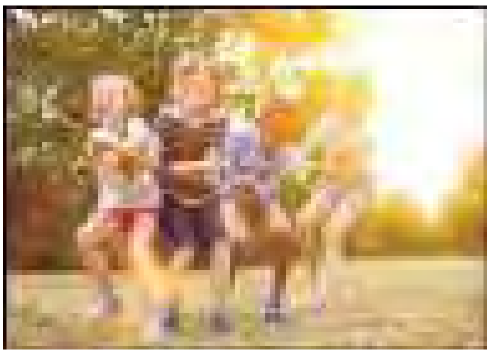


Fig. 3.1.1 Teamwork success brings cheers & prospers

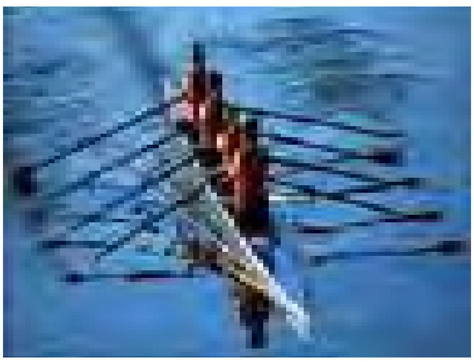


Fig. 3.1.2 Collaborative effort towards common goal

3.1.1.2 Effectiveness of Teamwork in City Gas Distribution/Installation facilities

- Teamwork is important for the successful completion of all city gas distribution construction facilities.
- A typical construction site includes many different trades, competing priorities and processing deadlines. In many work situations people meet and work as teams.
- In a construction project, there are many departments (teams) such as contract, finance, engineering / design, purchase / procurement, materials, quality assurance / quality control, HSE, etc. Teams supporting the construction team comprise–multi disciplines such as, civil, mechanical, electrical and instrumentation, piping, welding, painting / coating, duly form by individuals and teams. Hence, for a project to become successful, it needs teamwork of many group of teams. Piping / pipeline construction / installation activities need support of all the above teams either directly or indirectly.
- Cross-country pipelines and offshore pipelines installations involve fitting hundreds of joints and welding of large diameters (16 inch diameter to 36 inch diameter pipes) in a day and pipe laying for 2 to 3 kilometres a day. These cross-country pipelines and offshore pipelines installation involves many synchronized and simultaneous construction / installation activities which require effective teamwork not only within a team but with all other teams associated with pipeline works such as trenching, bedding, pipes stringing / fitting, lowering, fitting, welding, inspection and non-destructive testing (Radiography, Ultrasonic, etc), coating, backfilling, compaction, valves, gaskets installation and bolting, hydrotesting, etc.
- Time is very precise in cross-country and offshore pipelines installation. Pipeline laying equipment, cranes, and all other infrastructures will be left idle even if one team is not working effectively.
- Offshore pipeline installation is very challenging and critical. Adverse weather conditions such as wind speed, wind direction, sea waves, sea current, sea water flow direction, etc., will affect the progress of the pipeline installation work. Hence, personnel shall wait for the right time to commence the pipeline and complete the installation during favourable weather conditions.
- Thousands of rupee are spent on are installation costs for each second. If one team is not working effectively, collective teamwork gets affected, leading not only to the cost of installation going up, but subsequent activities and processes such as project construction, commissioning, operation and first oil production etc., will get delayed leading to a loss of millions of rupees.

3.1.1.3 Benefits of Teamwork

- By working together, teams can find the solutions that work best.
- Teamwork is good opportunity for everyone to exchange ideas and come up with creative ways of doing things.
- Team projects encourage employees to feel proud of their contribution.
- It encourages and nourishes new / fresh ideas and in sights to succeed in a competitive world.
- Turn knowledge into practical results that improve the organization´s services.
- Use a variety of communication processes (including technology) to support the sharing of information, knowledge and experience.
- Promote a culture of innovation to improve services and reach goals.
- Once a team succeeds, their brainstorming sessions will produce revolutionary ideas without hesitation. In many cases, the riskiest idea turns out to be the best idea.
- Teamwork allows employees the freedom to think different.

Team work boosts productivity as working within a team allows for shared workload among members and distibution of work according to each member’s skills and strengths.

- combining the talents of many individuals and therefore contributiob shall be more than the sum of the individual members.
- more hands on deck so that tasks are completed faster and more efficiently, thereby increasing productivity.

Fig. 3.1.3 Team work

Exercise

I. Answer the following questions.

1. Define teamwork.

2. What are the benefits of team work?

3. How dose teamwork boost productivity?

II. State whether the following statements are True or False.

1. Team work motivates unity in the workplace to work efficiently, and be supportive of one another.
   True ☐ False ☐
2. Creativity decreases when people work together in a team.
   True ☐ False ☐
3. Working as a team allows the members to take more risks.
   True ☐ False ☐
4. Open communication is restricted in teamwork.
   True ☐ False ☐

Notes

3.1.2 Communication in Teamwork

At the end of this topic, you will be able to:

1. determine the importance of communication with team members
2. list out the required primary communication skills
3. receive instructions and pass on information to team members
4. seek clarifications and advice from superiors/supervisor
5. list issues and problems
7. follow supervisor's instructions and advice
8. identify deviations, problems and issues and report to the supervisor.

3.1.2.1 Importance of Communication

- Communication is essential for achieving the organizations goals as it increases confidence.
- One of the most important characteristics of a good team is open communication.
- Good communication helps employees become more involved in their work with positive attitude.
- Clear, precise and timely communication of technical information prevents the occurrence of organizational problems, prevents reworking and eradicales time delay.
- A team that encourages open communication allows everyone to share their ideas and opinions without fear.
- When one communicate well within the team, it helps to eliminate misunderstandings and encourages a healthy and peaceful work environment.

Primary communication skills include:

i. the ability to articulate and express ideas and thoughts.

ii. the ability to listen attentively and actively.

iii. the ability to express, read, interpret and respond appropriately to non-verbal communication.

3.1.2.2 Effective communication with colleagues

a. Speaking with discretion and talking face to face

(i) Speaking with discretion prevents misunderstandings with colleagues. Face to face communication helps to build trust and enables us to sense and understand different points of viwes and open mindedness others feelings.

(ii) Offer constructive criticism

When giving feedback, personal feelings shall be left out. It must be cusured that coworkers fully understands, the message / information communicated.

(iii) Keep spoken and written communications short, simple and direct

Tips

When communicating with colleagues maintain confidentiality, and treat them as we would like to be treated.

b. Listening actively

- Listening actively shows that we are interested in the person's speaking to say and indicates that we respect them. One needs to listen closely, orienting oneself towards and look at them directly and maintain eye contact while they speak. It is essential *** to interrupt the speakers.
- Seeking clasification from the speaker is essential when is doubt. Avoiding any other work while listening is very important.

c. Reporting Issues

It is very important to report to the supervisor/site engineer of all work related issues that may affect work nature or quality. Immediate reporting of issues helps the superior/site engineers to resolve them before they affect the work progress, quality or cause damage to the site/workers or property.

(i) Deviation from the specification:

Significant change from the standard design requirements and specifications is called deviation. In case of any deviation from the drawing, specification procedure, site condition etc., it has to be reported to the supervisor.

The typical issues and problems that are to be reported include:

- Safety related problems and issues which need to be reported to safety officer. For example, unsafe act, risk identification, unsafe condition, near miss, etc.
- Non-availability of correct material, tools, equipment on time in the workshop/work site.
- Tools/equipment, materials that are not stored properly in the store/yard.
- Hazardous materials not being kept in the designated areas with correct marking.
- Routine housekeeping not being carried out.

3.1.2.3 Worksite Communication Methods

An organisations team focuses on common objectives and aims at finding solutions to shared problems. It uses formal processes such as work planning, facilitation, process execution and periodical review with respect to the benchmark to achieve its objectives. All these are communicated and shared with the teams in the site. Communication may be verbal, written, oral, face-to-face, visual, through display, through presentation, email, phone or through meetings and talks.

In each city gas sistribution site, many effective and efficient. They include:

i. providing copies of applicable work procedures, method statements, Inspection and Test Plans and work instructions to follow and case studies

ii. induction Training

iii. kick off meetings

iv. weekly safety and review meetings for all employees comprising all teams involved in the site.

v. daily tool box talk within team members

vi. displays and presentations.

1. Induction Training

- Induction training is a form of training given to new employees in relevant fields / areas of construction, HSE and quality. The training will enable them to identify and follow rules and responsibilities to perform in their specific job roles. Prior to employment, companies usually brief new employees about company policies and procedures involving safety and provide safety induction training. During safety induction, safety rules, safety requirements and safe working conditions with respect to the site conditions shall be explained.

Induction trainings include the following:

- The benefits of communicating information with the team members is outlined and benefits of working in a team, is explained. The layout of the workplace including entries and exits, location of facilities, first aid and security requirements are explained. Project specific conditions / requirements are explained. Project / Site specific health, safety, environmental and quality requirements are explained.

- Site specific rules that must be complied with are shared. For example, personal protective equipment (PPE) like hard hats that workers must wear and use. Roles and responsibilities are explained and clarified. Various communication channels and hierarchy are explained. Emergency contact numbers are given. Introduction to superiors, subordinates, colleagues and co-workers is done. Tour of the workplace, pointing out all important facilities is done. Instructions on how to complete day-to-day tasks in a safe manner are given.

Benefits of Induction Training

i. A strong induction process helps reduce stress and anxiety associated with a new job, increases confidence, improves morale and feelings about the new job and organisation. It also Increases the sense of acceptance into the organisation.

ii. Induction training helps employees to quickly adopt to new work environments and gets proper direction.

iii. New employees are made aware of specific site quality and HSE requirements.

v. New employees are able to quickly mingle with teammates / colleagues and feel safe and secured as they interact with other employees during induction training.

2. Kick off Meeting

- One appropriate situation to enhance team morale will be during the kick off meeting for a new project/new worksite or prior to starting any new critical activity. Starting with a kick off meeting is a common project management practice.
- The main purposes of the teams first meeting is to understand team tasks, level of requirements and the ways of achieving the same, assigning roles and responsibilities to and maintain effective working relationships among team members.

3. Tool Box Talk

- Tool box talks are one of the effective communication tools in the worksite for day-to-day activities.
- It helps to share knowledge, about work, abouth the organisation, safety procedure, to avoid delays and prevent processes form going wrong.
- Daily tool box talks are mandatory in oil and gas construction worksites and city gas distribution facilities.
- Tool box talk among the team members happen every morning commencing any work.

4. Daily tool box talks and discussion include:

- nature of the activity to be carried out
- Any specific requirements related to the process, product or services.
- list of materials required and their availability
- list of tools and machines required and their availability
- process details and resource allocations
- quality of the material available.
- safety safe work practices and their importance.

Exercise

I. Answer the following questions.

1. What are the benefits of effective communication with team members?

----

2. List some ways is which communication takes place is the worksite.

----

3. What is the purpose of induction training?

----

4. List the information that are discussed during toolbox talks

----

5. Why and when should issues and problems be reported to superiors?

II. State whether the following statements are True or False.

1. Distribution of approved construction/fabrication drawing to team members is very important.

   True ☐ False ☐

2. While conducting toolbox talks, safety and housekeeping are to be discussed.

   True ☐ False ☐

3. Toolbox talks are for all teams at a centralized assembly area.

   True ☐ False ☐

4. Toolbox talk is to discuss only safety related information and not for workrelated activities.

   True ☐ False ☐

Notes

3.1.3 Working with Colleagues as a Team with trust and respect

At the end of this topic, you will be able to:

1. explain the need for collaboration
2. develop good relationship with colleagues
3. work together with colleagues for a common goal
4. determine the value of teamwork
5. describe what teamwork trust and mutual respect are
6. list out ways to improve teamwork.

3.1.3.1 Collaboration

When empolyees work together towards a common goal they are in a team. Effective teams need to focus on both the group and the task. Trust, teamwork, communication and respect are keys to effective working relationships. Employees need to be aware of, the importance of working well with team members / colleagues. The development of team spirit requires frequent interactions among team members. Teamwork requires effective collaboration. The level of shared task, and awareness of expertise have a positive effect on the team as performance.

3.1.3.2 Team work

By working together, teams can find the solutions that work best. Often, a team works well together because team members rely on each other to bring individual talents to the table. Two heads are better than one to achieve the desired result.

Teamwork creates a system to ensure that deadlines are met and that there is high quality of work. When one colleague falls behind, there is another to pick up and complete it. Resources and information need to be shared with co-workers / colleagues, whenever required. Materials and tools borrowed from colleagues need to be promptly returned to maintain good relationship. Collaborating to come up with, hone and develop solutions is a great strength of working in teams. When people work together they can complete tasks faster by dividing the work to people of different abilities and knowledge. This helps accomplish tasks faster. A shared mission can help a group of people work together and create enthusiasm. When everyone is using their own abilities to work toward a common goal, the result is greater than the efforts of a single person, duly contributing to a smooth operation.

Fig. 3.1.4 - Teamwork is Key to Success

3.1.3.3 Hierarchy and Rapport

Each team member shall work in ways that show respect for colleagues and superiors and subordinates. They shall maintain good relations and ensure good rapport / with team members. Other's ideas, communication abilities, background, religion, work style and cultural traditions need to be respected.

3.1.3.4 Ways to Improve Teamwork Efficiency

Timely sharing and distributing collected materials, tools and tackles across the project team members as required, will improve team efficiency. Taking initiative to solve problems that arise during work is essential.

Commitments made to colleagues and superiors, need to met or time. This shall demonstrate that others can count on you.

Letting colleagues and superiors know in good time if work cannot be carried out as committed by duly explaining the reason is important. One should take responsibility for not meeting the commitments.

Exercise

I. Answer the following questions.

1. Why is collaboration important in teamwork?

----

2. How does one develop working relationships with colleagues?

----

3. How can teamwork efficiency be improved?

----

4. How can one be a good team member / colleague?

II. State whether the following statements are true or false.

1. Teams work well without collaboration.

   True ☐ False ☐

2. Team members don't rely on each other.

   True ☐ False ☐

3. Teamwork minimizes shared knowledge.

   True ☐ False ☐

4. Develop trust by gossiping.

   True ☐ False ☐

5. Teamwork does not necessitate confidence in each other's distinct abilities.

   True ☐ False ☐

Notes

3.1.4 Organisation's Policies, Procedures and Plans

At the end of this topic, you will be able to:

1. adhere to company policies
2. follow and implement organizational procedures and work as per method statements
3. implement Inspection and Test Plan
4. plan and execute day-to-day activities duly meeting the project schedules
5. develop work plan and organize required resources in co-ordination with team members
6. coordinate with team members to complete all assigned tasks.

3.1.4.1 Following and Implementing Organisation's Policies and Procedures

Each and every organisation / company has formulated policies, procedures and plans based on their objectives. All policies and objectives including safety policies are to be respected and adhered. Every employee is bound to work as per organisation / company policies and procedures. Pipe fitter shall go through the written policy statements of the organisation / company. Company / organisation policy not only productivity / delivery, but focuses on quality, safety, health, security.

The Pipe fitter has to follow all policies and implement the same. Similarly, the company may have various procedures like construction procedures, planning, execution, quality, monitoring etc. The pipe fitter needs to go through the relevant procedures, get doubts clasified with the supervisor, where necessary, follow and implement at all times.

A typical organisation will have various construction documents that include-Contract / Scope of work, Construction Plan and Procedures, Inspection and Test Plan (ITP), Method Statements, Work Instructions etc. These documents may be available individually or in combined form, depending on the quantum work of, criticality and applicability. The pipe fitter has to contact the supervisor and get access to the relevant documents / procedures, read, interpret is order to implement. These documents and drawings usually have revision number. Hence, the pipe fitter shall ensure with the supervisor that only the latest revision / version is following. Quality procedures will contain acceptance criteria or refere to acceptance criteria. A typical procedure will contain – list of reference documents, construction equipment, monitoring and measuring devices including their calibration requirements, working procedure, necessary inspection and testing, acceptance criteria and required quality reports / records. Procedure may include work instruction and methodology too.

3.1.4.2 Implementing Inspection and Test Plan (ITP)

Typical ITPs contain details about contract name / number, process description, where (location) it is applicable, for what (which item such as piping, equipment etc., for which project, for which discipline and responsibilities. ITPs have tabulation listing each step in the sequential manner, construction process activities / inspection stage, reference procedure, applicable industrial code / standard for each activity, acceptance standard, percentage of inspection, inspection level for the construction company, client and / or 3rd party inspection agency duly indicating / identifying inspection level / control points – Witness Point (W), Hold Point (H), monitoring (M) or Surveillance (S) or Random (R or I).

Hold Point (H): A 'hold' point is a mandatory inspection / verification / witness point beyond which work shall not proceed without approval / authorisation of the respective inspection party (only within construction company, client or 3rd party as applicable). Prior / advance notification the to respective inspection party is mandatory.

Witness Point: A 'witness' point provides a party (such as the customer, service provider and an inspection / regulatory authority) with opportunity to witness the inspection or test or aspect of the work at their discretion. Prior / advance notification to the respective party is mandatory. But, it is not necessary to wait for the respective inspection representative.

Monitoring / Surveillance: Intermittent monitoring of any stage of the work in progress is called surveillance. Prior notification is not required. Activity can proceed in routine manner. This activity is marked as 'I' or "M' in ITPs.
ITP requirements shall be complied with. As soon as the respective activities are completed, the pipe fitter shall inform his foreman / supervisor to arrange necessary inspection and testing as required by ITP. The pipe fitter shall not proceed to the next activity when the inspection indicated level is 'W', or 'H', till QA/QC team inspects and clears for further activities.

Typical inspection and test plan for process piping (controlling and reference / acceptance criteria will vary based on scope of work and contract specifications)

3.1.4.3 Sharing the Knowledge

To accomplish the task, the resource may be working drawings, working tools or equipment or knowledge, cranes / lifting equipment. Many groups in a location may be working with multidiscipline construction activities and more than one team may be assigned to perform pipe fitting works at a time with limited resources. For example, in case of crane / lifting equipment, a pipe fitter shall not demand separate crane / lifting equipment for them throughout the day, as the other group / teams will get affected. Hence, the pipe fitter should have ability to plan activities based on team priority as well the other teams priority / needs and share resources as much as possible to utilise the resources effectively and reduce the overall waiting time, idle time, overhead costs etc. In case, the crane is engaged with the other team, the pipe fitting team may plan and do other activities related to pipe fitting. Similarly, if the crane / lifting equipment is left idle, the pipe fitter immediately swing into action to execute the works which require crane / lifting equipment.

The pipe fitter shall liaise with the supervisor to know in the morning itself and if possible in the morning tool box talk, about the activities to be performed and have knowledge about available resources and execute the works accordingly.

Tips

While your strength may be creative thinking, a coworker might be good at organization and planning. Reinforcing both, will yield a constructive outcome. Hence, do not hesitate to share your abilities with the team.

3.1.4.4 **Planning and Organizing Resources and Working as a Team**

The process approach "Plan- Do- Check- Act (PDCA)" is a popular and effective tool / principle to any organization as a whole or each department to manage systems and processes. Each individual process / activity can be improved and made compatible by applying a Plan-Do-Check-Act approach.

In any organisation, the project / site activities are planned and scheduled by project planning and scheduling department using primavera, MS project or any other suitable programmed software and distributed to respective manager / supervisor for implementation and follow-up. Each team works with this plan and schedule. However, each activity has to be planned and executed in the field based on actual site conditions.

Work plan is required for an individual or group engaged in pipe fitting to accomplish a specific task to achieve target and deadlines. The advantages of work plan include:

i. prioritising work

ii. getting more work done in less time

iii. improving productivity

iv. producing quality work.

v. Achieving the target and deadlines in an efficient manner.

Fig. 3.1.5 Teamwork in construction sites

A pipe / pipeline fitting team shall plan their day to day work / activities, perform (do), verify / inspect (Check) and Act to improve the performance of processes of pipe fitting / jointing activities. The pipe fitting process has a set of interrelated activities using such as tangible input, piping materials, welding consumables, equipment and intangible ones like data, information, knowledge) to deliver the intended result of pipe fitting, welding and installation.

- If fit-up is okay, arrange for welding.
- If fit-up is not okay, analyse the root cause and do the needful to eliminate.
- Arrange to rectify / rework.
- Take necessary & tips / action for improvement to avoid recurrence.

- Study the workfront and priority and discuss with the superior about the next pipe installation / joint fit-up and the work plan (where, when, who,how).
- Make available approved procedures, drawings, WPS, ITPs.
- Arrange to receive the required piping material, ensuring material acceptance / release.
- Arrange welding equipment, electrodes / filler metals and all fitting accessories.
- Rise PTW and arrange cutting sets, grinding machines, fitting tools, clamps, etc.,

- Perform material cutting and prepare the joining edges.
- Visually inspect the prepared edges / weld faces.
- Align the pipe / pipe fittings and perform pipe fit-up as per drawing and WPS.
- If permitted, perform tack weld, otherwise, use pipe clamps.
- Notify QA/QC

- Monitor / measure / verify.
- Perform fit-up inspection / client inspection, where applicable.
- Perform dimensional inspection- level, position / location, orientation, alignment, root face, root gap.

Fig. 3.1.6 PDCA cycle

Sample format - Inspection and Test Plan

Sl. No.	ACTIVITY DESCRIPTION	CONTROLLING DOCUMENT	REFERENCE /ACCEPTANCE CRITERIA	VERIFYING DOCUMENT	Contractor	3rd Party	Company
1	Ensure availability of AFC drawings and approved procedures for piping installation	Document Status Register	Document Status Register. Information Management Plan	Document Status Register	R	R	R
2	Piping spools and piping materials (pipes, flanges, fittings, valves, gaskets, bolts and nuts, strainers etc). receiving inspection, material test certificates (MTC) verification	Material Receiving Inspection Procedure Material Identification and Traceability Procedure	ASME / ASTM piping Standard Drawing requirement and EN 10204, Contract specifications	Material Receiving Report, Project material status control log and Material Certificates	R	R	R
3	Piping materials handling, storage, preservation and protection	Material Control Procedure	ASME B31.3, Material Control Procedure, Contract specifications	Storage and preservation verification records	I	R	R
4	Verify that all piping materials are clearly marked with identification / traceability code prior to starting installation on the barge / worksite	Piping Fabrication Procedure Material Identification and Traceability Procedure	All traceability codes are clearly marked and transfer at all stages of fabrication and installation, ASME B31.3	Project material status control log and QC Control log	W	I	I
5	Ensure welding procedures and weld repair procedures have been qualified and approved by the Company	Piping and Structural Welding Book	ASME Sec IX, ASME B31.3, Contract specifications	List of approved WPS in the welding book	H	H	H
7	Ensure that Welder / Welding operator has been qualified for welding to be performed	Piping Welding procedure	ASME IX, ASME B31.3, Contract specifications	Welder Qualification Register	H	H	H
8	Piping alignment, position & orientation, elevation and levelness / straightness check	Piping installation procedure, Dimensional Control Procedure	AFC drawing, ASME B31.3, Contract specifications	Dimensional report, piping installation verification checklist	W	I	I

Exercise

I. Answer the following questions.

1. Describe the necessities and requirements for following and implementing organisation's policies and procedures.

   ----

2. What are the typical contents of "Inspection and Test Plan"?

   ----

3. Define the inspection levels 'hold point' and 'witness point'.

   ----

4. Justify knowledge sharing.

----

5. What are the advantages of 'work planning'?

   ____

6. Describe PDCA approach relevant to pipe fitting activity.

   ____

II. State whether the following statement True or False.

1. Method Statement is one of the construction document.

   True ☐ False ☐

2. Quality procedures will contain acceptance criteria or make reference to acceptance criteria.

   True ☐ False ☐

3. More than one team may be assigned to perform pipe fitting works at a time with limited resources. ITP will indicate respective activity inspection level / control points.

   True ☐ False ☐

4. Prior / advance notification to respective inspection party is mandatory if inspection level specified as "W"-witness point in ITP.

   True ☐ False ☐

5. Pipe fitter need not adhere to quality policy; but mandatorily with safety policy.

   True ☐ False ☐

Notes

Notes

Notes

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=fUXdrl9ch_Q

सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
& ENTREPRENEURSHIP

4. Follow Health, Safety and Security Procedures

Unit : 4.1 Knowledge and Practice of Health and Safety

Unit : 4.2 Fire Safety

Unit : 4.3 Safety Systems

Unit : 4.4 Emergencies, Rescue and First-aid Procedures

HYC/N 6104

Key learning outcomes

At the end of module, you will be able to:

1. identify and use appropriate personal protective equipment
2. identify job site hazards and state possible causes of risk
3. carryout safe work practices
4. state methods of accident prevention in the workplace
5. handle heavy objects safely using the correct procedure
6. work safely in pipeline trenches, elevated places and confined spaces
7. carryout good housekeeping practice
8. report all incidents to the supervisor
9. promote and maintain a positive safety culture
10. use the various fire extinguishers appropriately.

UNIT 4.1 Knowledge and Practice of Health and Safety

Unit Objectives

At the end of this unit, you will be able to:

1. identify and use appropriate personal protective equipment
2. state the names and location of people responsible for workplace safety
3. state the names and location of documents that refer to safety
4. identify job site hazards and state possible causes of risk
5. carryout safe work practices
6. handle heavy objects safely using correct procedure
7. work safely in pipeline trenches, elevated places and confined space
8. carryout good housekeeping practice.

4.1.1 Safety Standards and Personal Protective Equipment

At the end of this topic, you will be able to:

1. state applicable standards
2. explain the use of personal protective equipment.

Safety standards are standards designed to ensure the safety of personnel and products, production and activities. They may be advisory or compulsory and are normally laid down by an advisory or regulatory body.

4.1.1.1 Indian Safety Standards

IS 18001 – Safety management

IS 13367 – Cranes

IS 8235 – Equipment

IS 181 – Welding and thermal cutting

IS 2825 – Pressure piping

IS 2375 – Pipeline coding uses color codes

IS 5572 – Electrical safety

IS 7194 – Noise

IS 2190 – Fire safety

IS 2189 – Fire detection alarm

IS 3521 – Safety for Harness

IS 1179 – Ear protectors

IS 1179 – Eye & face protection

International Safety Standards

ANSI/ISEA Z87.1.2015 – American National Standards for occupational and education on eye and face protection devices

ISO 45001 – Occupational health and safety management systems

OSHA 18001 – Standard for the occupational safety and health administration

NE BOSH – National examination board in occupational safety and health

4.1.1.2 Safety terms and abbreviation

Hazard: Hazard is a potential source of harm or adverse health effect to humans, property or the environment or hazard is any agent that can cause harm or damage to human property or the environment.

Risk: Risk is a situation involving exposure to danger.

Hazardous substance can be any substance – solid, liquid or gas that may cause harm to personal health.

Abbreviation

PPE	–	Personal Protective Equipment
HSE	–	Health and Safety Environment
NSC	–	National Safety Council
NIOH	–	National Institute of Occupational Health
MAHCA	–	Major Accident Hazard Control Advisory division
OSH	–	Occupational Safety and Health
OSHA	–	Standard for the Occupational Safety and Health Administration
IOSH	–	Institution of Occupational Safety and Health
HAZOP	–	Hazard and Operability Study
ACGIH	–	American Conference of Government Industrial Hygienists
MSDS	–	Material Safety Data Sheet
IR	–	Infra-Red-lower frequency electromagnetic radiation
TLV	–	Threshold Limit Value
UV	–	Ultra-Violet-high frequency electromagnetic radiation
WEL	–	Workplace Exposure Limit
WSS	–	Workplace Safety Standards
HIRA	–	Hazard Identification and Risk Assessment
IER	–	Initial Environment Review

4.1.1.3 Personal Protective Equipment

PPE is a specialized clothing or equipment worn by employees for protection against health and safety hazards. PPE is designed to protect many parts of the body from injury or infection.

List of personal protective equipment

- Apron
- Helmet/Hard hats
- Goggles
- Face shield
- Hand Gloves
- Safety shoes and boots
- Coverall
- Safety belt/Harness
- Reflective jacket
- Dust mask
- Ear plug

List of Special Equipment

- H^2S- Monitor
- Breathing apparatus (SCBA, CABA, FABA)
- Eye wash station
- Fire detection alarm
- Smoke detector alarm

Safety helmet/Hard hat.

A hard hat is a type of helmet predominantly used in the workplace environment such as industries, piping, and pipeline construction sites to protect the head from injury due to falling objects or impact with other objects.

Apron

A fabric, usually in leather, tied around the waist and used to protect skin and clothes. PPE intended to protect pipe fitters from metal grinding spark, spatters, and high heat, adverse effect of gas cutting operation, etc..

Safety Goggles (Clear and shaded)

Safety goggles are a type of personal protective equipment (PPE) that is worn for eye protection from hazards coming from flying objects, dust or chemicals.

Fig. 4.1.1 Safety Helmet

Fig. 4.1.2 Apron

Fig. 4.1.3 Safety Goggles (Clear Image)

Fig. 4.1.4 Safety Goggles (Shaded Image)

Hand Gloves (Cotton cloth and leather gloves)

Hand gloves are personnel protective equipment worn during gas cutting, grinding works. They cover and protect the hands from the wrist to the fingers from accidents.

Safety Boots (with steel toed)

A steel toe boot is a durable boot or shoes that have a protective reinforcement in the toe. It protects the foot from hot spots and injury.

Coverall or boiler suit (flame resistance)

A boiler suit consists of a single piece of protective clothing that combines trousers and jacket. Pipe fitters wear it in order to protect them from dirt, spark etc., while performing pipe fitting and gas cutting, grinding works.

Fig. 4.1.5 Cotton Gloves

Fig. 4.1.6 Leather / Gloves Or asbestos

Fig. 4.1.7 Boots/safety shoes

Fig. 4.1.8 Boiler suit (Orange color)

Grinding face shields

Face shields are safety devices designed to protect the face from debris like flying objects, chemical splashes. Face shields are commonly used in grinding and cutting applications.

Reflective Jacket

It is a high visibility clothing, a type of personnel protective equipment (PPE) with high reflective properties. Reflective jackets will keep the person in good view with high visibility and should be worn while working in heights too.

Ear plug

A earplug is a device meant to be inserted in the ear canal to protect the ears from loud noises, There are two types of hearing protection – ear defenders and ear plugs. Both types have specific strength and limitations.

Fig. 4.1.9 Grinding Face Shield

Fig. 4.1.10 Reflective Jacket

Fig. 4.1.11 Ear Plug

Fig. 4.1.12 Ear Plug Defenders

Dust mask

It is a flexible pad worn over the nose and mouth to protect against dust in the piping and pipeline construction site.

Safety Belt/Harness

It is a fall protection product, equipment and system that protects workers who are working at heights. OSHA standard requires that fall protection should be provided at elevation of six feet and above in oil and gas construction industry and city gas distributions fecilities.

Special equipment used in piping and pipeline construction site (Oil and gas industry) Oil and Gas industry and city gas distributions fecilities.

Fig. 4.1.13 Dust Mask

Fig. 4.1.14 Safety Harness

Fig. 4.1.15 H_2 S-Gas Monitor Gas Detector (LEL Detector)

Fig. 4.1.16 Full space respirator

H_2S- Gas monitor / Detector

A gas detector is a device that detects the presence of hydrogen sulphide gases. The gas detectors can be used to detect combustible, flammable and toxic gases (H_2S), and oxygen depletion.

Tips

Hydrogen sulphide gas (H_2S) is a colourless, flammable, and extremely hazardous gas with a “rotten egg” smell.

Full space respirator

It is a piece of personal protective equipment for pipe fitters/workers in an environment where the air is contaminated, harmful or uncomfortable for breathing. This PPE provides continuous breathable air to the worker at construction and maintenance worksites.

Breathing Apparatus (BA)

It is a device, usually consisting of tank of oxygen (O_2) and a mouth piece. This enables the worker to breathe in difficult conditions, where there may be a lack of oxygen such as a confined spaces, smoke filled buildings and others. It provides breathable air in an immediately dangerous to life or health atmosphere/toxic air.

There are three types of breathing apparatus:

1. Self Contained Breathing Apparatus (SCBA).
2. Compressed Air Breathing Apparatus (CABA).
3. Fresh Air Breathing Apparatus (FABA).

Eye wash station

An emergency eye wash and safety shower station is an essential equipment for every oil and gas and city gas distribution piping construction site. Eye wash and safety shower stations serve the purpose of reducing workplace eye injury and keeping workers away from various dangers.

Fire Detection alarm

It is a system consisting of a device linked with a fire alarm control unit to produce an alarm signal in the office or control room. The system is designed to discover fires early thereby making enough time available for the safe evacuation of workers / occupants. Early detection plays a significant role in protecting workplace hazards. Property loss can be reduced and downtime for operation can also be reduced.

Smoke detection alarm

A smoke detector is a device fixed to the ceiling of a room which produces a loud noise if there is smoke in the air/room. Smoke detectors automatically detect and warn of the presence of smoke. Some detection alarm plays a significant role in preventing fire and protecting workers.

Fig. 4.1.17 Self Contained Breathing Apparatus

Fig. 4.1.18 Eye wash station

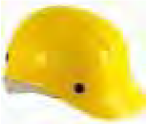
Fig. 4.1.19 (Fire detection alarm / Flame detection)

Fig. 4.1.20 Smoke detector

Practical

1. Look at the image below and identify the name of the PPE and safety devices.
2. Write the name and use of the PPE, devices in Table 1.

Table 1

SI.No.	Image	Name of PPE and devices	Uses	SI.No.	Image	Name of PPE and devices	Uses
1				7			
2				8			
3				9			
4				10			
5				11			
6				12			

Exercise

I. Answer the following questions.

I. List the name of any 4 Indian safety standards that are followed in oil and gas and city gas distribution fecilities piping and pipeline construction work.

----

2. List the name of any four international safety standards that are followed in oil and gas and city gas distribution fecilities plant piping construction activities.

----

3. Define the terms hazard and risk.

----

4. List the name of any six personal protective equipment used in piping and pipeline construction field.

----

5. What are the main advantages of using H_2S gas monitor?

   ----

6. List the advantages of employing smoke and fire detection system.

II. State whether the following statements are True or False.

1. Safety standards are designed to ensure personal and product safety.

   True ☐ False ☐

2. Any substance that may cause harm to human health is called a hazardous substance.

   True ☐ False ☐

3. Personal protective equipment are designed to protect many parts of human body from injury.

   True ☐ False ☐

4. A type of personal protective fabric that has high visibility while working in night is called reflective jacket.

   True ☐ False ☐

5. Hydrogen sulphide gas (H_2S) is a colourless gas which can be detected by the gas monitor.

   True ☐ False ☐

6. Boiler suits consist of a single piece of protective clothing and are used by pipe fitters.

   True ☐ False ☐

III. Explain the following abbreviation.

1. IS and BIS, 2. HSE, 3. OSHA, 4. MSDS, 5. IR to UV

Notes

4.1.2 Safety and Health Management System in Oil and Gas Industry and city gas distribution fecilities

At the end of this topic, you will be able to:

1. state the names of documents that refer to health and safety in the piping and pipeline construction site
2. locate the documents that refer to health and safety.

4.1.2.1 Responsible person for health and safety in the workplace

All workers are responsible for ensuring safety in the workplace. It is an employer's duty to protect the health, safety and welfare of the employees and any person who might be associated in the business is the site.

The primary responsibility is for employers to do whatever is reasonably practicable to achieve this. It is important to ensure that there is an effective company policy for health and safety and that all employees, contractors and temporary workers are made aware of their individual responsibility.

Safety and health documents include:			
1	Management safety and health policies	10	Safety statement
2	Safe work method statements	11	Training records
3	Risk assessment record	12	Appropriate organizational structure chart
4	Health and safety plan	13	Accident and incident reports
5	Strategies and action plan	14	Accident and illness health reports
6	HSE- Manual and Hand book	15	Emergency planning manual
7	Work health and safety procedure	16	Lesson learned and best practices
8	Permits (PTW – permit to work)	17	Safety and health audit reports
9	Contract documents		

Location of documents that refer to health and safety

HSE documents are located in piping and pipeline fabrication shop/construction site. Master copy of controlled documents are kept in project construction site office. These documents can be easily retrieved/referred in the workplace.

Exercise

I. Answer the following question.

1. What are the documents that are to be referred to with respect to then health and safety at workplace?

II. State wheher the following statements are True or False.

1. Safety training records, method statements, and safety risk assessment record are key documents that refer to health and safety.

   True ☐ False ☐

Notes

4.1.3 Hazardous work and Possible Causes of Risk in the Workplace

At the end of this topic, you will be able to:

1. identify hazardous work and possible causes of risk
2. define safe work practices while dealing with different type of hazards
3. identify common hazard signs displayed in various places in the site.

4.1.3.1 Introduction

Hazard exists in every workplace. The hazards that have the potential to harm workers at the workplace are to identified. Necessary precautionary measures are to be taken to prevent accidents, injuries, property damage and downtime.

4.1.3.2 Different categories of hazards

There are six categories of workplace hazards.

1) Safety hazards
2) Physical hazards
3) Chemical hazards
4) Ergonomic hazards
5) Biological hazards
6) Work organization hazards

4.1.3.3 Safety Hazards

Safety hazards are unsafe working conditions that can cause injury, illness and even death. Safety hazards are the most common workplace hazards. They include.

- slip/trip/fall
- working at height
- scaffolding
- ladders
- electrical
- confined spaces
- unprotected machinery

1. Slip / Trip / Fall

Slips are the results of too little friction or lack of traction between footwear and the floor surface. A trip is the result of a foot striking or colliding with an object which causes a loss in balance. Fall occurs when you are off balance.

Causes of risk

- spilliage of oil / water on floor make it slippery
- uneven floor and wet surfaces
- trailing cables
- standing on objects to access high levels
- collision with moving vehicles
- striking against fixed or stationary objects.

Risk control/prevent methods

- using signs and PPE
- keeping walkways and hallways free of debris and obstacles
- covering cables or cords in walkways
- cleaning up spills immediately
- sharing of information, instruction, training and supervision
- use of non-slip surfaces.

Fig. 4.1.21 Slip / Trip / Fall

2. Working at heights

Work at heights is working in any place, including a place at above or below ground level, where a person could be injured if they fall from that place.

Causes of risk

The main risks associated with work at heights are:

- falls and falling objects, poor housekeeping
- unprotected edges and unstable access equipment
- adverse weather conditions
- deterioration of materials

Fig. 4.1.22 Scaffolding

Fig. 4.1.21 Working at height

Risk control/prevention methods

- use working platforms, guard rails and toe boards
- use personal protective equipment
- involve persons with adequate level of competence
- identify training needs and provide necessary training

3. Scaffolding

A scaffold is any temporary, elevated work platform and its supporting structure used for holding people, materials or both. Scaffolding is used in piping construction.

Causes of risk

- falls from the work platform
- collapse of the structure
- objects falling from the platform
- fall from the scaffold during erection
- high winds
- scaffold not inspected prior to use.

Risk control/prevention methods

- use appropriate scaffold construction methods
- ensure stable access
- erect, move or alter scaffold properly
- inspect scaffold/scafftags before each shift and after alternations
- never work unless you are authorized to do so
- never climb scaffolding that has a red-tag on it.

4. Ladders

A piece of equipment/device used for climbing that has two long pieces of metal, with a series of steps or rungs between the long pieces on metal.

Fig. 4.1.23 Ladders

Causes of risk

- falls from heights
- falling off the ladders.
- ladder toppling sideways
- the ladder base slipping out from the wall
- Object falling from heights.

Risk control/prevention methods

- prior to using a ladder, inspect the ladder for any damage or missing steps or other defects
- ladders should be kept free of oil, grease and other slip causing agents
- only one person should climb, at a time on the ladder whenever it is used.
- use only on firm, level ground that is not slippery
- angle of the ladder should ideally be 75° horizontal
- face the ladder when ascending or descending
- when ascending or descending a ladder, do not carry any object or load maintaining 3 point contacts at all times.

5. Electrical

Electricity is a source of power that is often used to provide light.

Hazards of electricity

- Electric shock
- Fire and explosion
- Burns
- Use of electrical equipment in wet environment
- Arcing
- Working near overhead power lines
- Contact with underground power cables
- Work on live supplies.

Fig. 4.1.24 Electric shock / safety

Risk control/prevention methods

- always work under a permit to work condition method statement, and job safety analysis.
- follow the procedure and documented system to identify all hazards.
- lockout/Tag out and grounding cable before working on equipment.
- train operators in safe operation of the equipment.
- avoid using in wet conditions.

6. **Confined spaces**

A confined space is a fully or partially enclosed space that is not primarily designed or intended for continuous human occupancy. It may have only limited or restricted entrance or exit. For example, pipeline trench, vessels, tanks, towers, sewer system, pipes trenches.

Fig. 4.1.25 Confined trenches

Causes of Risk

toxic gases, oxygen deficiency, poor visibility, poor access/egress, adverse temperature

Risk control/prevention methods

- use gas monitor detector and check the presence of Hydrogen sulphide gases
- use signage to identify the confined space as a restricted access area
- all workers must undergo training and engage a suitably a qualified person
- undertake a risk assessment before working.

7. Unprotected Machinery

It is equipment or machinery not protected or kept unsafe.

Causes of Risk

- Crushing – The body is trapped between two moving parts.
- Shearing – A part of the body is trapped between two parts of the machine and the effect is like shearing of the trapped body part.
- Cutting – Contact with a moving sharp edged part such as a blade.
- Entanglement – Loose items such as clothing or hair get caught on a rotating machine part and the person is drawn into the machine.
- Drawing or trapping – A part of the body is caught between two moving parts and drawn into the machine.
- Impact – The body is struck by a powered part of a machine.

Fig. 4.1.26 Machinery / guards

Risk control/prevention methods

Protection from machinery hazards can be achieved by using guards that physically enclose the hazardous area of machine and prevent contact. Fixed guards are most effective at preventing contact.

4.1.3.4 Physical hazards

A physical hazard is defined as "a factor within the environment that can harm the body without necessarily touching it,". For example, radiation, UV/UR – rays, temperature/heat loud noise (constant), vibration.

a. Radiation

Radiation is energy that is emitted by a source. Ionizing radiation is present in a wide variety of workplaces and is used for various applications in nuclear power stations, scientific laboratories and piping construction sites.

Fig. 4.1.27 Radiation

Risk control/prevention methods

- procedure must be prepared including an Emergency action plan.
- the control of exposure to ionising radiation is based on the principles like time, distance, shielding, dose limit
- appointing radiation protection supervisor
- permit to Work
- work carried out at optimum times when practicable
- controlled area marked at the boundary using rope barriers
- display of suitable warning notices
- use of flashing warning lights like radiography, shooting, monitoring, personnel film badges.

b. Ultra-violet (UV) radiation: It is high frequency electromagnetic radiation (light) emitted by white hot materials produced during welding or excessive exposure to the sun.

Fig. 4.1.28 Controlled Radiation area

Risk control/prevention methods

- cover exposed skin; protect the eyes
- maintain a safe distance from the source of the radiation
- isolate and lock the source if workers have to approach inside safe distance
- use permit-to-work systems
- use eye protection (dark goggles) to prevent / escape of the beam/rays.

c. Temperature/Heat-stress

Heat stress is a body condition that occurs in response to exposure to heat or extreme temperatures.

Risk factors

- dehydration
- lack of acclimatization
- physically lacking in fitness
- lack of sleep
- medical condition.

Fig. 4.1.29 Heat stress

Risk control/prevention methods

Start drinking water. Before you start work, drink water as much as you need.

d. Loud noise (constant)

Noise pollution is, generally, defined as regular exposure to elevated sound level they may lead to adverse effects in humans or other living beings. For example, construction sounds like drilling or other machine operation.

Causes of Risk

- temporary reduction in hearing sensitivity as a result exposure to excessively loud noise for short duration.
- Noise Induced Hearing Loss (NIHL) which is permanent loss of hearing as a result of repeated exposure to excessively loud noise.
- inability to hear. For example, hazards such as vehicles, alarms and warning sirens
- exposure to industrial machinery noise.

Risk control/prevention methods

- carryout noise assessment
- reduce exposure to noise to the lowest level that is reasonably practicable
- provide information, instruction and training to employees
- provide hearing protection and enforce its use.

Fig. 4.1.30 Load Noise

4.1.3.5 Chemical Hazard

Chemical hazard is a type of occupational hazard caused by exposure to chemicals in the workplace. Chemicals are encountered in different physical forms such as dust, fumes, gases, mist, vapour and liquids. They affects us when the substances enter the body.

1. Chemical agents

- **Solid** – a solid block of material (For example, lead ingot)
- **Dust** – very small solid particles, normally, created by grinding, polishing, milling, blasting. (For example, flour dust, rock dust)

- **Fume** – very small metallic particles that have condensed from the gaseous state during work with molten metal (For example welding,)
- **Gas** – a basic state of matter that expands to fill the space available (For example, carbon dioxide)
- **Vapour** – the gaseous form of a substance that exists as a solid or liquid at normal temperature and pressure (**For example,** acetone)

2. **Classification of chemicals of hazardous to health**

- **Toxic** – small doses of some chemicals cause death or serious ill – health when inhaled, swallowed or absorbed via the skin (For example, potassium cyanide (KCN)).
- **Harmful** – Chemicals that cause death or serious ill – health when inhaled, swallowed or absorbed via the skin in large doses.
- **Corrosive** – Chemicals that destroy living tissue on contact (For example, concentrated sodium hydroxide) (NaOH)
- **Irritant** – Chemicals that cause inflammation of the skin or mucous membranes (For example, eyes and lungs) through immediate, prolonged or repeated contact (For example ozone O_3).
- **Carcinogenic** – Chemicals that may cause cancer (abnormal growth of cells in the body) when inhaled, swallowed or absorbed via the skin (For example, asbestos, glasswool)
- **Toxic to reproduction** – Chemicals that may cause sterility or affect an unborn child.

Risk control / preventive methods

1. Before using any hazardous material, check the MSDS (Material Safety Aata Sheet). If you cannot understand the information in the MSDS, seek advice from your supervisor.
2. Educate workers on effects of hazardous chemicals

Fig. 4.1.31 Toxic


Fig. 4.1.32 Harmful


Fig. 4.1.33 Corrosive

Fig. 4.1.34 Irritant

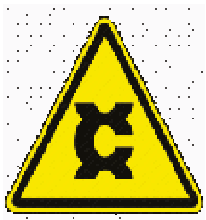


Fig. 4.1.35 Carcinogenic

3. Be aware of all sources of flammable gases.
4. Watch out for substance that can spark a fire.
5. Maintain and provide appropriate vents
6. Provide employees with proper PPE (Personal Protective Equipment).
7. Provide employees with respiratory protection, when necessary, to eliminate exposure to risks.

4.1.3.6 Ergonomic Hazards

Ergonomic hazards occur when the type of work, body positions and working conditions strain the body. Short–term exposure may result in "sore muscles" the next day or in the days following the exposure. But long–term exposure can result in serious long–terms illness. Ergonomic Hazards include:

- improperly adjusted work stations and chairs
- frequent lifting
- poor posture
- awkward movements,
- use of too much force
- vibration

Ergonomic Principles

The scientific study of people and their working condition is done in order to improve effectiveness. This

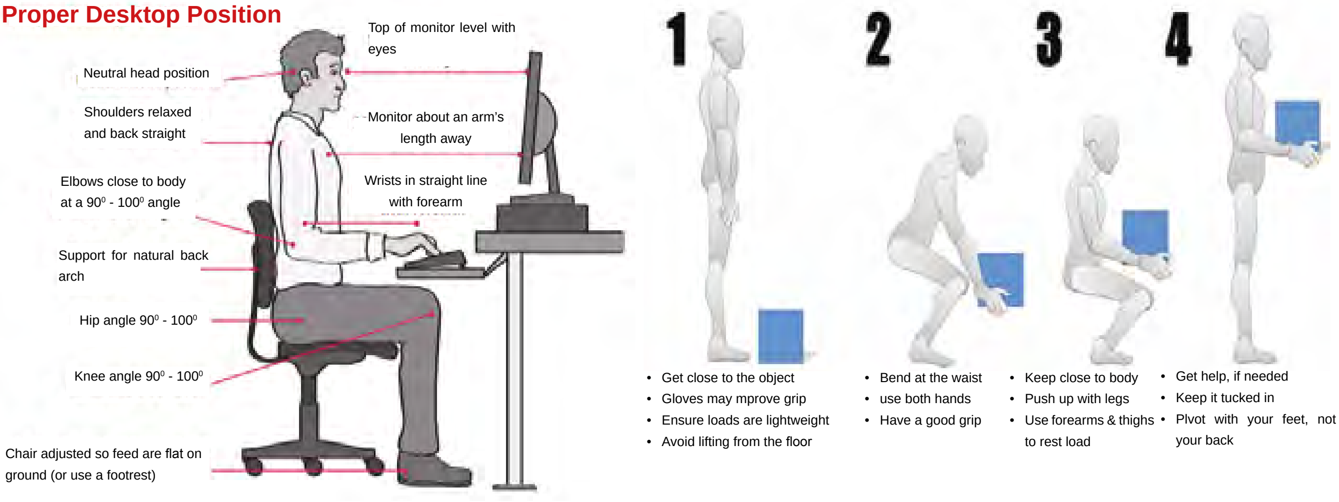


Fig. 4.1.36 Ergonomic Principles

addresses ergonomic issues from the perspective of the employee. It focuses on workstation limitations and creates healthier, stress – free work environment for employees.

1. Office ergonomic and occupational health
2. Principle for design of an office workstation
3. Furniture and Equipment selected

4.1.3.7 Common Hazard signs displayed in piping and pipeline construction sites

Hazards symbols or warning symbols are recognizable symbols designed to warn about hazardous or dangerous materials, location, or objects, including electric current, poison and radioactivity. Hazard symbols may appear different colours with common hazard signs.

Hazard signage in cludes:

- explosive
- corrosive
- flammable
- acute toxicity
- oxidizing
- fall Hazard

Fig. 4.1.37 Different hazard signage

Practical

1. Look at the image below and identify the name of the hazard signs
2. Write the name of hazard sign symbol in Table 2

SI.No.	Hazard Signage	Name of Signage
1		
2		
3		

SI.No.	Hazard Signage	Name of Signage
4		
5		
6		

Exercise

I. Answer the following questions.

1. What are the six categories of hazards encountered in the workplace?

   ----

2. What are the risks that commonly cause slip/trip/fall?

   ----

3. Why should ladders be inspected prior to using at the work site?

   ----

4. What are the electricity hazards?

   ----

5. How can electric shock be prevented?

   ----

6. Define the term “confined spaces”.

   ----

7. What are the risk control measures to be followed prior to entering in confined spaces?

II. State whether the following statements are True or False.

1. Contamination of a floor with a slippery agent may cause slip and fall.
   True ☐ False ☐
2. Providing information, instruction training and supervision can prevent fall/tripping hazards.
   True ☐ False ☐

3. Poor housekeeping leads to accidents

   True ☐ False ☐

4. The main risks associated with working at heights are falls and from falling objects.

   True ☐ False ☐

Notes

4.1.4 Accident Prevention in Oil and Gas Construction Site

At the end of this topic, you will be able to:

1. prevent accident and injury
2. prevent work related slips, trips and fall
3. prevent accident involving vehicle transport.

4.1.4.1 Accident

Accidents are unplanned occurrences like injuries, fatalities that result is loss of production or damage property and assets.

Preventing accident at Workplace

The best ways to prevent accident and injury to protect workforce include:

- preventing work related slips, trips and fall, electric shock
- avoiding Heat stress
- following all safety measures.

Electrical shock prevention methods

Electrical shock preventing methods include:

- always working under a permit to work systems
- always working on electrical equipment and conductors only when denergized / isolated
- lockout/tag out before working on electrical equipment
- ensuring that electrical equipment and power cords are not be in contact with water
- testing every circuit and every conductor every time before touching it
- wearing protective clothing, equipment and using insulated tools.

Fig. 4.1.38 Electric shock

4.1.4.2 Permit To Work (PTW)

A permit to work system is a safety procedure designed to protect the team working in oil and gas industries.

PTW will ensure that:

- all personnel are made aware of safety controls required
- necessary safety measures are taken and effectively monitored
- the working area and task is clearly defined
- the correct PPE is provided and used
- workplace work activity and equipment are assessed tested for adequete safety.

4.1.4.3 Safe handling

All hand tools should be regularly visually inspected of hand tools before use to ensure that they are in a good condition.

- use the correct size of spanner for the nut.
- ground down chisels and punches with mushroomed heads to prevent metal flying from splinters
- do not use screw drivers as chisels
- keep tools in racks or boxes when not in use
- protect sharp edges of tools
- always use eye protection to protect your eyes.

4.1.4.4 Power tools handling

Portable power tools are carefully selected to ensure suitability for the task and the environment. In practice, safe use of a portable power tool requires:

- visual inspection prior to use and keeping work area safe to operate electric tools.
- keeping cords away from heat, oil, and sharp edges
- disconnecting tools when not in use, before servicing and when changing accessories such as dies, blades bits etc.
- using of personal protective equipment
- storing electric tools in a dry place and not using electric tools in damp or wet locations
- removing all damaged portable power tools from use (working site) and tagging them " Do not use."

4.1.4.5 Preventing injuries and fatalities

Here are some specific methods to prevent injuries and fatalities at the construction site:

- provide safety training to all employees
- hold frequent crew safety meetings and tool box talks
- use appropriate personal protective equipment
- keep the workplace clean and tidy
- maintain equipment and tools and prevent falls
- do not take shortcut
- inspect the workplace thoroughly before workers enter the work site and confined spaces.
- carryout tool box talks with your personnel on a daily basis before starting work
- report all defects without delay with respect to plant, equipment, methods or system of work that may be unsafe.

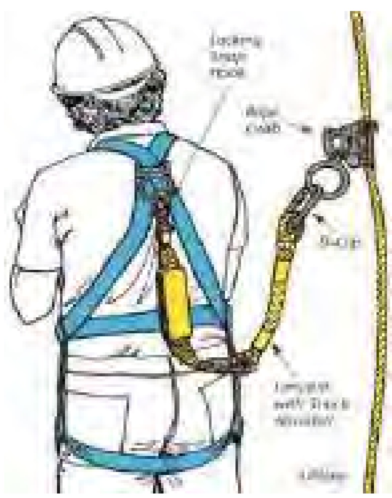


Fig. 4.1.39 Working at heights

4.1.4.6 Defensive Driving

Basic driving rules include the following:

- Seat belts must be fastened while driving
- Check rear view and side mirrors frequently
- Do not drive when you are tired and ill
- Vehicle must be driven only by suitably trained and qualified driver
- Keep eyes on the road, hands on the wheel, and attention on the traffic.
- Follows traffic rules, signs and signals
- Don't drink or take drugs and during driving

Golden rules for safe driving

a. Conduct pre-trip vehicle checks

b. Do not drive exceeding the posted speed limit and drive in a safe manner.

c. Never use mobile telephones while driving.

d. Do not drive at night in the work site, except when authorized.

e. Warn drivers of safety concerns and unsafe behaviuor.

f. Do not drive unless all passengers are wearing seat belts.

g. Do not drive when tired and do not let unfit drivers drive.

Exercise

I. Answer the following questions.

1. Define accident.

----

2. What are the methods to prevent electric shock?

----

3. Explain PTW.

----

4. How can heat stress controlled be at the work site?

----

5. What are the methods to prevent injuries?

----

6. State 5 golden rules for safe driving.

II. State whether the following statements are True or False.

1. Prior to work on electrical equipment conductors, must be de-energized.

   True ☐ False ☐

2. Permit To Work system (PTW) is one of the safety procedures used to protect the team working in piping construction sites.

   True ☐ False ☐

3. All hand and power tools should be visually inspected before used at the site.

   True ☐ False ☐

4. Tool box talks is are effective method of preventing injuries.

   True ☐ False ☐

Notes

4.1.5 Working Safely in and around Pipeline Trench

At the end of this topic, you will be able to:

1. perform safe pipe fitup work in and around trenches
2. handle heavy objects safely using correct lifting procedure
3. carryout good housekeeping practices.

4.1.5.1 Pipeline trench Excavation

Trenching is a construction method that involves digging a trench in the pipeline construction ground to install pipes. When the installation of the pipe is completed, the trench is filled and reinstated as to its original condition as for possible.

Pipeline trench excavation is defined as an any machine/manmade cut, cavity or depression on the earth's surface formed by removal of earth. Pipeline trench excavation is a narrow excavation in relation to its length, depth and width. The hazards of excavation work include:

- striking buried services
- people falling in
- objects falling in
- flooding
- collapse of adjacent structures/sides.

Pipe line trench collapse

Trench collapse can be prevented by:

Fig. 4.1.40 Pipeline trench

Fig. 4.1.41 Pipeline trench box

- battering (slopping) the trench side of the excavation as per approved pipeline drawing
- keeping heavy equipment away from the trench edges (For example, side boom/pipe layer, mobile crane, trench cutter)
- shoring – the side of the excavation can be supported with metal or timber that is fixed in place inside the excavation.
- trench box – the side of the excavation can be temporarily supported by a metal box that can be lifted into the excavation and moved along to give a protected work area.

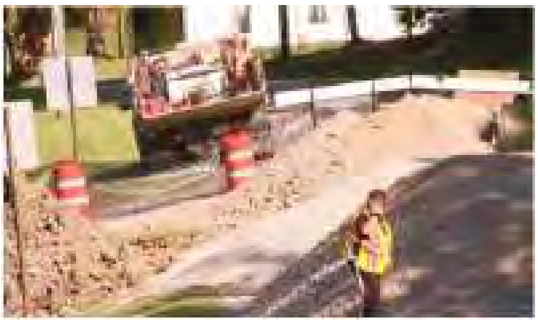


Fig. 4.1.42 Trench collapse

Safety in pipeline trench excavations

Safety precautions be followed in pipeline trench excavation include:

- excauation carrying out in accordance with written and approved procedures
- locating, identifying and mancing existing utility services in the area, such as electrical, FOC (fiber optic cable) gas, water and sewer facilities
- identifying and controlling all hazards that could result in worker injuries.

Fig. 4.1.43 Deep excavation

Fig. 4.1.44 Barricade

Safety to be followed in and around pipeline trench include:

- keep heavy equipment at least 1.5m from the edge of the excavation
- always wearing hard hat and full personal protective equipment
- in excavation over 1.5m a ladder must be available in the immediate area of the workers. The ladder should be of such a length that it goes from the bottom of the excavation and extends 1m above the ground.
- never standing in the blind spot of heavy equipment
- to be aware of electrical hazard from overhead or underground power lines.
- not to carryout activities into the pipeline trench without PTW (Permit To Work system)
- provide barricades for all pipeline trench excavations.

Tips

No worker should enter in to pipeline trench unless PTW is issued.

A pipeline trench excavation should be considered a confined space and appropriate evaluation and controls need to be undertaken to ensure safety of the workers.

4.1.5.2 Handle heavy objects safely using correct lifting procedures

Safety precautions when lifting heavy objects include:

- Correct tonnage capacity, to be verified along with lifting calibration certificate.
- Safety equipment that the pipe fitter (workers) should always wear–appropriate hand gloves, boiler suit, safety goggles, safety shoes with steel toed to protect worker.
- Understand what you are lifting, what the load is.
- Use proper slings and equipment.
- Barricade the lifting area. Employees should not be permitted to work under the area where materials are being loaded or unloaded.
- A trained and authorized signalman must be assigned for each lift. He must be clearly identified. (For Examples high visible vest)

- The weather conditions must be considered (wind & rain),

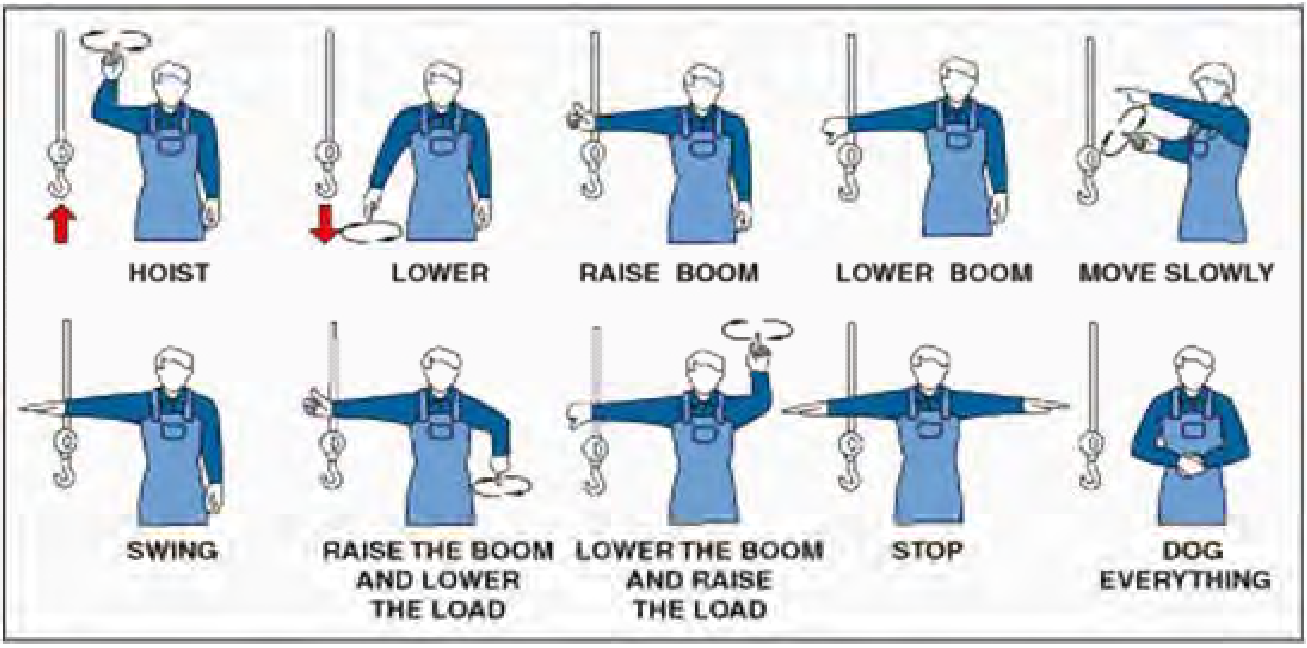


Fig. 4.1.45 Crane - Lifting signals

- Only competent employees (Riggers) should attach lifting gear and secure the load.
- An agreed method of communication between the crane operator and the signalman to be confirmed.
- Do not cross barricades and enter lifting area unless you are authorized.

4.1.5.3 List of mechanically operated load lifting equipment

- Cranes
- Fork lifts
- Hoists
- Eot-cranes
- Jib crane
- Gantry crane

Fig. 4.1.46 Mobile crane

There are several general requirements for safe lifting operations which include:

- verification and testing of the selected equipment load lifting capacity
- the stable and secure equipment condition. For example, mobile cranes with outriggers must be located on firm level ground to avoid the outriggers sinking and crane tipping / toppling.
- that all lifting equipment are visibly marked with the safe working load (SWL), the maximum load that the device is permitted to lift. All heavy lifting load should be marked with centre of gravity.
- that lifting operations are planned, carried out and supervised by competent persons.
- checking that the crane has been maintained and has a certificate of thorough examination in accordance with safety standards.
- providing a banksman to give directions to the crane operator with good means of communication between driver and operator.

- Checking that there are no obstructions such as overhead lines in the vicinity of the lift.
- to consider the lifting accessories that are used to attach the load to the crane. For example items such as chains, wire ropes, nylon slings, eyebolts, 'D' shackles. They should be regularly checked by visual inspection before putting them to use.

4.1.5.4 Periodic examination and testing of lifting equipment

Lifting equipment are always under a great deal of strain. If they are not maintained in good working conditions, it can eause accidents. There are, therefore, legal requirements for the thorough examination and testing of lifting equipment to ensure strength and stability. The legal requirements vary depending on region and type of equipment. In general lifting equipment should be thoroughly examined:

- before it is used for the first time where it has been installed.
- the frequency of "periodic" through examination will typically be every six months for lifting accessories.

Fork lift trucks

The hazards associated with forklift truck are:

- overturning of the truck
- fall of the load
- entrapment of a person riding on the forks

The precautions for safe use of forklift trucks include:

- restricting use to only trained operators
- routine visual inspection of the truck before use
- never using the forklift to lift people
- ensuring that safe working load limits of the truck are not exceeded
- observing site speed limits
- never travelling with obstructed vision.

Fig. 4.1.47 Forklift

Cranes

The main hazards associated with a mobile crane are:

- the crane collapsing or toppling over
- the arm of the crane striking against other structures during movement
- the load falling
- contact with live overhead cables
- overloading the crane beyond its lifting capacity
- failure to use the outriggers correctly
- using the crane in high winds.

Fig. 4.1.48 Mobile Crane

The precautions for the safe use of a mobile crane include:

- ensuring that the load to be lifted is within the safe lifting capacity of the crane
- using the outriggers correctly
- checking weather conditions and obeying manufacturer recommendations about maximum wind speed
- lifting the load as close to the ground as possible.

Side boom cranes (Pipe layer)

Side boom is a type of a construction vehicle used to lay pipes in to the pipeline trench.

Hazards and risks

- machine not used in serviceable conditions
- lowering of hydraulics without warning
- crush hazards/Injuries while raising or leaning the boom
- getting trapped between the boom lift and materials
- raising and lowering on an uneven ground
- boom lift coming into contact with live wires.

The precautions for safe use of pipe layer include:

- enclosed cab with integrated rollover protection structures as per the standard
- hose break protection to prevent lowering of the boom in the event of pipe breakage.
- overload warning device monitors to check LMI (Load Monitor Indicators).
- backup alarms fitted to all pipe layers, give a sand signall to warn personnel surrounding the machine.

Fig. 4.1.49 Toxic hazards signs

4.1.5.5 Good Housekeeping practices

Housekeeping

Every facility, whether private or commercial or industrial construction site, needs to be kept clean and tidy. This is where housekeeping comes in to deals with cleanliness and maintenance for the smooth running of the establishment/organization/ institution. Thus, housekeeping is about providing services to maintain a facility and looking after cleanliness, tideness and upkeep, on a daily and for long – term basis. The negative impressions and implications of poor housekeeping can affect workers. Morale is lowered for most people who must function every day in a messy, disorderly work environment,

General housekeeping rules to remember are:

1. Clean yourself up
2. Pickup your trash and debris and dispose of it properly, or place it where it will not pose a threat to others.
3. Keep your work area clean throughout the day.

Importance of Housekeeping

I. For an Industrial organization to function efficiently:

1. Housekeeping can help to prevent injuries and improve productivity
2. Housekeeping should be an ongoing process and not a one – time practice.

Advantage of Housekeeping

1. Good housekeeping prevent slips, trips and falls.
2. It eliminates fire hazards and controls dust.
3. Tracking material is simple.
4. It prevents falling of objects.
5. It enhances the aesthetic appearance of the place.
6. It promotes a safe and hygienic environment.

Fig. 4.1.50 Toxic hazards signs

Effects of poor House keeping

Poor Housekeeping causes a wide range of injuries and fatalities, ranging from painful slips, trips and fall to workers being unable to evacuate burning building , working site, working office because of blocked fire exits. These are some important house keeping tips to remember and practice:

- When you have finished using tools or materials, replace them in their respective places and clean up anything that is left on the work surfaces or floor.
- Ensure that all walkways are free from obstructions such as materials, tools or wires that could cause someone one to trip or fall.
- Dispose oily rags in covered metal containers that need to be emptied on a regular basis.
- Prepare a routine cleaning schedule.
- Remove projecting nails and other sharp objects or hammer to prevent someone getting injaved by stepping on them.

Practical

1. Look at the image below and identify the name of the PPE and safety devices.

SI.No.	Image	Name of the Image	PPE to be Used
1			
2			
3			

Exercise

I. Answer the following questions.

1. What are the hazards associated with pipe line trench excavations?

   ----

2. What are the safety precautionary measures to be followed while working in and around a pipe line trench?.

   ----

3. What are the safety precautions to be followed when lifting heavy objects?

   ----

4. Why are industrial construction's site housekeeping activities considered important?

   ----

5. List the main advantages of good housekeeping practices.

II. State whether the following statements are True of False.

1. Pipelines trench collapse can be prevented by sloping/battering.

   True ☐ False ☐

2. Prior to starting of pipeline trench excavation, the existing facility must be located, identified and marked.

   True ☐ False ☐

3. All heavy lifting equipment should be operated by only trained and authorized operators.

   True ☐ False ☐

4. Crane collapsing or toppling over may happen due to operating crane in high winds and overloading.

   True ☐ False ☐

5. All lifting equipment should be visibly marked with the Safe Working Load (SWL) and only Banksman should give directions to the crane operator.

   True ☐ False ☐

Notes

UNIT 4.2 Fire Safety

Unit Objectives

At the end of this unit, you will be able to:

1. state causes of fire in the worksite/workshop
2. state the general precautionary measures to be taken to fire prevent
3. explain the different types of fire and various types of fire extinguishers
4. explain good housekeeping practices necessary to prevent fire.

4.2.1 Fire Ignition, Classification and Fire Preventive Techniques

At the end of this topic, you will be able to:

1. identify the causes for fire in the oil and gas industry
2. define the general precautionary measures for preventing fire
3. explain rescue techniques applied during fire hazards.

4.2.1.1 Fire safety

Fire safety involves a set of practices intended to reduce the destruction caused by fire. Fire safety measures includes those that are intended to prevent ignition of an uncontrolled fire, and those that are used to limit the development and effects of a fire after it starts.

Basic principles: The basic principles of fire and combustion can be represented by the fire triangle.

For fire to exist three things must be present; Fuel, Oxyge, Heat.

Fuel – combustible materials or substances like liquid, solid or gas will burn in the presence of oxygen and high temperature.

Heat – A heat or ignition source is essential to start the combustion process. Once combustion has started, it generates its own heat which is usually sufficient to keep the fire burning. For example, petrol.

Oxygen – It is consumed during combustion when it is chemically mixed with fuel. Oxygen is present in the air at a concentration of 21%. Usually it exists in sufficient in the air to keep a fire burning.

The fire triangle is useful for two reasons

- fire prevention - keep the three elements apart so that fire cannot start
- fire fighting – remove one of the elements and the fire will go out.

Fig. 4.2.1 Fire triangle

4.2.1.2 Classification of fires

Fire is classified into four categories according to the fuel type. The classification is useful for identifying the type of fire extinguisher to use.

Class A fires are caused by ordinary combustible solid materials such as paper, wood, coal, textiles and plastics.

Class B fires are caused by flammable liquids such as petrol, oil, solvents and paints.

Class C fires involve energized electrical equipment such as motors, transformers and appliances.

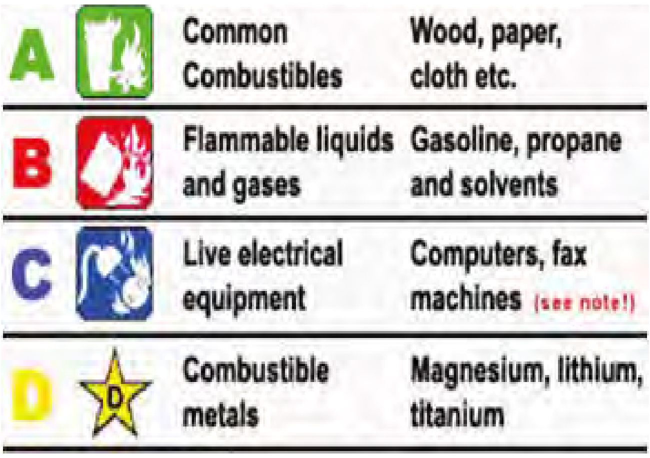
Class D fires are caused by combustible metals such as potassium, sodium, aluminum and magnesium.

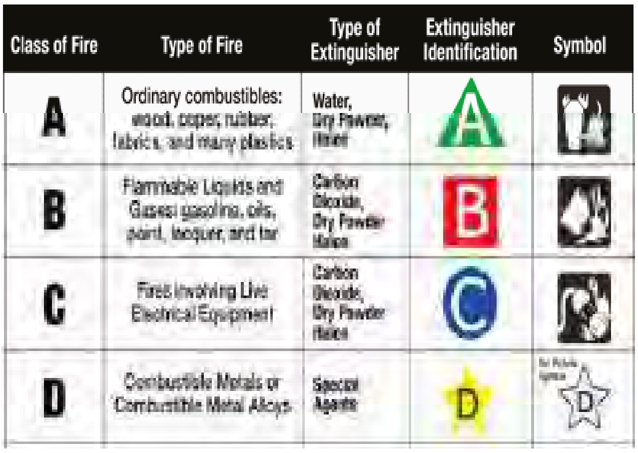
Common causes of workplace fire

Fires in workplaces start for many different reasons. Some of the most common causes of workplace fire are:

Faulty electrical equipment: faulty electrical equipment, delibrate ignition, smoking and hot work.

Faulty wiring, overloaded conductors, misused equipment and the incorrect use of electrical equipment in appropriate environments can cause fire in workplaces.





Class of Fire	Type of Fire	Type of Extinguisher	Extinguisher Identification	Symbol
A	Ordinary combustibles: wood, paper, rubber, fabrics, and many plastics	Water, Dry Powder, Halon	A	
B	Flammable Liquids and Gases: gasoline, oils, paint, lacquer, and tar	Carbon Dioxide, Dry Powder Halon	B	
C	Fires involving Live Electrical Equipment	Carbon Dioxide, Dry Powder Halon	C	
D	Combustible Metals or Combustible Metal Alloys	Special Agents	D	D

Fig. 4.2.2 Classification of fire

Deliberate ignition: Many Workplace fires are started deliberately. In some cases, the Workplaces have been targeted.

Smoking: Carelessly discarded smoking materials such as cigarette butts and matches cause smoking.

Hot work: Any work involving the use of a naked flames or potential ignition sources are classified as hot work. Activities that may produce or expose a possible source of ignition include, but are not limited to the following:

Welding/flame cutting, Electrical induction preheating, Grinding, Use of electrical soldering irons, Use of powered steel wire brushes.

Fig. 4.2.3 Welding

Fig. 4.2.4 Gas cutting

Fig. 4.2.5 Grinding

4.2.1.3 Unsafe use and storage of flammable liquids and gases

eventually never store a flammable liquefied compressed gas, such as propane, petrol, acetone near hot workplace as static sparks can be generated which could ignite a flammable vapour.

Mechanical heat generated by friction between moving parts such as a motor and its bearing is dangerous.

Extinguishing of fires

Isolating or removing any of the three factors (fuel, heat, oxygen) from the combination will extinguish the fire. There are three basic ways of achieving this:

- by removing the fuel from the vicinity of the fire

- cooling by using water to lower the temperature.
- smothering by isolating the fire from the supply of oxygen by blanketing it with foam, sand, etc.

Fire risk assessment

Fire risk assessment is a legal requirement in many countries. There are many different methods for carrying out a fire risk assessment.

a. Identify the fire hazards

- Sources of fuel
- Sources of ignition
- Sources of oxygen

b. Identify the people who might be harmed

- People in the work premises
- Give special consideration to vulnerable people/activities

Identify and implement fire precautions that are required

- fire preventions
- preventions of the spread of smoke and flames
- fire detection and alarm
- fire fighting equipment
- means of escape, signs and notices
- lighting.

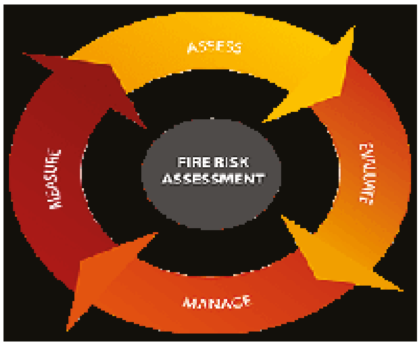


Fig. 4.2.6 Risk Assessments

4.2.1.4 Identify the fire hazards and preventive techniques

a. Common fire hazards in the workplace.

- flammable liquids and vapours.
- objects that generate heat
- overloading the power socket
- human error and negligence
- absence of fire detection and alarm system.
- Safety violation of work site / place.
- smoking
- waste and combustible materials being stored on the site.
- dust build up
- improper or unauthorized storage of flammable and hazardous materials.
- insufficient number and type of fire extinguishers.
- faculty electrical equipment
- hot work/hot surfaces

b. Fire preventive techniques applied during fire hazard

A range of preventive and precautionary measures will be necessary for all workplaces. It includes the following:

Fire prevention which means ways of minimizing the risk of a fire from occurring.
Prevention of the spread of smoke and flames means ways of minimizing the risk to people should a fire occur and asking them to evacuate the premises safely on time.

Fire detection and alarm to ensure that fire is detected as early as possible and evacuation of all the persons from the premises and altering any person trapped inside are important.

Automatic fire alarm system can be quite simple or very complicated depending on the Workplace in which it is installed. In some workplaces, the building and Workplaces are subdivided into zones and the fire alarm system can give different warning sounds depending on the zone the fire was detected in. In this way, phased evacuations can be achieved. The type of automatic fire detector that is used with a fire alarm system also varies depending upon the situation.

When fire starts in a building or work site there must be an appropriate system to detect the fire early and raise an alarm. A range of detection and alarm system exist with larger Workplaces having fully automatic fire alarm system relying on automated smoke or heat detectors linked to a central control system, which is in turn linked to alarm sounders and indicator lights.

4.2.1.5 Type of fire extinguishers

Portable fire extinguishers: fire extinguishers, flame extinguisher or extinguisher is an active fire protection device used to extinguish or control small fires. It is not intended for use on an out of control fire. Many type of fire extinguishers are available with different extinguishing agents to deal with different classes of fires.

- among the occupants of the building.

Fig. 4.2.7 Acetylene cylinder storage

Fig. 4.2.8 smoke detecting alarm

Fig. 4.2.9 Type of fire Extinguishers

Extinguishing media: Fire extinguishers are usually red. In some countries, colour coding system is used for extinguisher to enable quick recognition of the different types. The following types of portable fire extinguishers tools and methods are commonly found in Workplaces:

a. **Water filled extinguishers:** This type is suitable for class A fires and works by killing the fire. Standard water extinguishers are not suitable for use on class B, D fires or live electrical equipment.

b. **Dry powder type extinguishers:** Dry powder fire extinguishers are suitable for all classes and are used on live electrical equipment. This type of fire extinguishers are suitable for use on class C, D fires.

c. **Carbon di-oxide type extinguishers:** This type is suitable for class B fires, especially, fires involving live electrical equipment. It must be used with care because the body of the extinguisher gets very cold during use and can cause a freeze burn injury. Always check the operating instruction on the container/before use.

d. **Foam type fire extinguisher:** This type is most suitable for class A and B fires. It works by smothering the fire or preventing combustible vapours from mixing with air. Class B flammable liquids like gasoline, oil, grease, solvents must not be used where electrical equipment is involved. In addition to the portable extinguishers, fire fighting equipment may be used in workplaces.

e. **Fire blanket**: It is used to physically smother / kill small fires and is very useful for welding and gas cutting, grinding areas where hot working/spark/spatters kind of fires might occur. It is used also for smoothing burning clothing.

f. **Hose reels:** They are kept in buildings to allow fire fighting teams to fight fires.

g. **Sprinkler System:** Sprinkler systems are mainly used in office buildings and warehouses to automatically dowse a fire.

h. **Sting maintenance:** Fire extinguishers should be positioned on fire exit routes, near exit doors and close to the specific hazard. They are provided to protect against fire. They should be clearly visible and positioned with visible signs and must be easy to access.

i. **Frequent routine inspections:** Routine inspections help to ensure that extinguishers are present at their designated positions and that they appear to be in good order. This might be done as part of a routine housekeeping inspection or as a specific fire safety check.

Fig. 4.2.10 Fire blanket

Fig. 4.2.11 Firefighting hose reel

Fig. 4.2.12 Water sprinkling system

4.2.1.6 Evacuation of the workplace: When a fire emergency occurs, and people have to evacuated from a workplace, there must be one or more escape routes available for them to use. This escape route is the ''means of escape''. The following general principles can be applied:

- There should be a means of escape available to every person in a workplace whether they are in an office, work room, plant room, basement, on the roof or on a scaffold on a construction site.
- Two or more separate escape routes may have to be provided so that if one route is blocked, there is another route available.
- The escape route should be clearly marked with appropriate visible signs.
- Emergency lighting should be provided wherever necessary.

Assembly Points: An assembly point is a place where workers congregate once they have evacuated a building. This allows for a roll - call to be taken and identification of missing persons.

Assembly points should be

- at a safe distance from the building
- clearly signed / identifed.
- at a safe location (not in a high hazard area)
- known to each and every employee / workforce.

In some cases, a temporary assembly point or refuge may be provided inside a building. This is to be a protected location where people can wait for a short time.

Fig. 4.2.13 Emergency evacuation

Fig. 4.2.14 Assembly Point

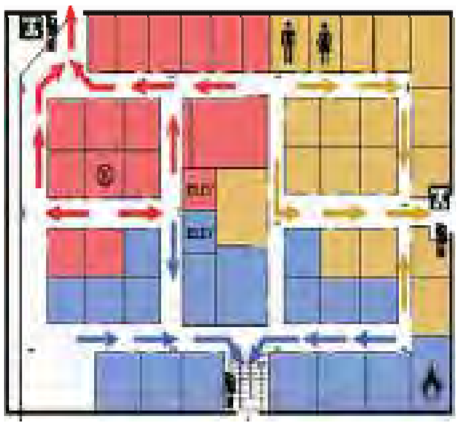


Fig. 4.2.15 Escape route

4.2.2 Method of Using Fire Extinguisher

At the end of this exercise, you will be able to:

1. use a fire extinguisher effectively.

Practical

Requirements	
Equipment/ Machines	
1. Personal Protective equipment	– 1 Set
2. Fire extinguisher	– 1 No

Methods of using a fire extinguisher when it is needed is just to remember PASS!

P – Pull the pin

A – Aim at the base of the fire

S – Squeeze the handle or lever

S – Sweep from side to side

Fig. 4.2.16 Fire extinguishing technique

Pull the Pin: This will allow you to discharge the extinguisher.

Aim at the Base of the fire: If you aim at the flames, the extinguishing agent will fly right through and may not be able to put the fire out. You have to hit at the base of the fire.

Squeeze the handle or lever: This depresses a button that releases the pressurized extinguishing agent from the extinguisher.

Sweep from side to side: Start using the extinguisher from a safe distance, and then move forward, duly sweeping from side to side. Once the fire is controlled, keep an eye on the area, in case it re-ignites.

Workers who might have to use portable fire extinguishers must be trained to use them safely. This training should include theoretical training (classsroom based) some practical training. This will, normally, involve workers in using real fire extinguisher to put out real fires, set up under controlled circumstances at the workplace.


Fig. 4.2.17 Pull the Pin


Fig. 4.2.18 Aim at the base of the fire

Fig. 4.2.19 Sweep from side to side

Exercise

I. Answer the following questions.

1. What are the three key elements that cause fire?

   ----

2. What are the classifications of fire?

   ----

3. List the fire hazards

   ----

4. How will you prevent a fire hazards?

   ----

5. How many types of fire extinguishers are used to put out the fire?

   ----

6. Explain "PASS" in fire safety.

   ----

7. Good housekeeping is very important at the work site/office. Why?

II. State whether the following statements are True or False.

1. Fire triangle is represented by the key factors/elements present – fuel, oxygen, heat.
   True ☐ False ☐
2. Class 'B' fires are fires caused by flammable liquids like petrol or solvents.
   True ☐ False ☐
3. Welding and grinding are two potential sources of ignition. These may produce fire.
   True ☐ False ☐
4. Fire extinguisher is an active fire protection device used to extinguish/control small fire.
   True ☐ False ☐
5. Dry powder type of fire extinguishers are suitable for all classes of fires.
   True ☐ False ☐

Notes

UNIT 4.3 Safety System

Unit Objectives

At the end of this unit, you will be able to:

1. locate unsafe conditions and stop any unsafe behaviour
2. record all miss incidents, damages, illness or injury
3. promote and maintain a positive safety environment in the workplace
4. ensure safe handling and storage of hazardous substances
5. assess safety threats and be alert to protect from threats
6. ensure of own safety and safety of others
7. report HSE concerns and issues and manage spills.

4.3.1 Comprehending and Implementing Safety System

At the end of this topic, you will be able to:

1. describe safety system requirements
2. comprehend safety system implementation requirements
3. recognise safety system acts, regulations, codes and standards.

4.3.1.1 Safety System Requirements

- Oil and Gas construction industry is a high hazard industry that comprises a broad range of simultaneous critical activities involving multidiscipline constructions comprising various phases and processes. It includes "alteration and repair" at the existing plants and facilities.
- Most accidents, injuries, illnesses can be prevented by taking simple measures or adopting proper working procedures and effectively implementing safety system. Working carefully with appropriate safety inplace will measures ensure fewer work injury and construction sites will become a safe and secure place to work in.
- Each and every organization develops a safety system in accordance with an appropriate international standard for safety management system and implements the same.
- Effectiveness of safety system implementation in each and every worksite should be monitored, measured, analysed and continuously improved.

4.3.1.2 Significance of Safety Pyramid

The safety pyramid (also known as safety triangle) is a pictorial depiction of a safety concept that describes the relationship between near misses, more serious incidents and accidents. Safety triangle is a theoretical model that describes a stable ratio between workplace incidents of varying degrees of severity. The safety triangle is a powerful piece of theory within the safety and risk management framework. Typical safety pyramid and safety pyramid statistics have been shown in figures 4.3.1 and 4.3.2 respectively.

Fig. 4.3.1 Typical Safety Pyramid

Fig. 4.3.2 Typical Safety Pyramid Statistics

4.3.1.3 Safety System Responsibilities

- Safety is everyone's responsibility. Everyone should show commitment towards work safety. Every worker deserves to make it safe every day. Safety is First! While planning and executing any activity safety symbols / signals shall always be respected. It is unlikely that things will improve unless workers participate in the safety process and safety management. Hence, workers participation is important in safety management system. During pipe fitting activities, at all safety systems need to be implemented and followed. Personnel, equipment, property, safety and safety existing facilities shall be ensured.

Fig. 4.3.3 Site Safety Symbols and details

Fig. 4.3.4 Ways to improve health and safety

4.3.1.4 Comprehending Safety System–Laws, Regulations, Codes and Standards

There are many national and international legislations, acts, codes and standards relevant to health, safety and environmental management. Safety Management System includes:

- ISO 45001:2018 Occupational Health & Safety Management System
- ISO 14001:2015 Environmental Management System

All safety systems like applicable laws, regulations, codes and standards' requirements shall be complied with in oil and gas construction industry.

1. **National Policy:** Safety and health occupies a very significant position in India's constitution which prohibits employment of children under 14 in factories and in hazardous occupations. It aims to protect the health and safety of all workers. It prevents employment in occupations unsuitable for the age and potential of the workers. The constitution provides a broad framework under which policies and programmes for occupational health and safety are established.

2. **Occupational Safety and Health Legislations and Regulatory Acts of India:** Many acts and legislations have been developed, implemented and monitored by various governing bodies. These rules / acts are also applicable to isolated storage installations and cross-country pipelines though the enforcement agencies are different.

Applicable legislations and regulatory acts include the following:

i. The Factories Act 1948, amended in 1954, 1970, 1976, 1987.

ii. The Petroleum Act,1934,supported by petroleum rules 2002, amended in 2011.

iii. The Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989.

iv. Building & Other Construction Workers Act 1996.

v. The Oil Fields Regulation and Development Act, 1948, an Act to provide for the regulation of oil fields and for the development of oil resources.

vi. The Petroleum and Natural Gas "Safety in Offshore Operations" Rules, 2009.

vii. The Petroleum and Natural Gas Regulation Board Act, 2006, an act to provide for the establishment of Petroleum and Natural Gas Regulatory Board to regulate the refining, processing, storage, transportation, distribution at petroleum products and natural gas excluding production of crude oil and natural gas so as to protect the interests of consumers and entities.

4.3.1.5 Comprehending and implementing safety system at worksite

All pipe fitters and pipe fitting team members shall comprehend safety system- laws, regulations and standards and implement / follow all safe practices that include:

1. tidiness of the & its with good lighting and fenced off from public
2. ascending or descending stairways to use the handrail and take only one step at a time.
3. erecting barricades/flagging around hazardous work areas, such as holes in decking and floor surfaces, trenches, road crossings, and overhead hazardous work.
4. permitting smoking in designated areas only. Prohibiting matches and lighters in restricted areas
5. all operating machinery and electrical switchgear with safety guards, switches, and alarms in place and functional
6. that whenever a safety device is removed from service or is found defective, the appropriate supervisor and affected parties shall be notified, the device tagged, and the action properly documented
7. that all block valves on pressure relief systems in service / nearby working areas, are chain-locked
8. that all fire extinguishers and other emergency equipment are in good condition, inspected regularly and kept clear of obstructions.

4.3.1.6 Comprehending and implementing safety system during pipe cutting, fitting and welding

1. Respective work permit is essential for oil and gas construction works. The work permit shall be specific to the respective work activities. The pipe fitting team shall not work without valid work permit. If the has work permit is expired, relevant work activities shall not be commenced until the work permit is properly renewed or new permit is obtained.
2. Defective equipment shall be removed and replaced.
3. All equipment shall be turned off, when not in use.
4. A portable fire extinguisher shall be available preferably within 6m (20 ft).
5. Combustibles around the work area shall be removed/protected.
6. All nearby sewers shall be covered, prior to work.

7. A qualified fire watch shall be maintained during operations and at every 30 minutes afterwards for critical works.
8. Cutting, welding, and brazing are not allowed in oxygen (O_2) prone environments (when O_2 concentration is greater than 23.5%)
9. Proper welding screens shall be used near other personnel / hazardous equipment / gas cylinders.

Gas welding, cutting, and brazing operations – compressed gas cylinders

- All connections/equipment shall be checked for leaks before use (For example, soap solution).
- Gas regulators shall be turned off and hoses bled off at the end of shift or task.
- Cutting and welding hoses shall be protected from potential damage during operations.
- Acetylene cylinders in use shall have a handle or valve wrench in place at all times.

Exercise

I. Answer the following questions.

1. Explain safety system requirements.

   ----

2. What is a safety pyramid?

   ----

3. Draw any three safety symbols and write their symbolic representations.

   ----

4. What are the responsibilities the employees of regarding construction site safety?

   ----

5. List out any five safety system implementation requirements.

II. State whether the following statements are True or False.

1. Permit To Work (PTW) is required for 'hot works'.

   True ☐ False ☐

2. Safety triangle is a theoretical model that describes a stable ratio between workplace incidents of varying degrees of severity.

   True ☐ False ☐

3. In construction sites, PPE is not required for non-hazardous area.

   True ☐ False ☐

4. ISO 14001 is meant for Occupational Health and Safety Management System.

   True ☐ False ☐

5. India's constitution prohibits employment of children under 16 in factories and in hazardous occupations.

   True ☐ False ☐

Notes

4.3.2 Safety Issues in Piping Installation Activites

At the end of this topic, you will be able to:

1. identify and specify construction site safety issues
2. state various hazards
3. recognise of effective fall arrest system is in place and follow fall protection requirements
4. explain safe installation and use of ladder, stairways ad scaffoldings.

4.3.2.1 One of the best ways to be safe, is to be able to identify safety hazards / issues before they lead to an accident. By being aware of potential dangers, safety can be made a part of routine work in the worksite. Construction site safety issues include:

- not wearing proper and appropriate PPE
- eExcavation work, pipe trench collapse
- electricity, electrocutions
- exposure to hazardous materials
- working at heights, Ladder safety , roof safety
- traffic vehicles and plant, crane safety, lifting and hoisting.
- falls, falling objects, slip and fall hazards.

Pipe fitters shall be familiar with all the above issues concerning safety in their work style. Some of the safety issues to be aware of include:

1. Equipment hazards

Pipe fitters use grinding machines with grinding wheels, torches and saws to cut to size / alter the size of pipes. Power grinding and cutting can lead to superficial cuts, deep wounds, nerve damage and even amputated limbs.

Tips

The sparks from a welding torch / cutting torch have the potential to burn the skin or seriously injure the eyes.

2. Exposure to hazardous materials

Some pipe fitters handle refrigerants, oxidizers, toxic gases, flammable products and other hazardous materials. These materials put workers at risk to several types of injuries.

Use of flammable products increases the risk for fires that cause burns and smoke inhalation. If pipe fitters inhale chemical fumes, these fumes can damage the respiratory tract.

If dangerous chemicals splash, they can burn the skin or injure the eyes.

Tips

Wearing appropriate masks, gloves, safety goggles and other types of personal protective equipment can shield pipe fitters from contact with hazardous materials.

3. Particle / fragments release

When pipe fitters hammer pipes or grinding to alter their size and shape, metal fragments sometimes break away from the pipes. These fragments can pierce the skin or enter the eyes. Wearing safety goggles with side shields protects the eyes from loose particles.

Tips

Pipe fitters should also wear appropriate clothing when performing hazardous tasks. Long-sleeved shirts, pants and gloves protect the skin from cuts and puncture wounds.

4. Repetitive stress musculoskeletal injuries

Pipe fitters shall never try to lift any weight more than 25 Kg. Pipe fitters sometimes carry heavy loads, increasing the risk for musculoskeletal injuries.

Tips

Using proper lifting techniques reduces the risk of these injuries. Pipe fitters should lift with their leg muscles instead of their back muscles.

5. Protection from falls and falling objects

a. Fall Protection

Fall protection is the most overlooked standard in the construction industry. It is cited as the most often and also is credited with the highest number of fatalities in the industry. Fall protection has to be the number one priority for firms and construction sites.

Tips

Fall arrest systems protect workers from falls by using harnesses (Refer fig 4.3.5 and Fig 4.3.6), webbing or other components to prevent people from falling than more than six feet. These systems also decrease the speed at which a worker falls, reducing the risk of serious impact injuries.

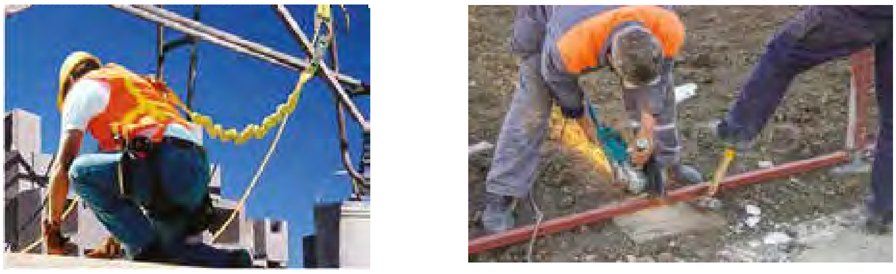


Fig. 4.3.5 Emphasising fall arrest safety system

b. Scaffolding

- Scaffolding is a temporary structure made of wooden planks and metal poles, guard rails and access ladders. The purpose of a working scaffold is to provide a safe working platform and access suitable for working team to carryout their work while working at height in construction sites.
- Both the workers on and below the scaffolding are prone for danger. Hardhats should be worn at all times to protect workers and to guard from falling objects. Additionally, pipe fitters should always wear non-skid work boots and tool lanyards to prevent slips and falls.
- Before the scaffold is used, direct scaffolding system connections and all access shall be evaluated by a competent person who shall inspect and confirm safety. Based on the evaluation, ensure that the supporting surfaces are capable of supporting the loads that are imposed.
- In addition to wearing hardhats, each employee on a scaffold shall be provided with additional protection

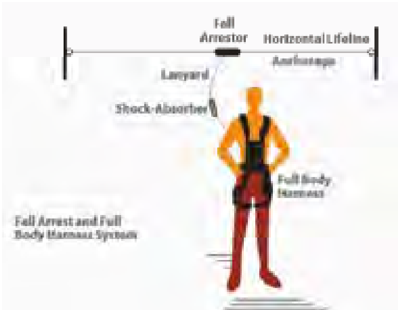


Fig. 4.3.6 Typical safety harness arrangement

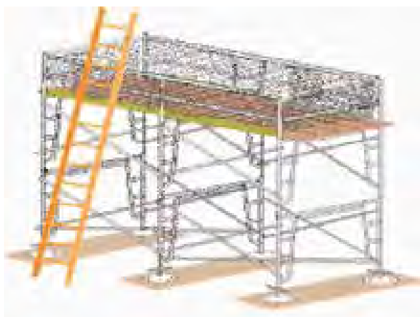


Fig. 4.3.7 Typical Scaffold

from falling hand tools, debris, and other small objects through the installation of toeboards, screens, or guardrail systems or through the erection of debris nets, catch platforms, or canopy structures that contain or deflect the falling objects.

The area below the scaffold to which objects can fall shall be barricaded, and employees shall not be permitted to enter that area.

A guardrail system shall be installed with openings small enough to prevent passage of potential falling objects.

c. Ladders

Ladder safety is another important necessity for pipe fitters. A pipe fitter must place a ladder on a firm surface to reduce the risk of falls. Securing the top and bottom of the ladder helps to prevent falls and injuries.

Tips

Improper ladder use such as incorrect ladder choice, failure to properly secure the ladder, attempting to carry tools up the ladder, has turned into leading causes of falls for construction workers.

Workers should always maintain three points of contact while on a ladder when include both the feet and at least one hand.

Ladder rungs, cleats, and steps shall be parallel, level and uniformly spaced when the ladder is in position for use.

When two or more separate ladders are used to reach an elevated work area, the ladders shall be offset with a platform or landing between the ladders.

Ladders shall not be moved, shifted, or extended while in use.

Ladder safety requirements have been depicted in fig 4.3.8. All safety requirements and precautionary measures shall be respected and adhered to.

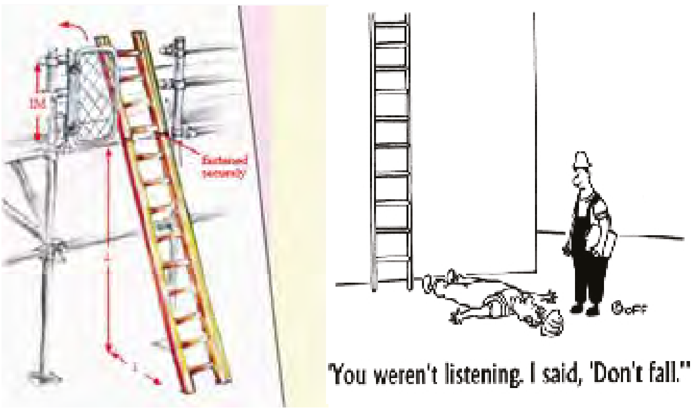


Fig. 4.3.8 Ladder Safety Requirements

Fig. 4.3.9 Neglecting Safety System

Exercise

I. Answer the following questions.

1. List out any six issues concerning safety in the construction site.

   ----

2. What are the possible hazards / injuries while operating pipe fitting works equipment?

   ----

3. Justify the requirements of fall protection in the construction site.

   ----

4. Describe full body safety harness system.

----

5. What are ladder arrrangements and positioning requirements to climb safely?

II. State whether the following statements are True or False.

1. Pipe fitters shall never try to lift any weight more than 25 Kg.

   True ☐ False ☐

2. While lifting heavy objects, keeping the load away from the body is a way to prevent musculoskeletal injuries.

   True ☐ False ☐

3. The maximum working at heights without using ladder, scaffold is 2.8 meters.

   True ☐ False ☐

4. Workers should always maintain minimum two points of contact while on a ladder.

   True ☐ False ☐

5. Ladders shall not be moved, shifted, or extended while occupied.

   True ☐ False ☐

Notes

4.3.3 Unsafe Act / Behaviour and Unsafe Condition

At the end of this topic, you will be able to:

1. define and identify unsafe act and unsafe conditions
2. identify and report unsafe act and unsafe conditions
3. prevent unsafe behavior.

Pipe fitter and other team members in the worksite are empowered to address and report unsafe conditions at the worksite and stop any unsafe act / behaviour.

4.3.3.1 Unsafe act

Unsafe act is any act that deviates from a generally recognized safe way or specified method of doing a job. It increases the probability, for the occurrence of an accident.

Fig. 4.3.10 Unsafe act and unsafe conditions.

Unsafe acts are performed when an employee fails to abide by safety rules and protocols. Unsafe acts are extremely dangerous, especially, in construction sites that require workers to handle heavy equipment or hazardous materials on a regular basis.

Unsafe Acts Include:

operating equipment without qualification or authorization

lack of/or improper use of PPE

failure to warn, failure to tag out/lockout, when required

erroneous operation of equipment

Fig. 4.3.11 Lifting weight unsafe acts (Typical)

Fig. 4.3.12 Grinding sparks impinge on gas cylinder

Bypassing or removal of safety devices

Tips

There are a number of mechanical aids available to reduce the amount of manual handling on site. These should be used wherever possible.

Loads that are bulky, heavy, unwieldy, or are to be carried over a long distance, require an assessment to be carried out and precautions put in place to minimise the risk of injuries.

Where possible larger loads should be broken down into smaller loads and/or team lifting should be considered, but with caution.

Classroom exercise: Identify all safety violations in fig 4.3.16 unsafe act and discuss

Fig. 4.3.13 Unsafe act of lifting too big

Fig. 4.3.14 Unsafe (before) and safe act

Fig. 4.3.15 Unsafe act to report after weight lifting

4.3.3.2 Unsafe Condition

Unsafe condition in the Workplace an act that is likely to cause damage to property or existing facilities or injury / accident. Unsafe conditions are hazardous situations or environments that have the potential to cause injury or death to an employee.

Unsafe conditions can be found in a variety of workplaces, but they might pose a special hazard to workers in industrial, construction manufacturing, or manual labour positions.

Fig. 4.3.16 Unsafe condition, unsafe act, near miss and accident

Examples of unsafe working conditions include:

- defective tools, equipment or supplies and using malfunctioning equipment or tools
- improperly secured machinery and poorly maintained equipment
- not providing safety gear (harnesses, safety masks, hardhats, etc.)
- unsecured openings, congestion in the workplace
- inadequate warning systems, poor housekeeping
- fire hazards in some cases, when there is the risk of a serious explosion
- anything that can cause falls such as working from heights including ladders, scaffolds, roofs or any raised work area, steep trenches
- hazardous air / atmospheric conditions make workers come away with respiratory issues and other workplace diseases after being forced to breathe contaminated air
- spills and tripsare caused by cords running across the floor or ice, oil, etc.

4.3.3.3 Unsafe Work Practices

All workers should feel confident that their workplace is secure from hazards. When unsafe work practices prevail, they result in health issues and an accident happens. The consequences can be life-altering. Hardworking personnel may be injured or killed on job sites. Many accidents can be prevented.

Fig. 4.3.17 Example of unsafe act

Fig. 4.3.18 Example of Unsafe acts and unsafe condition

Unsafe work practices cause all types of injuries. Poor conditions could cause slips or trip and fall accidents that impact an employee's physical and mental well being.

Construction sites are filled with hazards, such as ramps, ladders, scaffolding, heavy equipment, and power tools that could cause devastating injuries. That is why it is crucial for employers to have safety procedures in place.

1. **Observe the figure 4.3.18 that a welder welding a piping with following unsafe action and unsafe conditions:**

i. Working in restricted area where trapping is possible. (unsafe condition)

ii. The welder is supporting the pipe and welding. (unsafe act)

iii. No hand safety gloves are worn in the right hand in which the welder is holding the electrode holder. (unsafe act)

2. **Observe the pipe lowering activity figure 4.3.19. Unsafe acts are standing very near to the trench, no trench barricade, steep trench without adequate slope.**

3. **Observe the pipe lowering fig 4.3.20 and note the unsafe acts and unsafe conditions.**

i. Positioning of crane too close to the trench edge and operating it. (unsafe condition)

Fig. 4.3.19 Pipe lowering in unsafe condition (standing very near to trench edge)

Fig. 4.3.20 Pipe lowering unsafe act and unsafe conditions

Fig. 4.3.21 Crane Toppling

ii. Using single slings instead of the recommended minimum two slings to hold the pipe. (Unsafe act)

iii. Using wrong equipment(poclain) for pipe lowering (Safety violation – unsafe act)

iv. Standing on top of the pipe which is being lowered. (Safety violation – unsafe act)

Cranes / vehicles working too close to the side of the trench or rubble piled near the trench sides may result in collapse.

Tips

Ensure that the excavation is inspected daily.

Locate where underground pipes and cables are before hitting them.

There is no safe ground that "will not collapse".

Trench sides can collapse without warning.

The banksman must be trained to give clear signals.

Practical

1. Identify unsafe act and unsafe conditions from the following figure.

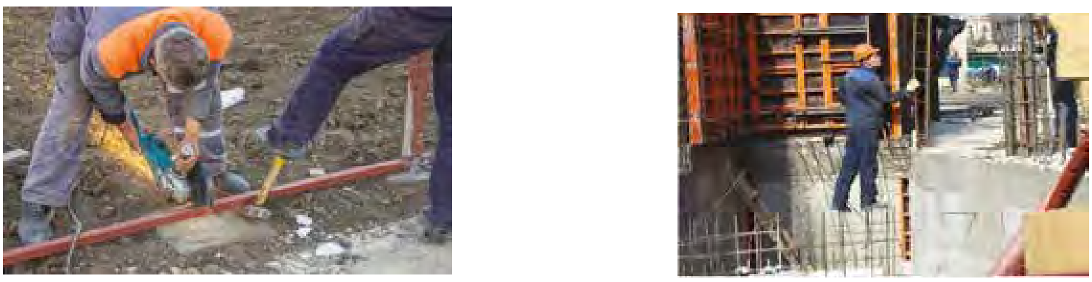


Fig. 4.3.22 Typical construction site work with unsafe act and unsafe condition

Exercise

I. Answer the following questions.

1. Define unsafe act and unsafe conditions.

   ----

2. List out any five unsafe acts.

   ----

3. List out any five unsafe conditions.

   ----

4. What is the manual load lifting limitation?

II. State whether the following statements are True or False.

1. Failure to utilize necessary safety equipment such as goggles and masks is an unsafe act.

   True ☐ False ☐

2. Safety gear refers to harnesses, safety masks, hardhats, etc.

   True ☐ False ☐

Notes

4.3.4 Reporting Near Miss Incident, Illness or Injury

At the end of this topic, you will be able to:

1. define and identify near miss
2. implement near miss reporting and recording system
3. identify and report safety concern issues
4. report incidents, injury, illness and accidents to supervisor.

4.3.4.1 Near Near miss

Near miss is an unplanned event / incident that did not result in injury, illness or damage to property, but had the potential to do so.

Near miss incidents should be regarded as early warnings about something that is somewhere wrong in the system. A faulty process or management system, invariably, is the root cause for risk that leads to the near miss and should be the focus of improvement. Other familiar terms for these events are a “close call,” a “narrow escape,” or in the case of moving objects, “near collision” or a “near hit.”

An employee walks down the hall, stepping over an extension cord stretched across his path. He turns a corner and nearly collides with another worker.

4.3.4.2 Near miss reporting systems

Near miss reporting system is one of the vital requirement in the safety system. “Reporting near miss” means “preventing future incidents/accidents”. Near miss incidents often precede loss producing events. They may be overlooked as there was no harm. Recognizing, recording and reporting near miss incidents can significantly improve worker safety and enhance an organization's safety culture.

4.3.4.3 Benefits of near miss reporting systems

- Provides convenient opportunity for "employee participation," which is the basic component of a successful safety management system.
- Creates an open culture, where everyone shares and contributes towards safety for themselves and other in a responsible manner.

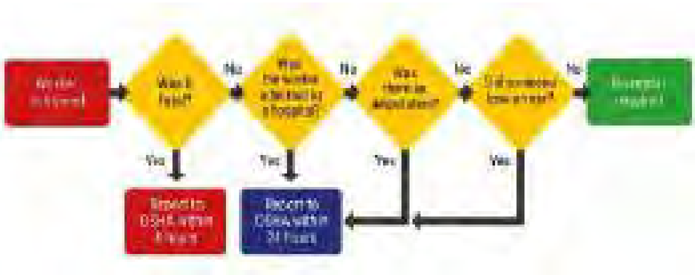


Fig. 4.3.23 Injury or illness reporting

Fig. 4.3.24 Emphasising nearmiss reporting

4.3.4.4 HSE concerns and issues Reporting

1. What is safety concern?

Safety concern means "any condition, practice, or violation that could cause a substantial probability of an accident, physical harm, property existing facilities, loss / damage, and/or environmental impact".

If something to that might be hazardous is in spotted workplace, reporting it to the supervisor / foreman and safety representative straightaway is important. Some areas where are can easily find hazards include equipment safety, electrical safety, fire safety, manual handling or hazardous substances.

Reporting all injury, illness and incidents

Reparting incidents is an ideal resource from which safety improvements can be developed and implemented. When incidents or injuries occur and get reported, it will help to assess, identify the underlying safety problems, analyse the root cause, investigate and improve safe work procedures and practices.

Report all fires, spills, and releases, no matter how small, to your supervisor immediately.

Report any unsafe act, unsafe condition, practice, near miss, or incident to your supervisor immediately.

Typical incident reports shall include – date, time, location, what happened, etc.

Fig. 4.3.25 Report all incidents

Fig. 4.3.26 Typical content of incident report

An accident can be defined as an unforeseen and unexpected event often resulting from lack of asareness or careless behaviour causing injury, illness, or damage to property.

Fig. 4.3.27 Emphasising accident reporting

Fig. 4.3.28 Incident Management Cycle

Exercise

I. Answer the following questions.

1. Define near-miss.

   ----

2. What ae the benefits of reporting incidents?

   ----

3. Why should illness be reported to the supervisor?

II. State whether the following statements are True or False.

1. Reporting near miss" means "Preventing future incidents/accidents".

   True ☐ False ☐

2. Near miss reporting system provides sufficient data for statistical analysis and performance measurement.

   True ☐ False ☐

3. Incident reports will be an ideal resource from which safety improvements can be developed and implemented.

   True ☐ False ☐

Notes

4.3.5 Promoting and Maintaining Positive Safety Culture

At the end of this topic, you will be able to:

1. list the importance of safety culture
2. promote and maintain positive safety culture in the workplace
3. implement safe working practices.

4.3.5.1 Safety culture

The safety culture of an organisation / construction site is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour. It determines the commitment to, and the style and proficiency of, an organisation's health and safety management.

Safety culture refers to how safety is addressed and communicated in the workplace. It encompasses the attitudes, beliefs, perceptions, and values of all employees in an organization in relation to safety. Mental health is at the forefront of safety in the workplace.

Positive safety culture

The creation and maintenance of a positive safety culture is an ongoing process and it takes a lot of effort. With a strong and positive safety culture, employees feel cared for and are happier in the workplace. This happiness translates into fewer sick days, higher productivity and strong retention rate. Positive safety cultures and proactive safety systems work hand-in-hand. In a positive safety culture,

i. nothing takes precedence over safe work under any circumstances. The workforce never feels as if safe work procedures are an obstacle or hindrance to do their job tasks correctly, on time, and without reprimand.
ii. all personnel, from the front line to the senior leadership, share the same responsibility for safe work. All personnel, have an equal responsibility in keeping themselves and othera safe.
iii. the safety system is informed by the workforce, not designed and enforced by management.

4.3.5.2 Establishing and maintaining a strong and positive safety culture in workplace shall be by

Maintaining Safety Culture

- effective communication
- providing appropriate training
- developing and implementing a positive reporting process
- involving all colleagues /workers
- engagement in Joint Health and Safety Committee (JHSC).

Always Clear Up Your Own Rubbish

"A clean site is a safe site"

Fig. 4.3.29 Workplace cleaning

a. Communication

A great way to increase safety communication, while building a positive culture, is to hold weekly or monthly safety talks. It includes displaying safety policies and best practices at all important / prominent work locations.

b. Providing Training

Training employees demonstrates commitment to safety. Trained employees readily embrace safety culture as they are aware of hazards and the effect that they can have if they do not maintain workplace safety.

c. Leading by example

Leading by example means following all safety policies and encouraging employees to do the same. If management is commited to safety, employees will follow as they see policies and procedures being followed by their superiors and co-workers.

Tips

All waste should be disposed of in the correct skips. Keep passages clear all the time. Sortout materials and pile them up safely. The stacks should not be too high.Beware of floor openings and ensure that they are fenced or covered.Provide sufficient lighting.

4.3.5.3 Developing and implementing a positive reporting process

Rewarding employees who report safety hazards or concerns, will encourage the employees. A positive safety culture will be much easier to build and maintain when employees feel comfortable reporting concerns and believe that the reporting process is positive.

Exercise

I. Answer the following questions.

1. Describe positive safety culture.

   ----

2. Write short notes on "establishing and maintaining a strong and positive safety culture in the workplace".

   ----

3. What are the actions / steps that will promote a positive safety culture in the workplace?

II. State whether the following statements are True or False.

1. In positive safety culture, the safety system is informed by the management.

   True ☐ False ☐

2. Culture is a set of values, behaviorus, and norms that guide interactions between people.

   True ☐ False ☐

3. Risk assessment is the process of defining what hazards exist or might appear in the workplace.

   True ☐ False ☐

4. A positive safety culture will be much easy to build and maintain when employees feel uncomfortable to report concerns.

   True ☐ False ☐

Notes

4.3.6 Assessing Threats and Protection from Threats

At the end of this topic, you will be able to:

1. identify of threats, risks, leakage and rupture of pipe lines
2. soft different types of threats
3. identify the possible sources of threats
4. perform threat assessment and work towards protection from threats.

4.3.6.1 Threats and risks

Threat – An action, potential action, or inaction that is likely to cause damage, harm or loss.

To comprehend threat assessment means to use tools and or professional judgment to assess the prevention of similar or same threats.

Vulnerability – Weaknesses or gaps in the protection of assets that can be exploited by threats in order to compromise the asset.

Risk – The potential or possibility of the occurrence of compromise, loss, injury or other adverse consequences.

4.3.6.2 Categorization of threads

In general, threats that compromise pipeline integrity are categorized into three groups: time-dependent threats, time-independent threats, and stable threats.

Time-dependent threats are issues with a pipeline that occur over time. This includes internal and external corrosion and stress corrosion cracking (SCC). These threats can be partially mitigated by adding protective measures to pipe infrastructure (For example, protective coatings).

Time-independent threats are issues that occur as a result of an external force. The most common threat is pipeline damage caused by erosion, operator error during excavation and/or operations.

Stable threats are those that remain benign unless activated by a change in operations or the surrounding environment. The most common stable threats are physical defects in pipeline infrastructure that occur during the manufacturing process.

4.3.6.3 Possible sources of threats

Some hazardous liquids, such as propane pose a hazard of fire or explosion threat.

For natural gas pipelines, the greatest risk / threat is associated with fires or explosions caused by ignition of the natural gas.

The release of natural gas, primarily, methane which is a very potent greenhouse gas, contributes to climate change.

Factors such as type of materials used, installation techniques, seam type, whether corrosion prevention measures were used, and how the pipeline is maintained all these impact a rupture to occur during the aging of a pipeline. Fig 4.3.30 shows the pipe rupture due to fatigue crack.

Fig. 4.3.30 Pipeline rupture due to fatigue crack.

Fig. 4.3.31 Pipeline leak due to 3rd party attack

Terrorism in oil and gas pipelines is a threat. Improvised explosive devices have been the preferred method of attack against gas and oil facilities worldwide.

Tips

Threats due to – internal corrosion, external corrosion, stress corrosion cracking shall be considered as these might lead to leakage, pipeline burst / explosion.

Threats due to - human error, excavation damage, earth movement, outside force or adverse weather shall be taken into account during threat assessment.

Fig. 4.3.32 Typical 3rd party threats

Possible third party threats to pipelines have been depicted in fig 4.3.31 and 4.3.32

4.3.6.4 Safety measures to overcome third party threats

- Patrolling – Increasing patrolling, when construction is in progress and area included is in vulnerable locations.
- Public awareness programmes-arranging necessary awareness when the for land owners and public is important.
- Barricading barricading the construction area of interest / location or access route when construction work is in progress has to be done.
- Installing additional warning markers for proposed/internal roads and at boundary are essential.
- Installing additional boundary markers at every 10m of interval in the block is necessary.

4.3.6.5 Threat assessment

Fig. 4.3.33 Threat assessment

Fig. 4.3.34 Pipeline explosion due to rupture

Fig. 4.3.35 Pipeline explosion due to corrosion

Any threat which may cause failure of the pipeline requires assessment / analysis. During installation of pipelines, all threats, vulnerabilities and risks shall be assessed and proper and effective protecting measures be taken.

Time dependent threats and stable threats need continuous assessment, monitoring and integrity check during plant and pipeline operations / and duing use.

4.3.6.6 Workplace Violence

Violence in the workplace is a threat during construction, installation and operation of a piping system / pipelines. By detecting and interceding "at risk" or intimidating behaviour in the early stages, the threat can be mitigated and/or avoided.

Workplace "threats" can be both internal (co-worker, supervisor or customer) or external (family member, stranger).

All the above probable / possible threats shall be identified in advance and appropriate action shall be taken to prevent threats at Workplace.

Workplace Violence Prevention Policy: One of the first measures that employers should take is to create a "No Threats, No Violence" policy toward workplace violence in the organisation.

Exercise

I. Answer the following questions.

1. Propose any five safety measures to overcome third party threats.

   ----

2. What are the factors for workplace violence?

   ----

3. What are some possible sources of threats?

II. State whether the following statements are True or False.

1. Internal and external corrosion and stress corrosion cracking are time independent threats.

   True ☐ False ☐

2. Pipeline ruptures are more common and cause more damage as opposed to pipeline leaks.

   True ☐ False ☐

3. Terrorism in oil and gas pipelines is a time dependent threat.

   True ☐ False ☐

4. Pipeline leak may lead to fluid leak; but not rupture.

   True ☐ False ☐

Notes

4.3.7 Handling and Storage of Hazardous Substances and Their

At the end of this topic, you will be able to:

1. identify and describe the property of different petroleum products
2. handle and store of hazardous substances and chemicals
3. handle, store and use gas cylinders.

4.3.7.1 Petroleum products

Examples of petroleum products include kerosene, heating oil, diesel, fuel, gasoline, LPG and natural / LNG gas, etc. Petroleum products are complex mixtures derived from crude oil and have similar chemical and physical properties. Natural gas is environment friendly and safe to handle. It produces emissions upto 65 per cent lesser than coal & 225 per cent lesser emissions than oil.

At the same time, natural gas is highly inflammable and explosive in nature. If it is not handled with care, it has great potential to cause devastation.

4.3.8.2 Handling and storage of hazardous substances

1. General requirements for handling and storage of hazardous substances

Chemicals and other hazardous substances shall be handled as per PCB COSHH (Control of Substance Hazardous to Health) rules and shall be accompanied with the Material Safety Data Sheets (M.S.D.S.).

Never store hazardous items / products in food containers. Keep them in original containers without removing the labels.

All chemical or hazardous material containers shall be properly labelled and stored in accordance with manufacturer's recommendations. Drums shall be stored in secondary containment areas or on drum containment pallets.

Proper personal protective equipment (PPE) prescribed by the Chemical Hazard Bulletin (CHB) or Material Safety Data Sheet (MSDS) shall be worn when handling chemicals or hazardous materials.

The following are the chemicals associated with piping fabrication and installation work:

gasoline, diesel, lubricating oils, paints, thinners, gaseous hydrocarbon (acetylene, nitrogen), pesticides, mild acid and alkaline for X-ray processing. Tightly seal paint cans / containers before storing. Paint should be kept in dry areas and away from sparks and flames. Flammable products such as gasoline, kerosene, paint thinner etc shall be stored in approved containers only. Incidenst during transportation, handling, and use of chemical substances shall be immediately reported to the supervisor. Prompt containment / clean up action and safe handling methods shall be followed.

2. Extremely or highly flammable items storage and handling

i. Storage of extremely or highly flammable items

extremely or highly flammable items / containers shall be in a closed steel or thick plywood box located at the ground level, preferably, in an outside locked store. The store must be cool and well ventilated including ventilation at or near floor level because the vapours of most highly flammable liquids are heavier than air.

Tips

Container shall bear the label "flammable".

Do not store flammable and oxidizing chemicals together.

ii. Safe handling of extremely or highly flammable Items

These items shall be handled at well ventilated area to prevent any build-up of flammable gases and vapours.

Tips

Before opening a bottle containing a flammable liquid, always make sure there is no open flame within 2 metres.

3. Oxidizing chemicals

An oxidizing substance is one that produces heat or evolves oxygen in contact with other substances that have causes oxygen them to burn strongly or become explosive or spontaneously combustible. Oxidizing chemicals include hydrogen peroxide and other strong peroxides, nitric acid, ammonium nitrate, sodium nitrite, perchloric acid, sodium chlorate, chromic acid, potassium dichromate, calcium hypochlorite bleach powder, and potassium permanganate.

4. Corrosive chemicals

A corrosive chemical is one that can destroy living tissue and is also capable of damaging inanimate substances.

Tips

Phenol, strong acids such as concentrated sulphuric acid, nitric acid, glacial acetic acid, trichloroacetic acid, o-phosphoric acid, caustic alkalis such as sodium hydroxide (caustic soda), and potassium hydroxide (caustic potash) are corrosive chemicals.

Corrosive chemicals should be stored at low levels.
Never add water to acid.

5. Explosive chemicals – storage and handling

Always read carefully the manufacturers' instructions regarding the storage and handling of explosive chemicals carefully.

Tips

Perchloric acid, if allowed to dry on woodwork, brickwork or fabric, chemical will explode and cause a fire on impact.

Picric acid must be stored under water. If allowed to dry, it can be explosive.

Diethyl-ether and other ethers when exposed to air and sunlight, can form shock-sensitive explosive peroxides.

6. Handling environmentally dangerous chemicals

It shall be ensured that the drainage and waste disposal systems of laboratories are safe, adequate and in good condition. Hazardous chemicals and reagents must not be discharged into open drains or disposed off on open ground. Sufficient water must be used when flushing hazardous chemicals and reagents through the plumbing system.

Fig. 4.3.36 Respecting Safety Signage

Tips

The sewer system should not be used to dispose of highly toxic chemicals, water-immiscible chemicals,

4.3.8.3 Handling, storage and safe use of gas cylinders

During construction, risks and vulnerability associated with gas cylinders shall be assessed and required precautionary measures shall be taken while handling, using and storing cylinders.

1. Safe handling & storage of gas cylinders

Secure protective caps on all cylinders that are not in use.

Properly secure cylinders in an upright position during movement.

All cylinders shall be properly labelled.

Tips

Use cylinder trolleys, material baskets, cylinder racks, and other proper types of equipment to transport cylinders.

Do not store cylinders at temperatures exceeding 54 °C (130 °F).

Keep stored oxygen (O2) cylinders separated from fuel gas cylinders by minimum 6.1 m (20 ft) or by a 1.5 m (5 ft) high, non-combustible barrier.

Keep cylinders away from direct flame, sunlight, and other heat sources.

2. Using Gas Cylinders

Use approved pressure – reducing regulators on all cylinders with a check valve connected to the cylinder valve.

Always close the cylinder valve before attempting to stop leaks.

Do not use oil or grease as a lubricant on gas cylinder valves or attachments.

Protect cylinders from direct flame, sunlight, and otherheat sources.

Inspect all gauges, regulators, hoses, and cylinders for damage.

Fig. 4.3.37 Unsafe storage of cylinders

Exercise

I. Answer the following questions.

1. What are the recommendations for safe handling and storage of hazardous products?

   ----

2. List out any possible six chemicals associated with piping fabrication and installation work either directly or indirectly.

   ----

3. Explain the requirement for safe handling and storage of extremely or highly flammable items.

   ----

4. List - out any five oxidizing chemicals?

   ----

5. How will you handle and use gas cylinders?

II. State whether following statements are True or False.

1. Natural gas is highly inflammable.

   True ☐ False ☐

2. MSDS stands for Material Storage Data Sheet.

   True ☐ False ☐

3. The safe method is add acid to water.

   True ☐ False ☐

4. Do not store cylinders at temperatures below 54 °C.

   True ☐ False ☐

Notes

4.3.8 Spills Management

At the end of this topic, you will be able to:

1. list the necessities for spill management
2. prepare response action plan for a chemical spillage
3. describe method to safe handling of spills
4. list measures for preventing chemical spills in the workplace
5. describe six basic steps involved with dealing with spills.

4.3.8.1 Spill management requirements

Like fire, chemicals are very useful for a broad variety of functions. But just like fire, many chemicals are inherently hazardous or even deadly when they're not used in a properly controlled manner.

An organisations safety plan addresses about are chemicals that are normally used in worksites and what should be done in the event of a spill. How that plan is structured depends both on the specific chemicals that are being used and how workers may come in contact with them.

Under no circumstances shall liquid waste, such as paints or solvents, be allowed to soak into the ground or be poured down the drains. This is "hazardous waste" and should be disposed off in line with current version of applicable safe disposal legislations.

4.3.8.2 Contingency plan for minor hydrocarbon spills

There shall be a contingency plan to respond to minor hydrocarbon spills of oil and other liquid chemical wastes, which includes:

i. using drip pans for collection of waste lubricants during equipment maintenance work
ii. immediate cleaning with appropriate absorbent granules and powders

iii. using storage restriction (bond wall containment)

iv. identifying potential leak points on storage containers

v. routine inspection of chemical storage facilities and area by Safety (HSE) Officers.

4.3.8.3 Spill clean - up products and materials

Cleaning up spills in the workplace needs the right combination of absorbent materials and people trained in the correct and effective use. Without these two vital elements, spills can cause significant damage by way of environmental issues, injuries, extra management burdens and at high costs.

b. Dispersants are for use when oil is on water. They break it into droplets which disperse further through the water, allowing natural breakdown to happen faster.

c. Surface cleaners help to break down the oil to make it easier to lift away. They are applied as a powder or liquid. The resulting mixture of cleaner and oil is still a pollutant, so it must not be washed down the drain.

Fig. 4.3.38 Typical Spill handling materials

Small non-hazardous spills do not require any special cleaning materials or spill plan. Following simple cleaning steps is sufficient.

Identify and is isolate spill. Always follow workplace procedures for clean-up and disposal.

Apply absorbent to the perimeter of the spill to form a bund and stop spill migration.

Continue to apply absorbent working to the centre until spill is completely covered and no free liquid is visible.

Sweep with a stiff broom working dry material over spill area to remove all surface oil. Dispose of in accordance with local regulations.

Fig. 4.3.39 Cleaning small non-hazardous spills.

4.3.8.4 Spill response action plan

While the steps to take in any spill response action plan are similar, one thing that must be considered is the size of the spill. If the spill involves 50 gallons or more of a liquid, this likely of qualify as a major spill. However, there are no set rules. A major spill in one workspace could involve just a gallon of liquid or ever less.

At the very least, spill action plan should reflect the information in the MSDS, and should be certain that the correct PPE and spill control materials are on hand. Training is another critical aspect for a sound spill response plan.

Fig. 4.3.40 Cautioning wet floor

Fig. 4.3.41 Chemical spill containment and cleaning

4.3.8.5 Handling and responding to spills

Generally speaking, regardless of the level of hazard involved, there are six basic steps involved with dealing with spills. While the specific actions related to each step may vary, as will the people responsible for handling each step, they form the basis of a spill response.

Fig. 4.3.42 Typical spill response procedure for a smaller spills

1. Communicate the hazard

Immediately notify others working in the area and any supervisory personnel of the hazard. If the situation warrants it, evacuate the area. It is an excellent idea to have someone who is familiar with the incident and the layout of the worksite to remain on the scene to assist the first responders, as it is safe to do so.

Make sure that anyone who is injured or has been contaminated is removed from the immediate area and taken to a safe place. If appropriate and safe, flush contaminated areas with water while waiting for the medical personnel to arrive.

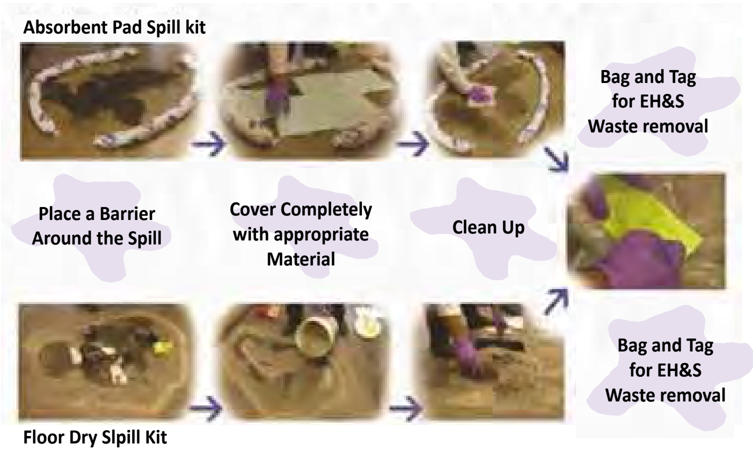


Fig. 4.3.43 Typical Spill cleaning procedure

2. Prepare for spill clean up

Isolate the area. Install warning cones around the immediate area and barricade (a 25-foot radius is recommended).

Tips

If the contents of the spill have been identified, get the Safety Data Sheets related to the liquid to review warnings and hazard information.

3. Control the spill

This step focuses on ensuring that the spill does not become worse.

If possible (and appropriate), shut down potential sources of heat or ignition. Increase ventilation to the area if that will safely disperse any fumes. If the fumes present a hazard of their own, it is usually better to isolate the area by closing the doors and windows after the workplace has been evacuated.

4. Contain the hazard / spill

The first action must be to stop whatever has been spilled. Think first of the drains, and deploy drain covers to stop spilled material. Then, thinking about drains further away, put some form of barrier to stop the spilled liquids from spreading.

Once the situation has been addressed, take steps to keep the spill from spreading to other areas or contaminating adjacent surfaces. Start spreading materials around the perimeter of the spill to prevent it from expanding.

If the spill is spreading, fast containing the spill becomes critical. Have handy such things as sand, clay or even pet litter. These are absorbent materials that will help to absorb and block the spill from spreading.

5. Clean up the spill and any damage

Collect the material used to contain or neutralize the spill, and dispose it off in the specified manner. If the spill is small, it need may be a plastic bag, while larger spills may require plastic pails or drums. In some cases, will also need to dispose of any equipment such as brooms or dustpans that you used to clean up the material. If what you have gathered qualifies as a hazardous material, be sure to label it accordingly and dispose as specified by local laws and environmental regulations.

Clean the surfaces that were affected by the spill with the correct material, whether that's bleach, a mild detergent, water, or some other material appropriate for the material that was spilled. Instead of rinsing the area after cleaning, you may need to use another method such as more absorbent material.

6. Safe Disposal

Whatever has been used to mop a spill can not just be dumped in a bin. It must be disposed off responsibly. As a general rule, this will mean in the same way that the spilled material would have to be disposed off.

Having a supply of appropriate bags handy – resistant to the spilled material, – will mean you have the first step of disposal 'in the bag.'

7. Documenting / recording the spill

Most workplaces will require that the spill and the clean up operation are documented in order to evaluate how effectively the spill response plan worked. Also, to look for ways to prevent such a spill from happening again. This spill management shall be one of the lessons learnt. If documented, it will help to tackle the similar spills or to make changes in the spill response plan and to take preventive action to avoid such spills.

Exercise

I. Answer the following questions.

1. List out potential areas or processes for occurrence of spills.

   ----

2. Provide tips for preventing spills at the workplace.

   ----

3. Prepare response action plan for a chemical spill at the workplace.

   ----

4. Describe the five basic steps involved in dealing with spills.

II. State whether following statements are True or False.

1. Ensure chemicals are stored above the eye level.

   True ☐ False ☐

2. Absorbents change the physical or chemical properties of the spill they are cleaning.

   True ☐ False ☐

3. After surface cleaning, the resulting mixture of cleaner and oil must be washed down to the drain.

   True ☐ False ☐

Notes

UNIT 4.4 Emergencies, Rescue and First aid Procedures

Unit Objectives

At the end of this unit, you will be able to:

1. determine various dangers associate with the use of electrical equipment
2. describe appropriate basic first-aid treatment relevant to electrical shock, eye injuries, heart attack
3. describe medical emergency in real or simulated environments.

4.4.1 work Hazards

At the end of this topic, you will be able to:

1. free a person from electrocution
2. administer appropriate first-aid treatment to the victims
3. respond promptly appropriate to an accident situation
4. explain basic techniques of bandaging.

4.4.1.1 Electrocution

Electrocution results when a person is exposed to a lethal amount of electrical energy. An electrical hazard can be defined as a serious workplace hazard that exposes workers to the following.

- burns
- electrocution
- shock
- arc flash / arc blast
- fire
- explosions

Fig. 4.4.1 Electrocution

Rescue a person from electrocution

First if you can do so very quickly, turn the source of electricity off. It may be a light switch or circuif breaker. If not possible to do this quickly, you need to find something long and non-conductive such as a plastic / Insulated material. Use this to knock the person away from the circuit. Do not physically touch the person.

Once the person away from the circuit, check whether the person is breathing and has pulse. If you can, start CPR if needed, until paramedics/first-aid team arrive.

Common accidents and emergencies are caused by bleeding, burns, choking, electric, shock, fracture, poisoning

a. Bleeding

Bleeding is the loss of blood. It can happen outside or inside the body. One bleeds on getting a cut or wound. Bleeding can also be due to an injury to internal organs.

Type of Bleeding

i First aid for bleeding is to prevent further blood loss and minimise the effect of shock.

ii Capillary bleeding refers to superficial abrasion and wounds.

iii Venous bleeding is more severe than capillary bleeding. It is not serious like arterial bleeding.

iv Arterial bleeding is characterised by brighter red blood that may pulsate or spurt.

Fig. 4.4.2 Bleeding hand injury

Fig. 4.4.3 Bleeding first-aid

Fig. 4.4.4 Burns first-aid

Fig. 4.4.5 Eye wash station

b. Burns

To treat a burn, follow the first-aid advice below:

- get the person away from the heat source to stop the burning.
- cool the burns with cool or lukewarm running water for 10-15 minutes. Do not use ice, iced water or any cream, ointment.
- remove any clothing or jewellery that is near the burnt area of the skin.

c. Choking

If choking is mild:

- encourage the person to cough to try to clear the blockage
- encourage the person to try of spit out the object if its in the mouth
- do not put your fingers in their mouth to help them, because they may accidentally bite you.

If choking is severe, then person will not be able to speak, cry, cough or breaths. Without help, they will eventually become unconscious. Stand behind the person and give one side support to their chest with one hand, lean the person forward so that the object blocking their throat/ air passage will come out of their mouth.

d. Fracture

First aid for fracture

If you suspect that someone has a broken bone, provide first-aid treatment and help them get first-aid.

Stop any bleeding

If they are bleeding, apply pressure to the wound using a sterile bandage a cloth or a clean piece of clothing.

Immobilize the injured area

If you suspect that they have broken a bone in their neck or back, help them stay as still as possible until the ambulance and the firstaid team arrives.

e. Poisoning

Symptoms and treatment for poisoning depend on the poison which is taken, how much of it is taken and how much has entered the body. A person is poisoned when he/she

- eats, drinks or inhales a suspected or known poison
- gets poison on the skin or in the eyes
- is bitten or strung by reptiles, spiders, insects, or marine animals.

In case of poisoning, if the victim has collapsed or has stopped breathing, do not delay. Inform the safety officer and call for an ambulance.

First-aid for poisoning on the skin: Carefully remove the contaminated clothing and wash the exposed areas with sufficient amount of (room temperature) ordinary water.

In the eye: Rinse the eyes with a slow gentle stream of water from a eye wash station for 10 to 15 minutes. Allow the stream to flow from the inner corner of the eye across the eye to the outer corner.

Bites

For insect bites and stings, wash the area of the bite with soap and water. Place cold compressed or ice pack on the area for 10 minutes and call for an ambulance.

4.4.2 Heart attack or cardiac arrest due to electric shock

When providing firstaid, one needs to follow some rules.

Cardiac arrest: In cases where the heart has stopped beating, act immediately. Check if:

- the carotid pulse in the neck can be felt
- the casualty is blue around the lips
- the pupil of his eyes are widely dilated.

Fig. 4.4.6 Cardio-Pulmonary resuscitation

Fig. 4.4.7 Accident response worksite first-aid

Lay the victim on his back on a firm surface.

Kneel alongside, facing the chest and locate the lower part of the breastbone.

Place the palm of one hand on the center of the lower part of the breastbone, keeping your fingers off the ribs. Cover the palm with your other hand and lock your fingers together.

Keeping your arms straight, press sharply down on the lower part of the breastbon. Then release the pressure.

Repeat this 15 times at a rate of at least once per second.

Check the carotid pulse.

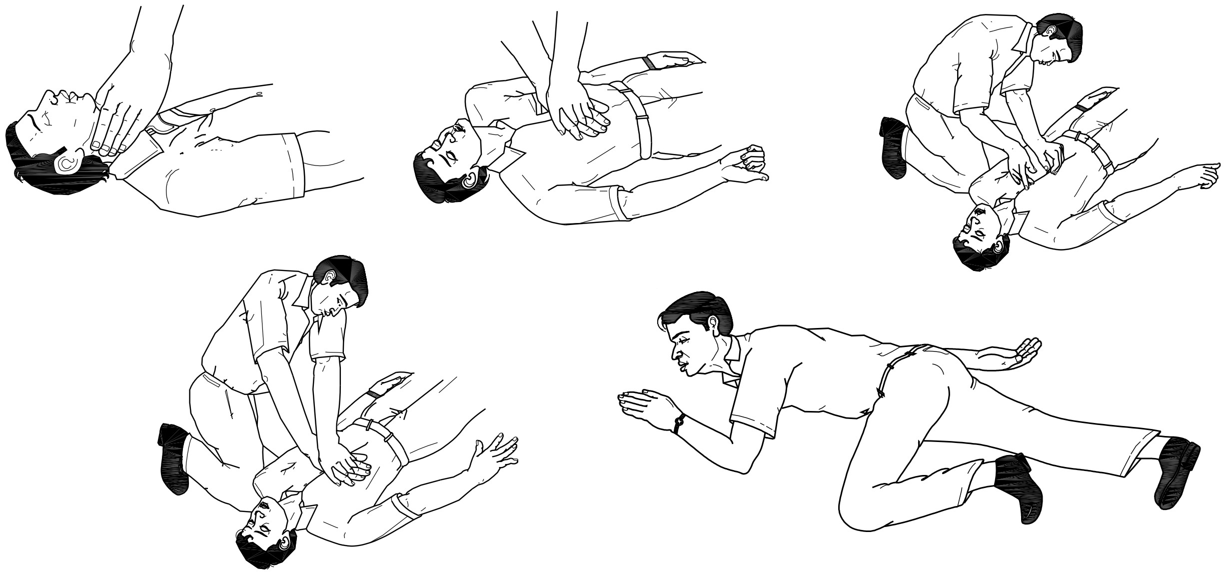


Fig. 4.4.8 Cordiopulmonary resusation (CPR)

Move back to the victim's mouth to give two breaths (mouth-to-mouth breathing)

Continue with another 15 compressions, followed by a further two breaths of mouth-mouth breathing, and so on, checking for the pulse at frequent intervals.

As soon as the heartbeat returns, stop the compressions immediately but continue with mouth-to-mouth breathing until natural breathing is fully restored.

Place the victim in the recovery position. Keep him warm and get quick medical help.

4.4.1.3 Bandage

A bandage is a piece of material used either to cover wounds to keep the dressing in place, to apply pressure to controll bleeding. All bandages should be applied by a trained first-aid person only. There are three major types of bandages.

roller bandages, tubular bandages, triangular bandages.

Techniques for bandaging

Each bandaging technique consists of various basic forms of bandaging. The following five basic forms of bandaging that can be used to apply most types of bandages:

circular bandages

spiral bandages

figure of eight bandaging

recurrent bandaging

reverse spiral bandaging

Fig. 4.4.9 Circular

Fig. 4.4.10 Spiral

Fig. 4.4.11 Figure of eight

Application technique for bandages

- Select the appropriate bandage material
- Select appropriate width of bandage
- Prepare the patient for bandaging
- Apply the bandage
- Check the blood circulation and the skin below the bandage.

Fig. 4.4.12 Recurrent

Fig. 4.4.13 Teverse spiral

Tips

Important factors need to be considered and remembered at work site.

Make sure your work site has an unlocked first-aid kit.

Before assisting a victim, protect yourself first.

Make sure that the tongue does not block the victim's airway/air passage.

See that the victim has a pulse and good blood circulation as you check for bleeding.

It is very important to know that a person with serious neck or back injuries should not be moved.

Look for an emergency medical identification card.

Do not give fluid to an unconscious or semi-conscious person.

Have someone call for medical assistance while you perform first-aid.

Exercise

I. Answer the following questions.

2. Name some serious electrical workplace hazards.

   ----

3. Explain how to free a person from electrocution.

   ----

4. Explain first-aid for burns and bleeding?

   ----

5. What are the three major types of bandage?

II. State whether the following statements are True or False.

1. Whenever we free a person from electrocution, the first step to do is unplug or isolate the poewr source immediately.

   True ☐ False ☐

2. Skin burn is a type of injury to tissues which is caused by heat or cold.

   True ☐ False ☐

3. Chocking is caused by a mechanical obstruction of the airway that prevents normal breathing.

   True ☐ False ☐

4. In case of cardiac arrest, first you should call for an ambulance or medical help.

   True ☐ False ☐

Notes

4.4.2 Responding to Emergency Situations

At the end of this topic, you will be able to:

1. respond promptly to an accident
2. report an emergency situation
3. perform rescue activity during an accident in real or simulated environments
4. describe about potential injured personal safe handling methods of an injured person.

4.4.2.1 Prompt response to accidents

Time is everything in an emergency situation whether the incident is the result of an accident, a health problem, fire, oil spill. It is, therefore, vital for every worker/workforce to understand how to respond during such situations.

A situation may occur where trained first-aider or safety officer is not immediately available. In this situation, the person on the location must assist the victim, by providing initial care to the best of their ability, as quickly as possible. For life threatening or critical situations, the nearest person has to call an ambulance and report to the safety officer and project construction manager.

First-aid

First-aid means the provision of initial care for a person suffering from an injury through the services of someone who is available on the spot. It is, usually, provided by non-experts, but trained persons, until a trained first-aider arrives at the spot.

Fig. 4.4.14 Response at Construction side

Fig. 4.4.15 First Aid

Accident rescue activity in the work site

If the person is injured, it is important to avoid moving the injured worker because of the risks of causing complications. Rescue departments have an obligation to perform their duties in the most effective way, efficiently and without delay.

Rescue operation

Rescue comprises responsive operations that usually involve the saving of human life or prevention of injury during an incident or preventing damage to assets.

Tools used for rescue operation

Rescue operation is supported by special vehicles such as fire department or ambulance vehicles.

Different tasks in the rescue operation

- prioritizing the injured people
- escape routes
- assembly point for evacuated people
- first-aid

Prioritizing the injured people

It is necessary to evacuate the building construction site. The first priority is to find out who can be evacuated based on how injured each person is. Only after we have brought the injured people safely in the assembly area, can the injured people be prioritized where the victims the victims get the top priority.

Rescue Plan

The main elements and methods for execution of rescue plans include:

- primary preparations before the occurrence of the accident
- procedure during the incident and the sequence of operation
- procedures on the worksite after the incident is over and primary reports
- analyzing the incident.

Evacuation procedure on site

Procedures applicable on the site will follow the same sequence:

- Conduct evacuation in the direction that is opposite to that of the wind, especially, in sites located in the wind's direction.
- Provide ambulance and rescue personnel with adequate clothing and fire fighters in case a fire breaks out.

Moving a sick or injured patiensts / workers

A first-aider should avoid lifting a person off the ground. The safer alternative is to drag the patient in line with the long axis of the body, using either the arms or the legs to drag, keeping the body aligned.

The safest first-aid methods of moving a patient are:

1. arm drag method, blanket lift method, clothing drag method, leg drag method.

4.4.2.2 Participate in emergency situation in the work site

Piping fabrication workshop or pipe line laying worksite (Workplaces) need a contingency plan for emergencies. Emergency situations can have a wider impacts. Special procedures are needed for emergencies such as serious injuries, explosion, poisoning, electrocution, fire radiation and chemical spills.

Quick and effective action may help to ease the situation and minimisethe consequences. However, in emergencies first-aid trained workers are more likely to respond reliably if they are well trained and competent and they take part in regular and realistic practice.

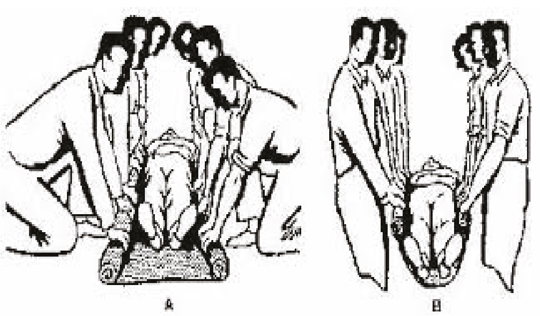


Fig. 4.4.16 Blanket lift method

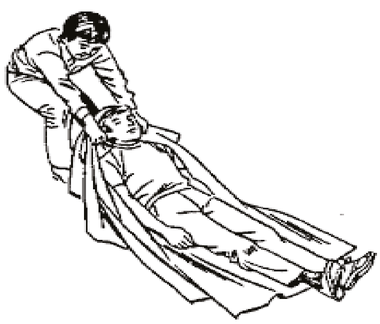


Fig. 4.4.17 Clothing Drag method

Fig. 4.4.18 Leg Drag Method

4.4.2.3 Emergency response plan It must include:

- scope and purpose
- abbreviations used
- emergency arrangements
- emergency reporting
- duties and responsibilities
- emergency response equipment and safety equipment
- portable gas detectors
- breathing apparatus
- communication
- oil spill or pollution.

Fig. 4.4.19 Emergency Response plan - ERP

Emergency response plan is provided in accordance with the company / contractor safety management system requirements, This document is an integral part of the project HSE – management system.

Emergency Response Plan - ERP

Emergency arrangements

An emergency is defined as any sudden, abnormal or un planned situation which requires immediate attention. It may endanger human life, environment or have an adverse effect on company assets and reputation. Some identified emergency situations are:

- medical Evacuation
- fire
- gas leaking (H_2S)
- serious accidents / fatalities
- oil spill / Pollution

Fig. 4.4.20 Assembly point

Gas release and first-aid in case of H_2S exposure

- If gas release occur, the following procedure is to be followed:
- Pipe fitter and welder use 15 minutes SCBA (Self Contained Breathing Apparatus). Plug in the cascade system and secure the site.
- Safety officer / medic, should have first-aid kit (FA) to unwind the master point,
- Conduct head count,
- Provide first-aid to the victims, if any, and shift all the personnel to a safe location.

Tips

1. Act quickly but calmly during an emergency.
2. Know phone numbers and where your company / project / institute emergency phone is available and where first-aid kits are kept.
3. Get professional emergency medical help as soon as possible when someone is seriously injured.

Emergency response Dos and Don'ts	
Dos	Don'ts
Make sure that someone knows where you are at all times, and have someone periodically check on you.	Move a person with head, neck or back injuries unless he is in immediate danger.
Know who to call for professional emergency, medical help and what information will be needed.	Forget to tell a supervisor if a first-aid kit needs to be restocked.

Information to give during an emergency situation

1. The location of the emergency and how to reach there
2. What happened and how many people are injured
3. What type of first-aid is being given
4. What additional hazard exist
5. Your name and the number you are calling from

4.4.2.4 Complete written report of the incident / accident report

1. Prepare accident / incident report
2. Report to concern authority / supervisor
3. Submit / send report to person responsible

Accident Report

Health and safety department shall have a useful guide entitled investigating accidents and incidents. It may also have reasons and benefits for investigating accidents. It also outlines a four-step investigation process.

- Step 1 Gathering the Information
- Step 2 Analyzing the information
- Step 3 Identifying risk control measures
- Step 4 The action plan and its implementation

Accident reports tend to concentrate on ''cause of injury.'' In the case of a multiple cause accident, we need to consider if it involves an unsafe act, an unsafe condition and an unsafe person and how these interact. Since, an incident could cause a fatality, a serious injury, a minor injury or just a near miss, all incidents should ideally be investigated. The purpose should be to find the cause with the intention of preventing a recurrence rather than to blame.

Accident reports form should include the following information:

1. Name and personal details of the person who met with the accident
2. Date, day and time of the accident
3. Where the accident happened department and specific location
4. Occupation of the person involved
5. Job being done at the time of the accident
6. Nature of injury or damage
7. What caused the accident
8. Immediate remedial action
9. Recommendations to prevent the accident in future.

Incident Report Format

Dept:____**Name:**______________________________

____**Date:**______________________________

Name of victim____________________________Age____________________Sex______________

Date of injury____________________Time________________Works No________________________

Nature of injury____

Where and how did accident occur?____

Unasafe acts or conditions____

Witnesses____

Corrective / Remedial action____

Recommendations____

Accident Report Format

VICTIM: Name______________________________Works No.____________________Dept__________

Age________________________Sex______________________

Occupation when injured____

Was this his/her regular occupation?____

If not, state regular occupation____

How long was he/she employed?____

ACCIDENT: Date________________Time__________________Place_____________________________

Description of how the accident happened (include name, part, and plant number of machine or tool involved)

Was part of machine that cause the accident properly guarded?__________________________________

Type of feed________________________________Type of guard________________________________

Was the employee following safety rules?____

If not, why?____

Way the injury the result of lack of ordinary care?__________________If so, how?______________________

Did some other person cause the accident?____

If so, how?____

How can its recurrence be prevented?____

INJURY: Describe injury and part of person injured

____

Did the victim resume work after medical attention?____

If not, was he/she sent home or to the hospital?____

Home or hospital address____

____

Exercise

I. Answer the following questions.

I. How will you respond to an accident at your worksite?

----

2. What are the rescue activities to be taken during an accident in your construction / worksite in case the helper or co-worker is injured?

----

3. Which are the methods to be used for moving injured workers / patients?

----

4. What are the key factors to be included while preparing an emergency plan?

----

5. What is to be done in the event of fire at your worksite plant/ camp?

----

7. What are the key information that need to be include in accident reports?

II. State whether the following statements are True or False.

1. In oil and gas project construction site, every worker should understand how to respond to an accident.

   True ☐ False ☐

2. In life threatening situations the nearest person should call an ambulance first and then report to the safety officer.

   True ☐ False ☐

3. Rescue plan should be prepared before the occurrence of the accident.

   True ☐ False ☐

4. Whenever evacuation mock drills, are conducted, are the worker should move to the opposite direction of the wind.

   True ☐ False ☐

Notes

Notes

Notes

Scan the QR codes or click on the link to watch the related videos

https://www.youtube.com/watch?v=L4sUQZta8Rw

5. Annexure

S No.	Module No.	Unit No. and Name	Topic Name	Page No.	URL	QR Code (s)
ELECTIVE - I (Oil & Gas)						
1	Module 1	Perform Pipe Fitting activity	Understanding the Piping and Pipeline layout drawings	14	https://www.youtube.com/watch?v=g191eS009Gg	Piping_How to read isometric drawings_Basic
2	Module 1	Perform Pipe Fitting activity	Understanding the Piping and Pipeline layout drawings	14	https://www.youtube.com/watch?v=y9Re2xPTM_8	Piping Isometric Drawing
3	Module 1	Perform Pipe Fitting activity	Mathematical Skills in Pipe Fitting	43	https://www.youtube.com/watch?v=uetc3jQGfSk	Piping Isometrics | Symbols | Preparation | Examples | Basic Engineering
4	Module 1	Perform Pipe Fitting activity	Mathematical Skills in Pipe Fitting	43	https://www.youtube.com/watch?v=O9UgBE-FITI	Pipe elbow/bend layout piping
5	Module 1	Perform Pipe Fitting activity	Different types of material used in Pipe Fitting	53	https://www.youtube.com/watch?v=eqwBR-jaEQ4	PIPE MATERIAL
6	Module 1	Perform Pipe Fitting activity	Preparation of Piping & Pipleline - types of pipe bends elbows and shapes	65	https://www.youtube.com/watch?v=8oO2p91rXeI	Pipe Fittings
7	Module 1	Perform Pipe Fitting activity	Preparation of Piping & Pipleline - Flanges and its types	65	https://www.youtube.com/watch?v=Xo60anxN8nw&t=156s	Types of Flanges used in the Oil & Gas Industry

S No.	Module No.	Unit No. and Name	Topic Name	Page No.	URL	QR Code (s)
8	Module 1	Perform Pipe Fitting activity	Preparation of Piping & Pipleline - Gaskets and its types	65	https://www.youtube.com/watch?v=503fYa8r718	Types of Pipe Gasket
9	Module 1	Perform Pipe Fitting activity	Preparation of Piping & Pipleline - Valve Installation	65	https://www.youtube.com/watch?v=BeHxGJYNyy0&t=29s	Types of Valves For Piping in Oil & Gas
10	Module 1	Perform Pipe Fitting activity	Preparation of Piping & Pipleline - Valves Functional tests	65	https://www.youtube.com/watch?v=KBVdjeUtMYE	Piping Engineering : Valve Testing
11	Module 2	Jointing and pipe laying activity	Pipeline Layout for Petroleum Product Distribution	179	https://www.youtube.com/watch?v=NEGohTCkkYY	Onshore Oil & Gas Pipeline Construction Sequence
12	Module 2	Jointing and pipe laying activity	Pipeline Layout for Petroleum Product Distribution - Oil & Gas Products	179	https://www.youtube.com/watch?v=vD0kbdIS6kE	Petroleum refining processes
13	Module 2	Jointing and pipe laying activity	Oil & Gas Products - Pipeline instruments control	189	https://www.youtube.com/watch?v=PxVP5Fun3Gg	What is SCADA

S No.	Module No.	Unit No. and Name	Topic Name	Page No.	URL	QR Code (s)
14	Module 2	Jointing and pipe lay-ing activity	Knowledge of different types of Joining in Pipeline	197	https://www.youtube.com/watch?v=d_l3SdqlQ68	
15	Module 2	Jointing and pipe lay-ing activity	Different Types of Welding Processes	197	https://www.youtube.com/watch?v=b0EfJaYUfF8	Types of Welding Processes | Classification of Welding Processes
16	Module 2	Jointing and pipe lay-ing activity	Knowledge of Non Destructive Test	197	https://www.youtube.com/watch?v=4_uZ3Acfjus	Piping Qc NDT
ELECTIVE - II (City Gas Distribution)						
17	Module 1	Fitting, Welding basics and Jointing process of materials	Mathematical Skills in Pipe Fitting	357	https://www.youtube.com/watch?v=uetc3jQGfSk	Piping Isometrics | Symbols | Preparation | Examples | Basic Engineering
18	Module 1	Fitting, Welding basics and Jointing process of materials	Knowledge on different types of materiasl used in Pipe Fitting	367	https://www.youtube.com/watch?v=eqwBR-jaEQ4	PIPE MATERIAL
19	Module 2	Perform Electrofusion Welding	Procedures and techniques for PE pipeline installation - Chain Trenching Method	565	https://www.youtube.com/watch?v=rK8Li4a4s9Y&t=58s	Trenching in pipeline

S No.	Module No.	Unit No. and Name	Topic Name	Page No.	URL	QR Code (s)
20	Module 2	Perform Electrofusion Welding	Procedures and techniques for PE pipeline installation - Trenchless Method	565	https://www.youtube.com/watch?v=Vb458tuDY1M	Horizontal Directional Drilling
21	Module 2	Perform Electrofusion Welding	Electrofusion Principle	578	https://www.youtube.com/watch?v=Nh5uO6PmHp8	Electrofusion Welding Procedure
22	Module 2	Perform Electrofusion Welding	Electrofusion Principle - Effects of Expansion and contraction of Pipes	626	https://www.youtube.com/watch?v=cCsVxWwRN90	The Effects Of Thermal Expansion and Contraction On Pipes
Compulsary NOS (Non-Core)						
23	Module 3	Work Effectively in a team	Team Work	671	https://www.youtube.com/watch?v=fUXdrl9ch_Q	Good teamwork and bad teamwork
24	Module 4	Health, Safety and Security Procedure	Fire Safety	715	https://www.youtube.com/watch?v=L4sUQZta8Rw	ABC'S OF Fire extinguisher

Notes

Skill India

कौशल भारत - कुशल भारत

सत्यमेव जयते

GOVERNMENT OF INDIA

MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP

N·S·D·C

National Skill Development Corporation

Transforming the skill landscape

HSSC

HYDROCARBON SECTOR SKILL COUNCIL

Address: OIDB Bhawan Tower C, 2nd Floor, Plot No. 2, Vikas Marg, Sector 73, Noida 201301 (UP)

E-mail: admin@hsscindia.in

Web: www.hsscindia.in

Price: ₹