WELDER (STRUCTURAL)

NSQF LEVEL - 3

TRADE THEORY

SECTOR : CAPITAL GOODS & MANUFACTURING

(As per revised syllabus July 2022 - 1200 Hrs)

Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
GOVERNMENT OF INDIA

Nimi

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

Post Box No. 3142, CTI Campus, Guindy, Chennai - 600 032

Sector **: Capital Goods & Manufacturing**

Duration **: 1 Year**

Trade **: Welder (Structural) - Trade Theory - NSQF Level - 3 (Revised 2022)**

Developed & Published by

National Instructional Media Institute
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First Edition : June 2023 Copies : 1000

Rs.285/-

FOREWORD

The Government of India has set an ambitious target of imparting skills by to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of Media Development Committee members of various stakeholders viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **Welder (Structural) - Trade Theory - NSQF Level - 3 (Revised 2022) in Capital Goods & Manufacturing Sector** under **Annual Pattern.** The NSQF Level - 3 (Revised 2022) Trade Practical will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 3 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 3 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these Instructional Media Packages IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

Additional Secretary /Director General of Training
Ministry of Skill Development & Entrepreneurship,
Government of India.

New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under Directorate General of Training, Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of Federal Republic of Germany. The prime objective of this Institute is to develop and provide instructional materials for various trades as per the prescribed syllabus under the Craftsman and Apprenticeship Training Schemes.

The instructional materials are created keeping in mind, the main objective of Vocational Training under NCVT/ NAC in India, which is to help an individual to master skills to do a job. The instructional materials are generated in the form of Instructional Media Packages (IMPs). An IMP consists of Theory book, Practical book, Test and Assignment book, Instructor Guide, Audio Visual Aid (Wall charts and Transparencies) and other support materials.

The trade practical book consists of series of exercises to be completed by the trainees in the workshop. These exercises are designed to ensure that all the skills in the prescribed syllabus are covered. The trade theory book provides related theoretical knowledge required to enable the trainee to do a job. The test and assignments will enable the instructor to give assignments for the evaluation of the performance of a trainee. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also help him to assess the trainee's understanding. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirements, day to day lessons and demonstrations.

In order to perform the skills in a productive manner instructional videos are embedded in QR code of the exercise in this instructional material so as to integrate the skill learning with the procedural practical steps given in the exercise. The instructional videos will improve the quality of standard on practical training and will motivate the trainees to focus and perform the skill seamlessly.

IMPs also deals with the complex skills required to be developed for effective team work. Necessary care has also been taken to include important skill areas of allied trades as prescribed in the syllabus.

The availability of a complete Instructional Media Package in an institute helps both the trainer and management to impart effective training.

The IMPs are the outcome of collective efforts of the staff members of NIMI and the members of the Media Development Committees specially drawn from Public and Private sector industries, various training institutes under the Directorate General of Training (DGT), Government and Private ITIs.

NIMI would like to take this opportunity to convey sincere thanks to the Directors of Employment & Training of various State Governments, Training Departments of Industries both in the Public and Private sectors, Officers of DGT and DGT field institutes, proof readers, individual media developers and coordinators, but for whose active support NIMI would not have been able to bring out this materials.

Chennai - 600 032 **EXECUTIVE DIRECTOR**

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisation to bring out this IMP **(Trade Theory)** for the trade of **Welder (Structural) - NSQF Level - 3 (Revised 2022)** under the **Capital Goods & Manufacturing** Sector for ITIs.

MEDIA DEVELOPMENT COMMITTEE MEMBERS

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NIMI records its appreciation of the Data Entry, CAD, DTP Operators for their excellent and devoted services in the process of development of this Instructional Material.

NIMI also acknowledges with thanks, the invaluable efforts rendered by all other staff who have contributed for the development of this Instructional Material.

NIMI is grateful to all others who have directly or indirectly helped in developing this IMP.

INTRODUCTION

TRADE PRACTICAL

The trade practical manual is intented to be used in workshop . It consists of a series of practical exercises to be completed by the trainees during the two years course of the **Welder Structural** in **Capital Goods & Manufacturing** trade supplemented and supported by instructions/ informations to assist in performing the exercises. These exercises are designed to ensure that all the skills in compliance with NSQF Level - 3 (Revised 2022)

This manual is divided into Seven modules. The Seven modules are given below

Module 1	Introduction Training and Welding process
Module 2	Welding Technique
Module 3	Weldability of Metals
Module 4	Gas cutting and Welding practice
Module 5	Gas Tungsten Arc welding
Module 6	Pipe Welding & Modern Welding Process
Module 7	Fabrication & Testing

The skill training in the shop floor is planned through a series of practical exercises centred around some practical project. However, there are few instances where the individual exercise does not form a part of project.

While developing the practical manual a sincere effort was made to prepare each exercise which will be easy to understand and carry out even by below average trainee. However the development team accept that there is a scope for further improvement. NIMI looks forward to the suggestions from the experienced training faculty for improving the manual.

TRADE THEORY

The manual of trade theory consists of theoretical information for the two years course of the **Welder (Structural)** in **Capital Goods & Manufacturing** Trade. The contents are sequenced according to the practical exercise contained in the manual on Trade Theory. Attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This co-relation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

The trade theory has to be taught and learnt along with the corresponding exercise contained in the manual on trade practical. The indications about the corresponding practical exercises are given in every sheet of this manual.

It will be preferable to teach/learn the trade theory connected to each exercise at least one class before performing the related skills in the shop floor. The trade theory is to be treated as an integrated part of each exercise.

The material is not for the purpose of self learning and should be considered as supplementary to class room instruction.

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

S.No.	Learning Outcome	Ref. Ex.No.
1	Join MS sheet by Gas welding in different positions following safety precautions. (NOS: CSC/N0204)	1.1.01 - 1.1.08
2	Join MS plates by SMAW in different positions. (Mapped NOS: CSC/N0204)	1.1.09 - 1.1.11
3	Perform straight, bevel & circular cutting on MS plate by Oxy-acetylene cutting process. (Mapped NOS: CSC/N0201)	1.2.12 - 1.2.34
4	Perform different type of MS pipe joints by Gas welding (OAW). (NOS: CSC/N0204)	1.3.35 & 1.3.36
5	Weld different types of MS pipe joints by SMAW. (Mapped NOS: CSC/N0204)	1.3.37 - 1.3.48
6	Weld Stainless steel, Cast iron, Aluminium and Brass by OAW. (NOS:CSC/N0204)	1.3.49 - 1.3.51
7	Perform Arc gauging on MS plate. (NOS: CSC/N0204)	1.3.52 - 1.3.54
8	Perform plasma arc cutting. (Mapped NOS: CSC/N0207)	1.4.55
9	Perform fillet welding on M.S plates 1F,2F,3F,4F& 5F positions by SMAW. (Mapped NOS: CSC/N0204)	1.4.56 - 1.4.63
10	Perform Full penetration Single "V" butt joint on MS plates in 1G,2G,3G &4G position adapting root Inspection and clearance by D.P test. (Mapped NOS: CSC/N0204)	1.4.64 - 1.4.69
11	Perform welding of MS, SS and Aluminium sheets, M.S tubes (square butt T,Y,K joints) by GTAW in down hand position. (Mapped NOS: CSC/N0212)	1.5.70 & 1.5.71
12	Perform bending, straightening and edge planing for fabrication of structures. (Mapped-NOS: CSC/N0303)	1.5.72 - 1.5.75
13	Perform Double bevel butt joint on dissimilar thickness MS Flats In down hand positions by SMAW with root Inspection by D.P test and back gouging and with root Inspection by D.P test and back gougingand adapting skip welding & back step welding method for controlling distortion. (Mapped NOS:CSC/N0204)	1.6.76
14	Performe welding of pipe joints different positions by SMAW (Mapped NOS: CSC/N0204)	1.6.77 & 1.6.78
15	Perform Lap, T, Corner joints on GMAW and Flux Cored Arc welding process on M.S in down hand position. (Mapped NOS: CSC/N0209, CSC/N0205)	1.6.79
16	Perform Automatic Submerged Arc Welding machine. (Mapped NOS: CSC/N0211)	1.6.80
17	Manufacture simple structures with L angles, I section and channel sections using welding fixture by SMAW. (Mapped NOS: CSC/N0204)	1.7.81 & 1.7.82
18	Fabricate pipe/cone on M.S. sheet by SMAW. (Mapped NOS: CSC/N0204, CSC/N0303)	1.7.83
19	Prepare weld test specimen as per a standard. Carry out non destructive testing of welds. (Mapped NOS: CSC/N0204)	1.7.84

SYLLABUS FOR WELDER (STRUCTURAL)

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 25Hrs; Professional Knowledge 4Hrs	Join MS sheet by Gas welding in different positions following safety precautions. (NOS: CSC/N0204)	Induction training: 1. Familiarization with the Institute. 2. Importance of trade Training. 3. Machinery used in the trade. 4. Introduction to safety equipment and their use etc. 5. Hack sawing, filing square to dimensions. 6. Marking out on MS plate and punching 7. Setting up of Arc welding machine & accessories and Striking an arc. 8. Setting of oxy-acetylene welding equipment, Lighting and setting of flame.	- General discipline in the Institute. - Elementary First Aid. - Importance of Welding in Industry. - Safety precautions in Shielded Metal Arc Welding, and Oxy-Acetylene Welding and Cutting. - Introduction and definition of welding. - Arc and Gas Welding Equipments, tools and accessories. - Various Welding Processes and its applications. - Arc and Gas Welding terms and definitions.
Professional Skill 22Hrs; Professional Knowledge 04Hrs	Join MS plates by SMAW in different positions. (Mapped NOS: CSC/ N0204)	9. Fusion run without and with filler rod on M.S. sheet 2 mm thick in flat position. 10 Edge joint on MS sheet 2 mm thick in flat position without filler rod. 11 Marking and straight line cutting of MS plate. 10 mm thick by gas.	- Different process of metal joining methods: Bolting, riveting, seaming etc. - Types of welding joints and its applications. Edge preparation and fit up for different thickness. - Surface Cleaning.
Professional Skill 184Hrs; Professional Knowledge 31Hrs	Perform straight, bevel & circular cutting on MS plate by Oxy-acetylene cutting process. (Mapped NOS: CSC/ N0201)	12 Straight line beads on M.S. plate 10 mm thick in flat position. 13 Small prototype of power transmission tower (skelton) fabrication from MS rode of 0 4mm. 14 Square butt joint on M.S. sheet 2 mm thick in flat Position. 15 Fillet "T" joint on M.S. Plate 10 mm thick in flat position.	- Basic electricity applicable to arc welding and related electrical terms & definitions. - Heat and temperature and its terms related to welding. - Principle of arc welding. And characteristics of arc. - Common gases used for welding & cutting, flame temperatures and uses. - Types of oxy-acetylene flames and uses. - Oxy-Acetylene Cutting Equipment principle, parameters and application.
		16 Beveling of MS plates 10 mm thick. By gas cutting. 17 Open corner joint on MS sheet 2 mm thick in flat Position 18 Fillet lap joint on M.S. plate 10 mm thick in flat position.	- Arc welding power sources: Transformer, Rectifier and Inverter type welding machines and its care & maintenance. - Advantages and disadvantages of A.C. and D.C. welding machines.

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
		19 Triangular beam fabrication from 8mm & 4mm dia. MS rode with GMAW length 3 feet. 20 Fillet"T"jointonMSsheet 2 mm thick in flat position 21 Open Corner joint on MS plate 10 mm thick in flat position.	- Welding positions as per EN & ASME: flat, horizontal, vertical and overhead position. - Weld slope and rotation. - Welding symbols as per BIS & AWS.
		22 Fillet Lap joint on MS sheet 2 mm thick in flat position. 23 Single "V" Butt joint on M S plate 12 mm thick in flat position (1G).	- Arc length - types - effects of arc length. - Polarity: Types and applications.
		24 Square Butt joint on M.S. sheet. 2 mm thick in Horizontal postion. 25 Straight line beads and multi layer practice on M.S. Plate 10 mm thick in Horizontal position. 26 F "T" 10 mm thick in Horizontal position.	- Calcium carbide uses and hazards. - Acetylene gas properties - Acetylene gas Flash back arrestor.
		27 Fillet Lap joint on M.S. sheet 2mm thick in horizontal position. 28 Fillet Lap joint on M.S.plate 2mm thick in horizontal position.	- Oxygen gas and its properties. - Charging process of oxygen and acetylene gases. - Oxygen and Dissolved Acetylene gas cylinders and Color coding for different gas cylinders. - Gas regulators I & II stage and uses.
		29 Fusion run with filler rod in verti cal position on 2mm thick M.S.sheet. 30 Square Butt joint on M.S. sheet. 2 mm thick in vertical position. 31 Single Vee Butt joint on M.S. plate 12 mm thick in horizontal position (2G).	- Oxy acetylene gas welding Systems (Low pressure and High pressure). Difference between gas welding blow pipe(LP & HP) and gas cutting blow pipe. - Gas welding techniques. Rightward and Leftward techniques.
		32. Weaved bead on M.S Plate 10mm in vertical position. 33. Fillet "T" joint on M.S sheet 2 mm thick in vertical position. 34. F "T" 10 mm thick in vertical position.	- Arc blow - causes and methods of controlling. - Distortion in arc & gas welding and methods employed to minimize distortion. - Arc Welding defects, causes and Remedies.
Professional Skill 19Hrs; Professional Knowledge	Perform different type of MS pipe joints by Gas welding (OAW). (NOS: CSC/N0204)	35 Structural pipe welding butt joint on MS pipe 0 50 and 3mm WT in 1G position. 36 Fillet Lap joint on M.S. Plate 10 mm in vertical position	- Specification of pipes, various types of pipe joints, pipe welding positions, and procedure. - Difference between pipe welding and plate welding.

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 117 Hrs Professional Knowledge 23Hrs	Weld different types of MS pipe joints by SMAW. (Mapped NOS: CSC/N0204)	37 Open Corner joint on MS plate 10 mm thick in vertical position. (10hrs.) 38 Pipe welding - Elbow joint on MS pipe 0 -50 and 3mm WT.	- Pipe development for Elbow joint, "T" joint, Y joint and branch joint. - Uses of Manifold system
		39 Pipe welding "T" joint on MS pipe 0 - 50 and 3mm WT. 40 Single "V" Butt joint on MS plate 12 mm thick in vertical position (3G).	- Gas welding filler rods, specifi cation and sizes. - Gas welding fluxes - types and functions. - Gas Brazing & Soldering: prin ciples, types fluxes & uses. - Gas welding defects, causes and remedies.
		41 Pipe welding 45 ° angle joint on MS pipe 0-50 and 3mm WT. 42 Straight line beads on M.S. plate 10mm thick in over head position.	- Electrode: types, functions of flux, coating factor, sizes of electrodes. - Effects of moisture pick up. - Storage and baking of electrodes.
		43 Pipe Flange joint on M.S plate with MS pipe 050 mm X 3mm WT. 44 Fillet "T" 10 mm thick in over head position.	- Weldability of metals, importance of pre heating, post heating and maintenance of inter pass tem perature.
		45 Pipe welding butt joint on MS pipe 0-50 and 5 mm WT. in 1G position. 46 Fillet Lap joint on M.S. plate 10 mm thick in overhead position.	- Welding of low, medium and high carbon steel and alloy steels.
		47 Single "V" Butt joint on MS plate 10mm thick in over head position(4G). 48 Pipe butt joint on M.S. pipe 0-50mm WT 6mm (1G Rolled).	- Stainless steel: types- weld decay and weldability.
Professional Skill 24 Hrs; Professional Knowledge 04 Hrs	Weld Stainless steel, Cast iron, Aluminium and Brass by OAW. (NOS:CSC/N0204)	49 Square Butt joint on S.S sheet. 2 mm thick in flat position. 50 Square Butt joint on S.S. Sheet 2 mm thick in flat position. 51 Square Butt joint on Brass sheet 2 mm thick in flat position.	- Brass - types - properties and welding methods. - Copper - types - properties and welding methods.
Professional Skill 25Hrs;	Perform Arc gauging on MS plate. (NOS: CSC/N0204)	52 Square Butt & Lap joint on M.S.sheet 2 mm thick by brazing.Single "V" butt joint C.I. plate 6mm thick in flat position.	- Aluminum properties and weldability, Welding methods

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Knowledge 08Hrs		53 Arc gouging on MS plate 10 mm thick.	- Arc cutting & gouging,
		54 Square Butt joint on Aluminium sheet. 3 mm thick in flat position. Bronze welding of cast iron (Single "V" butt joint) 6mm thick plate.	- Cast iron and its properties types. - Welding methods of cast iron.
Professional Skill 18Hrs; Professional Knowledge 04Hrs	Perform plasma arc cutting. (Mapped NOS: CSC/N0207)	55 Setting up Gas cutting equipment and cutting MS Flats to required size.	- Outline of the subjects to be cov ered - Importance of structural welding - Welding processes-brief description, Classification and application
Professional Skill 118Hrs; Professional Knowledge 23Hrs	Perform fillet welding on M.S plates 1F,2F,3F,4F& 5F positions by SMAW. (Mapped NOS: CSC/N0204)	56 Setting up SMAW Welding equip ment and making straight and weav ing bead on MS in all positions. Practice on plasma cutting. Practice on gouging techniques.	- Welding terms and definitions - Principles of OxyAcetylene Cut ting and equipments required. - Principles of shielded metals arc welding, its advantages and limitations.
		57 Weld joint preparation for fillet weld (Cutting to size, fit up, tack weld etc.). 58 Fillet, Lap and T joint on MS flat by SMAW, position - 1F.	- Types of weld joints. - Basic Electricity applicable to welding - Arc welding power source AC / DC - advantages and disadvantages - Types of metal and their characteristics. - Classification of steel and their Weldability. - Heat affected zone and requirement for pre- heating and maintaining inter pass temperature.
		Weld joint preparation for fillet welds (cutting to size, fit up, tack weld etc.).Fillet, lap and T joint on MS flat by SMAW position - 2F.	- Welding symbols and their importance - Welding positions and necessity of positional welding. - Weld joint edge preparation. - Welding procedure and techniques - Tack welding, root run welding, intermediate and cover pass welding, cleaning, checking etc.
		59 Weld joint preparation for fillet welds (cutting to size, fit up, tack weld etc.).Fillet, lap and T joint on MS flat by SMAW, position - 3F.	- Welding tools and accessories - Arc and its characteristics - Polarity types and application - Arc length - Welding fixtures and clamps
		60 Weld joint preparation for fillet welds (cutting to size, fit up, tack weld etc.)	- Coated electrodes- Types, description - Standard size and length of electrodes.

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
		61 Fillet, lap and T joint on MS flat by SMAW position - 4F.	- Selection of electrodes and coating factor. - Electrode storage and necessity of backing.
		62 Weld joint preparation for pipe fil let welding.	- Effect of Heat on Weldments.
		63 Pipe to pipe fillet weld on MS pipes by SMAW, position -5F.	- Welding distortion and stresses.
Professional Skill 75 Hrs; Professional Knowledge 12Hrs	Perform Full penetration Single "V" butt joint on MS plates in 1G,2G,3G &4G position adapting root Inspection and clearance by D.P test. (Mapped NOS: CSC/N0204)	64 Weld joint preparation for plate groove welding.Full penetration Single "V"butt joint on MS Flat by SMAW in 1G Positions.Root pass welding & LPI testing.Cover pass welding &inspection.	- Methods of controlling distortion by various methods. - Methods of relieving stress on Weldments. - Advantages of welded structures over riveted structures
		65 Weld joint preparation for plate groove welding.Full penetration Single "V"butt joint on MS Flat by SMAW in 2G Positions.Root pass welding & LPI testing.Cover pass welding & inspection.	- Types of Steel sections / forms used in structural fabrication and their standard sizes - Importance of structural welding and workmanship - Necessity of Qualifying welders, welding operators and tack welders - Necessity of Qualifying the welding procedure - Positions of test plates for filter welds and groove welds
		66 Full penetration single "V" butt joint on MS Flat by SMAW in 3G Positions. 67 MS Flat by SMAW in 4G Positions. 68 Root pass welding & LPI testing. 69 Cover pass welding & inspection.	- Types of Fillet welded and groove welded joints on statically loaded structures. - Types of fillet welded and groove welded joints on dynamically loaded structures
Professional Skill 19Hrs; Professional Knowledge 04Hrs	Perform welding of MS, SS and Aluminium sheets, M.S tubes (square butt T,Y,K joints) by GTAW in down hand position. (Mapped NOS: CSC/N0212)	70 Setting up GTAW welding equipment and making beading practice on MS in down hand position. 71 Square butt joint on M.S Sheet in down hand position.	- GTAW equipments - Advantages of GTAW Welding process - Power source types AC/DC - Types of polarity and application
Professional Skill 55 Hrs;	Perform bending, straightening and edge planing for fabrication of structures.	72 Suare butt joint on S.S Sheet in down hand position.	- Tungsten electrode, types, sizes and uses - Types of shielding gases - Preparation for TIG Welding under drift conditions

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Knowledge 12Hrs	(Mapped-NOS: CSC/N0303)	73 Square butt joint on Aluminium in down hand position.	- Necessity of back purging
		74 M.S square butt Tube (Square or rectangular) welding.	- Types of Tubular structures used on structural fabrication
		75 T,Y,K tube(Square or rectangular) joints by TIG welding.	- Development of templates for marking and preparation of pipe elbow, - T, Y and K joints (Similar and dissimilar diameter pipe connections)
Professional Skill 23Hrs; Professional Knowledge 04Hrs	Perform Double bevel butt joint on dissimilar thickness MS Flats In down hand positions by SMAW with root Inspection by D.P test and back gouging and with root Inspection by D.P test and back gougingand adapting skip welding & back step welding method for controlling distortion. (Mapped NOS:CSC/ N0204)	76 Double bevel butt joint on MS Flats in dissimilar thickness in down hand positions by SMAW. Root Inspection. Back Gouging. Adopting weld sequence for controlling distortion.	- Types of welding defects - Causes and remedy.
Professional Skill 19Hrs; Professional Knowledge 04Hrs	Performe welding of pipe joints different positions by SMAW (Mapped NOS: CSC/N0204)	77 Pipe Elbow and T joints on MS pipes by SMAW in flat position. (10hrs. 78 Pipe Y and K connection on M.S. pipe by SMAW, positions – Horizontal.	- Procedure of rectifying, weld defects -Gouging methods , grinding, testing with die penetrant, preheating and re welding
Professional Skill 18Hrs; Professional Knowledge 04Hrs	Perform Lap, T, Corner joints on GMAW and Flux Cored Arc welding process on M.S in down hand position. (Mapped NOS: CSC/N0209, CSC/N0205)	79 Practice on C02 welding and Flux Cored Arc Welding.	- Introduction to GMAW, Flux cored arc welding - Advantages - Power source- Wire feeder - Electrode wires - shielding gases - Types of metal transfer and welding parameters.
Professional Skill 18Hrs; Professional Knowledge 04 Hrs	Perform Automatic Submerged Arc Welding machine. (Mapped NOS: CSC/N0211)	80 Practice on Automatic Submerged ArcWelding machine	- Introduction to Submerged arcwelding (SAW). Advantage,limitation, Equipment and operating conditions.

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 25 Hrs; Professional Knowledge 05 Hrs	Manufacture simple structures with L angles, I section and channel sections using welding fixture by SMAW. (Mapped NOS: CSC/N0204)	81 Manufacturing of simple structures with L angles, I section and channel sections using welding fixture by SMAW.Correction of distortion by cold &hot.Manufacturing of structures using M.S. Flat by SMAW. 82 Adapting skip welding & back step welding method for controlling distortion	- Procedure of structural fabrication. - Planning for structural members, marking and edge preparation, assembling, tack welding, measurement of weldment size, root pass welding, inspection of root pass welding, making cover pass and Inspection & Testing etc. Inspection and testing of weldments. Visual inspection kits and Gauges
Professional Skill 18Hrs; Professional Knowledge 04 Hrs	Fabricate pipe/cone on M.S. sheet by SMAW. (Mapped NOS: CSC/N0204, CSC/N0303)	83 Fabrication of pipe/cone on M.S. sheet bySMAW.	- Non-destructive testing methods - Structural welding codes andstandards - Writing procedure for WPS and PQR - Requirement for qualification in different codes
Professional Skill 18Hrs; Professional Knowledge 04Hrs	Prepare weld test specimen as per a standard. Carry out non destructive testing of welds. (Mapped NOS: CSC/N0204)	84 Weld test specimen -preparation as per standardInspection & Testing.	- Qualification procedure under variouscodes. - Different tests and inspection involved In qualification.

General discipline in the Institute

Objectives: At the end of this lesson you shall be able to
- **follow the general discipline laid down by the institute**
- **avoid any undesirable actions as a learner**
- **keep up the moral image and reputation of the institute.**

General discipline: always be polite, courteous while speaking to any person, (Principal, Training and Office staff, your co-trainee and any other person visiting your institute)

Do not get into argument with others on matters related to your training and with the office while seeking clarifications.

Do not bring bad name to your institute by your improper actions.

Do not waste your precious time in gossiping with your friends and on activities other than training.

Do not be late to the theory and practical classes.

Do not unnecessarily interfere in other's activities.

Be very attentive and listen to the lecture carefully during the theory classes and practical demonstration given by the training staff.

Give respect to your trainer and all other training staff, office staff and co-trainees.

Be interested in all the training activities.

Do not make noise or be playful while undergoing training.

Keep the institute premises neat and avoid polluting the environment.

Do not take away any material from the institute which does not belong to you.

Always attend the institute well dressed and with good physical appearance.

Be regular to attend the training without fail and avoid abstaining from the theory or practical classes for simple reasons.

Prepare well before writing a test/examination.

Avoid any malpractice during the test/examination.

Write your theory and practical records regularly and submit them on time for correction

Take care of your safety as well as other's safety while doing the practical.

Elementary first aid

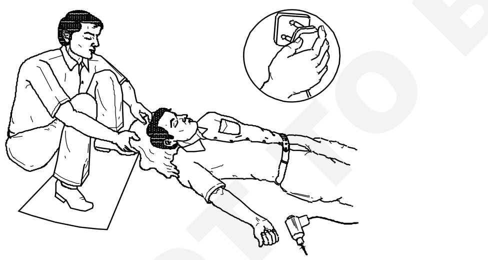
Objectives: At the end of this lesson you shall be able to
- **understand the first aid treatment to be given for**
- **breathing problems**
- **electric shock**
- **burns caused by direct flame or by chemical**
- **large wounds with or without severe bleeding**
- **eye injuries due to hot flying particles.**

Electrical shock and breathing problems: The severity of an electric shock will depend on the level of the current which passes through the body and the length of time of contact, Do not delay to disconnect the contact.

If the person is still in contact with the electric supply break the contact either by switching off the power by removing the plug or wrenching the cable free. If not, stand on some insulating material such as dry wood, rubber or plastic, or using whatever is at hand to insulate yourself and break the contact by pushing or pulling the person free. (Fig 1 & 2)

Fig 1

Fig 2



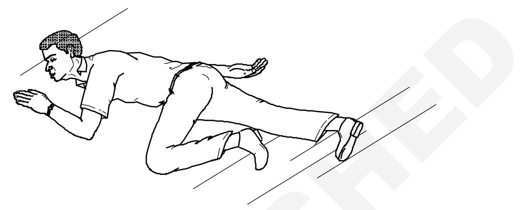
If you remain un-insulated, do not touch the victim with your bare hands until the circuit is made dead or he is moved away from the equipment.

If the victim is at a height from the ground level, proper safety actions must be taken to prevent him from falling or at least make him fall safely.

Electric burns on the victim may not cover a big area but may be deep seated. All you can do is to cover the area with a clean, sterile dressing and treat for shock, Get expert help as quickly as possible.

If the affected person is unconscious but is breathing, loosen the clothing about the neck, chest and waist and place the affected person in the recovery position.(Fig 3)

Fig 3

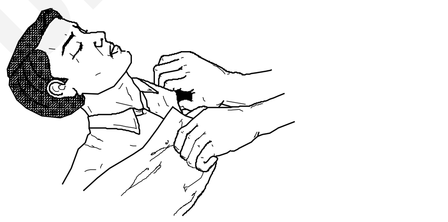


Keep a constant check on the breathing and pulse rate.

Keep the affected person warm and comfortable.(Fig 4)

Send for help.

Fig 4



Do not give an unconscious person anything by mouth.

Do not leave an unconscious person unattended.

If the casuality is not breathing-act once-don't waste time!

Electric shock: The severity of an electric shock will depend on the level of the current which passes through the body and the length of time of the contact.

Other factors that contribute to the severity of shocks are:

- The age of the person.
- Not wearing insulating footwear or wearing wet footwear.
- Weather condition.
- Floor is wet.
- Main voltage etc.

Effects of an electric shock: The effect of the current at very low levels may only be an unpleasant tingling sensation, but this itself may be sufficient to cause one to lose his balance and fall.

At higher levels of current, the person receiving the shock may be thrown off his feet and will experience severe pain, and possibly minor burns at the point of contact.

At an excessive level of current flow, the muscles may contract and the person may be unable to release his grip on the conductor, He may lose consciousness and the muscles of the heart may contract spasmodically (Fibrillation). This may be fatal.

Electric shock can also cause burning of the skin at the point of contact.

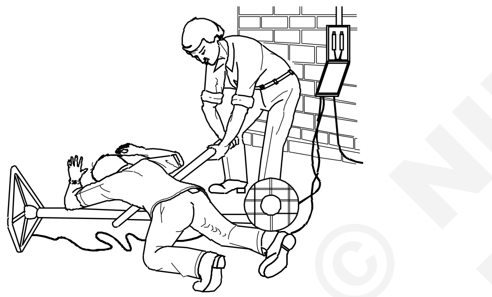
Treatment for electric shock:

Prompt treatment is essential

If assistance is available nearby. send for medical aid, then carry on with emergency treatment.

Switch off the current, if this can be done without undue delay. Otherwise, remove the victim from contact with the live conductor, using dry non-conducting materials such as a wooden bar, rope, a scarf, the victim's coat-tails, any dry article of clothing, a belt, rolled-up newspaper, non-metallic hose, PVC tubling, bakelite paper, tube etc. (Fig 5)

Fig 5



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Avoid direct contact with the victim. Wrap your hands in dry material if rubber gloves are not available

Electrical burns: A person receiving an electric shock may also get burns when the current passes through his body. Do not waste time by applying first aid to the burns until breathing has been restored and the patient can breathe normally - unaided.

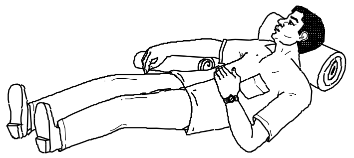
Burns and scalds: Burns are very painful. If a large area of the body is burnt, give no treatment, except to exclude the air. eg, by covering with water, clean paper, or a clean shirt. This relieves the pain.

Severe bleeding: Any wound which is bleeding profusely, especially in the wrist, hand or fingers must be considered serious and must receive professional attention. As an immediate first aid measure, pressure on the wound itself is the best means of stopping the bleeding and avoiding infection.

Immediate action: Always in cases of severe bleeding:

- Make the patient lie down and rest.
- If possible, raise the injured part above the level of the body. (Fig 6)

Fig 6



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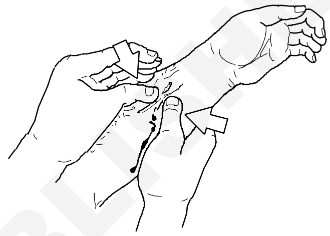
- Apply pressure on the wound.
- Call for assistance.

To control severe bleeding: Squeeze together the sides of the wound. Apply pressure as long as it is necessary to stop the bleeding. When the bleeding has stopped, put a dressing over the wound, and cover it with a pad of soft material. (Fig 7)

Fig 7



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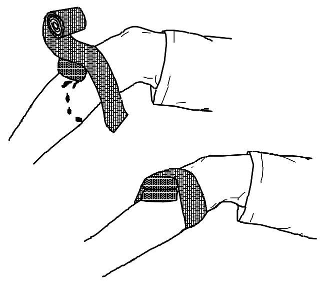
For an abdominal stab wound, which may be caused by falling on a sharp tool, keep the patient bending over the wound to stop internal bleeding.

Large wound: Apply a clean pad (Preferably an individual dressing) and bandage firmly in place, If the bleeding is very severe apply more than one dressing. (Fig 8)

Fig 8



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Follow the right methods of artificial respiration.

Eye injury: For eye irritation caused by arc flashes, use a mild eye drop and apply 2 to 3 drops for 3 or 4 times a day. If the injury is due to a metal chip or slag particles entering the eye then take the injured person to an eye doctor immediately for treatment. Never rub the eye for any type of eye injury. It will cause a permanent vision problem. Also do not apply any eye drop or ointment without consulting an eye doctor.

Importance of welding in Industry

Objectives: At the end of this lesson you shall be able to
- **realise and state the importance of welding in industry**
- **state the advantages of welding over other methods of joining metals.**

In engineering industry, joining of different type of metals is necessary to make various components/parts having different shapes. Various type of parts are joined by bolting or riveting if thickness of metal is more. Example: Iron bridges, steam boilers, roof trusses, etc. For joining thin sheets (2mm thick and below) sheet metal joints are used. Example: Tin containers, oil drums, buckets, funnels, hoppers etc, also thin sheets can be joined by soldering and brazing.

But very heavy thick plates used in heavy industries are not joined by riveting or bolting as the joints will not be able to withstand heavy loads. Also the cost of production will be more. So many special materials for special applications like space ships, atomic power generation, thin walled containers for storing chemicals. etc have been developed in the recent years. They can be joined easily at a lower cost with good joint strength by using welding. A welded joint is the strongest joint of all the other types of joints, The efficiency of a welded joint is 100% whereas the efficiency of other types of joints are less than 70%

So all industries are using welding for the CG & M of various structures.

Advantages of welding over methods of joining metals

Welding method: Welding is metal joining method in which the joining edges are heated and fused together to form permanent (homogeneous) bond/joint.

Comparison between welding and other metal joining methods

Riveting, assembling with bolt, seaming, soldering and brazing all result in temporary joints. Welding is the only method to join metals permanently.

The temporary joints can be separated if:

- the head of the rivet is cut
- nut of the bolt is unscrewed
- hook of the seam is opened
- more heat is given than that required for soldering and brazing.

Advantages of welding

Welding is superior to other metal joining methods because it:

- is a permanent pressure tight joint
- occupies less space
- gives more economy of material
- has less weight
- Withstands high temperature and pressure equal to joined material
- can be done quickly
- gives no colour change to joints

It is the strongest joint and any type of metal of any thickness can be joined.

Safety precautions in shielded metal arc welding and oxy - Acetylene welding and cutting

Objectives: At the end of this lesson you shall be able to
- **safety precautions in SMAW**
- **safety precautions in oxy - acetylene welding and cutting (OAW & OAGC).**

Safety precautions in shielded metal arc welding

Ne sure the welder is properly installed and grounded.

Never weld without adequate ventilation.

Take proper precautions to prevent files.

Protect your entire body with fire retardant clothing, shoes, and gloves.

Wear eye protection at all times.

Weld only in a fire safe area.

Safety precautions in on oxy - Acetylene welding and cutting OAW & OAGC)

Inspect equipment for leaks at all connections using approved leak - test solutions.

Inspect hoses for leaks and worn places.

Replace bad hoses.

Protect hoses and cylinders from sparks, flames and hot metal.

Use flint lighter to ignite the flame.

Stand to the side (away from regulators) when opening cylinder valves.

Open cylinder valves very slowly to keep sudden high pressure from exploding the regulators.

Only open the acetylene cylinder value 1/4-3/4 turn ; cylinder key in place so the cylinder can be quickly in an emergency.

Open and light acetylene first, then open and adjust. Oxygen to a neutral flame.

Have a fire extinguisher easily accessible at the welding site.

All cutting and equipment, including gloves and clothing. Should e kept free of grease and oil.

Clean gas cutting torch tips before lighting.

Only use firction lighters to ignite torches.

Follow the manufacturer's when shutting down a gas cutting torch.

Introduction and definition of welding

Objectives: At the end of this lesson you shall be able to
- **state the invention of welding**
- **describe the different ways to weld.**

The history of joining metals goes back several millennia. Called forge welding, the earliest come from the Bronze and Iron Ages in Europe and the Middle East. The middle Ages brought advances in forge welding. in which blacksmiths used to heat the metal repeatedly until bonding occurred

In 1801, Sir Humphry Davy discovered the electrical arc. In 1802, Russian Scientist Vasily Petrov also discovered the electric arc and subsequently proposed possible practical applications such as welding. In 1881-82, a Russian Inventor NIkolai Benardos and polish Stainshlaw olszewski created the first electric arc, welding method known as carbon arc welding; they used carbon electrodes.

The advances in arc welding continued with the invention of metal electrodes in the late 1800's by a Russian, Nikolai Slavyanov (1888), and an American, C.L. Coffin (1890). Around 1900, A.P. Strohmenger released a coated metal electrode in Britain, which gave a more stable arc.

In 1905, Russian scientist Vladmir mitkevich proposed using a three-phase electric arc for welding. In 1919, alternating current welding was invented by C.J. Holslag but did not become popular for another decade.

Welding is a CG & M process that joins materials normally metals. This is often done by melting the work pieces and adding a filler material to form pool of molten material that cools to become a strong joint, with pressure sometimes used in conjunction with the heat or by itself, to produce the weld. This is in contrast with soldering & brazing, which involve melting a lower-melting-point material to form a bond between them, without melting the work pieces.

There are many different ways to weld. Such as; Shielded Metal Arc Welding (SMAW). Gas Tungsten Arc Welding (GTAW), and Gas Metal Arc Welding (GMAW).

GMAW involves a wire fed "gun" that feeds wire at an adjustable speed and sprays a shielding gas (generally pure Argon or a mix of Argon and Co_2) over the weld puddle to protect it from the effect of atmosphere.

GTAW involves a much smaller hand-held gun that has a tungsten rod inside of it. With most, you use a pedal to adjust your amount of heat and hold a filler metal with your other hand and slowly feed it.

Stick welding or Shielded Metal Arc Welding has an electrode that has flux, the protecting for the puddle, around it. The electrode holder holds the electrode as it slowly melts away. Slag protects the weld puddle from the affection of atmosphere. Flux-core is almost identical to stick welding except once again you have a wire feeding gun; the wire has a thin flux coating around it that protects the weld puddle.

Many different sources of energy can be used for welding, including a gas flame, an electrical arc, a laser, an Electron Beam (EB), Friction, and ultrasound. While often an industrial process, welding may be performed in many different environments, including in open air, under water, and on outer space,. Welding is a potentially hazardous undertaking and precautions are required to avoid burns, electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to intense ultraviolet radiation.

Definition:

Welding is a process of joining two or more, similar or dissimilar metals by heating them to a suitable temperature with or without the application of pressure, filler materials and flux welding is used for making permanent joints

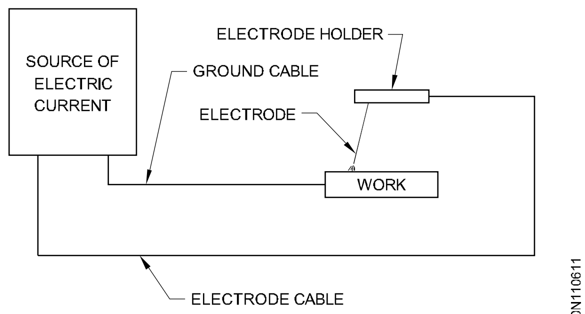
Arc and gas welding equipments tools and accessories

Objectives : At the end of this lesson you shall be able to
- **state the necessity of an arc welding machine**
- **name the different types of arc welding machine.**

In arc welding process, the source of heat is electricity. (High ampere-low voltage)

The required electrical energy for welding is obtained from an arc welding machine, a power source. (Fig 1)

Fig 1

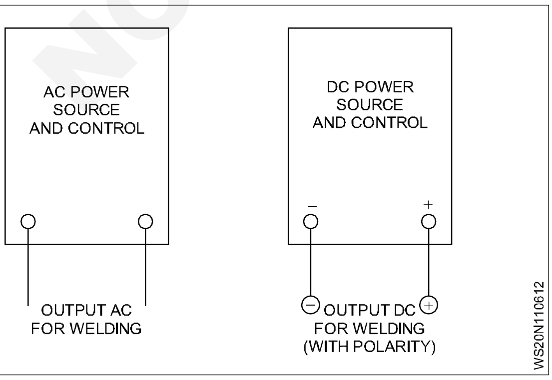


SIMPLE WELDING CIRCUIT

Necessity

- The equipment is used to
- Provide Ac or DC welding supply for arc welding
- Provide higher voltage (OCV) for striking the arc and lower voltage (AV) for maintaining the arc
- Change the high voltage of the main supply (AC) to low voltage and heavy current supply (AC or DC) suitable for arc welding
- Establish a relationship between arc voltage and welding current
- Control and adjust the required welding current during arc welding
- Weld with all gauges of electrode
- Weld thin and thick plates. both ferrous and non-ferrous metals.

Fig 2



Type (Fig 2): Basically power sources are:

- Alternating current welding machine
- Direct current welding machine.

These may be further classified as DC machines and AC machines.

DC machines

- Motor generator set
- Engine generator set
- Rectifier set

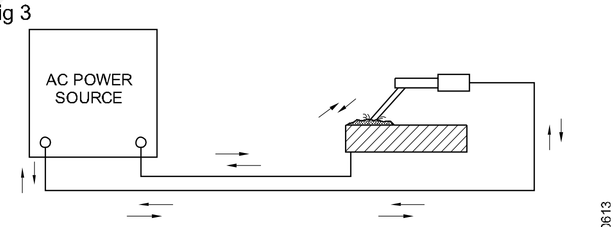
AC machines

- Transformer sets

AC means alternating current. It changes or reverses its direction of flow of current 50 times per second, if it is 50 cycles/sec. (Fig 3)

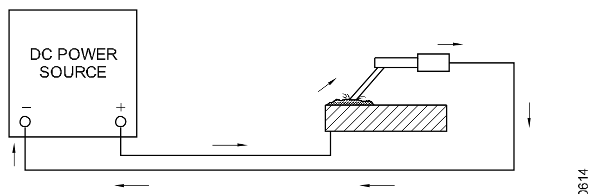
DC means direct current. it flows steadily and constantly in one direction. (Fig 4)

Fig 3



CURRENT FLOW REVERSES ITS DIRECTION 50 CYCLES / SEC.

Fig 4



CURRENT FLOW IN ONE DIRECTION CONSTANTLY i.e., FROM +ve TO -ve.

Care and maintenance of arc welding machines and accessories

Every machine and accessory used for any useful purpose requires some care and maintenance to increase its usage for a long time. In the case of arc welding machines and accessories the following points are important.

Arc welding machines: Do not keep the machine in open air. In a AC welding generator do not put the starting switch on DELTA position directly: keep the switch on START position first. Run it for a few seconds and then put the switch in DELTA position. Do not disconnect the cooling fan of a welding generator.

Maintain the cooling oil in the transformer welding set.

Periodically drain the cooling oil from the transformer and purify, and refill the transformer. Fix the input cables form the mains to the machine and the electrode and earth cable firmly. Replace the carbon brushes of the DC welding generator whenever necessary.

Do not clean any welding machine with water. The dust and other impurities are to be removed by compressed air only. Operate all control knobs and handles gently.

Avoid loose connections at the main fuses, starting switch.etc.

Arc welding accessories: Ensure the welding and earth cables are of standard amperage. The cables are to be joined only by sockets. Use the right capacity electrode holder and earth clamp. Avoid temporary arrangements to join cables or to connect earth clamp with the table or job. Avoid direct contact of electrode-holder with work table or job or earth connections. For this, hang the electrode-holder on the insulated hanger of the welding table. Use a properly insulated electrode-holder. Avoid over running of the trolley wheel etc. on the welding or return cable. Avoid stray arcing on the work table or on the job.

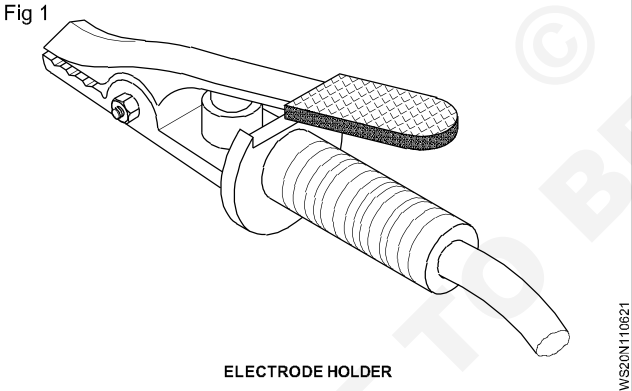
Arc and gas welding accessories

Objectives: At the end of this lesson you shall be able to
- **identify the arc welding accessories**
- **explain the function of each accessory.**

Arc welding accessories: Some very important items, used by a welder with an arc welding machine during the welding operation, are called arc welding accessories.

Electrode-holder (Fig 1): It is a clamping device used to grip and manipulate the electrode during arc welding. It is made of copper/copper alloy for better electrical conductivity.

Fig 1



ELECTRODE HOLDER

Partially or fully insulated holders are made in various sizes i.e. 200 - 300 - 500 amps.

The electrode-holder is connected to the welding machine by a welding cable.

Earth clamp (Fig 2): It is used to connect the earth cable firmly to the job on welding table. It is also made of copper/copper alloys.

Screw or spring-loaded earth clamps are made in various sizes i.e. 200 - 300 - 500 amps. (Fig 3)

Welding cables/leads: These are used to carry the welding current from the welding machine to the work and back.

The lead from the welding machine to the electrode-holder is called electrode cable.

Fig 2

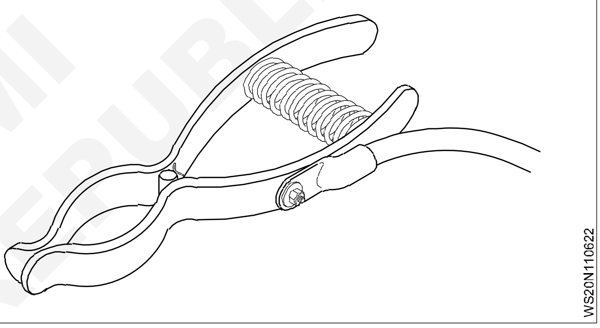
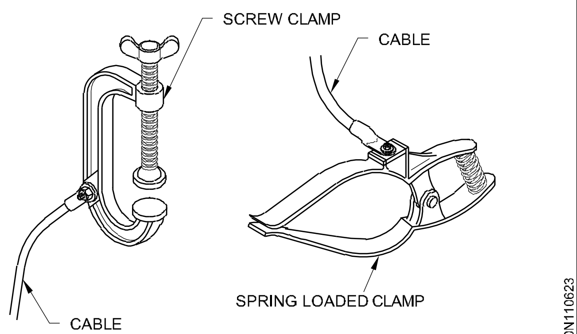


Fig 3



WORK CABLE ATTACHMENTS

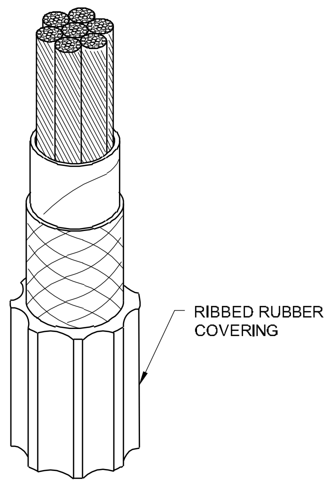
The lead from the work or job through the earth clamp to the welding machine is called earth (ground) cable.

Cables are made of super flexible rubber insulation, having fine copper wires and woven fabric reinforcing layers. (Fig 4)

Welding cables are made in various sizes (cross-sections) i.e. 300, 400, 600 amps etc.

Loose joints or bad contacts cause overheating of the cables.

Fig 4

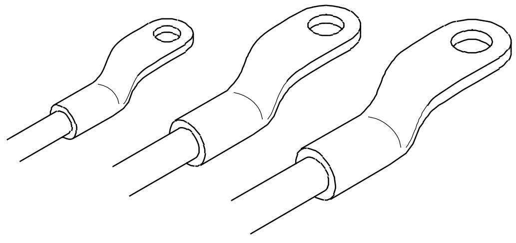


WELDING CABLE WITH HEAVY RIBBED OUTER RUBBER COVERING

The same size welding cables must be used for the electrode and the job.

The cable connection must be made with suitable cable attachments (lugs). (Fig 5)

Fig 5



LUGS FOR WELDING LEADS

THE THREE SIZES WILL FIT CABLES FROM NO 6 TO 4/0. THEY MAY BE CONNECTED TO THE LEAD BY SOLDERING OR MECHANICAL CRIMPING

The length of the cable has considerable effect on the size to be used.

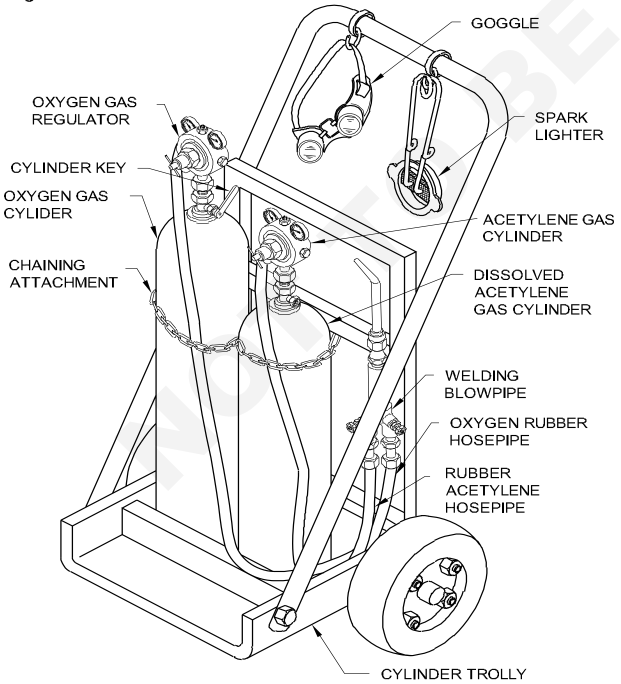
Gas welding tools and accessories

Objectives: At the end of this lesson you shall be able to

- **distinguish between the features of oxygen and acetylene gas cylinders**
- **compare the features of oxygen and acetylene gas regulators**
- **distinguish between the house-connectors used in oxygen and acetylene regulators**
- **describe the function of hose-protectors**
- **state the functions of blowpipes and nozzles.**

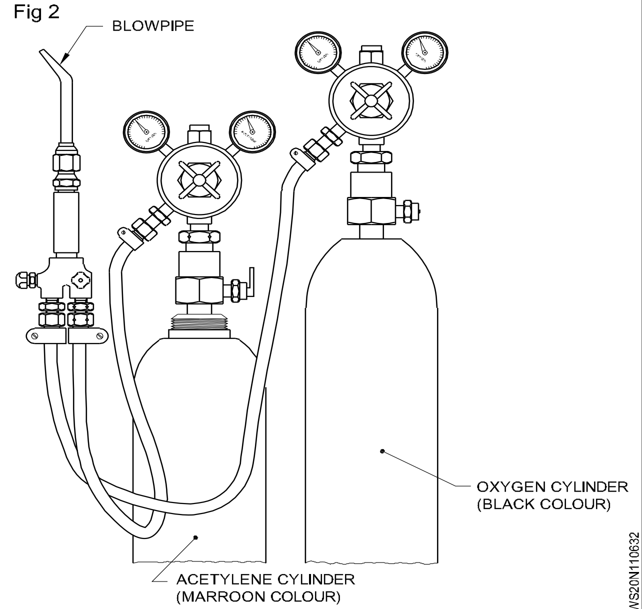
Oxy-acetylene welding is a method of joining metals by heating them to the melting point using a mixture of oxygen and acetylene gases. (Fig 1)

Fig 1



Oxygen gas cylinders: The oxygen required for gas welding is stored in bottle-shaped cylinders. These cylinders are painted in black colour. (Fig 2) Oxygen cylinders can store gas to a capacity of 7 m^3 with the pressure ranging between 120 to 150 kg/cm^2 . Oxygen gas cylinder valves are right hand threaded.

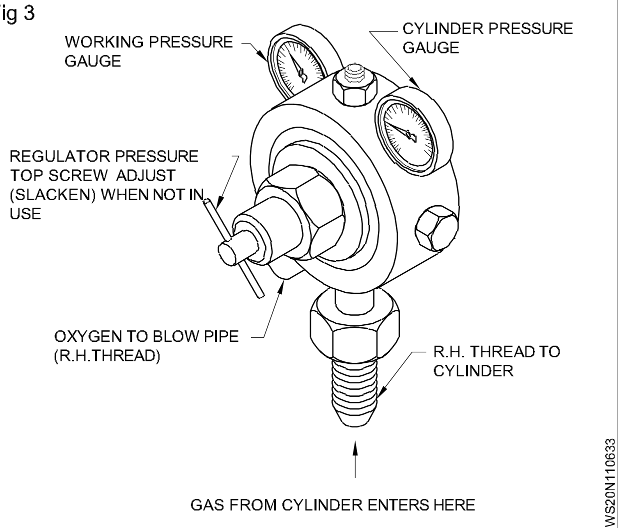
Fig 2



Dissolved acetylene cylinders: The acetylene gas used in gas welding is stored in steel bottles (cylinders) painted in maroon colour. The normal storing capacity of storing acetylene in dissolved state is $6m^3$ with the pressure ranging between 15-16 kg/cm^2.

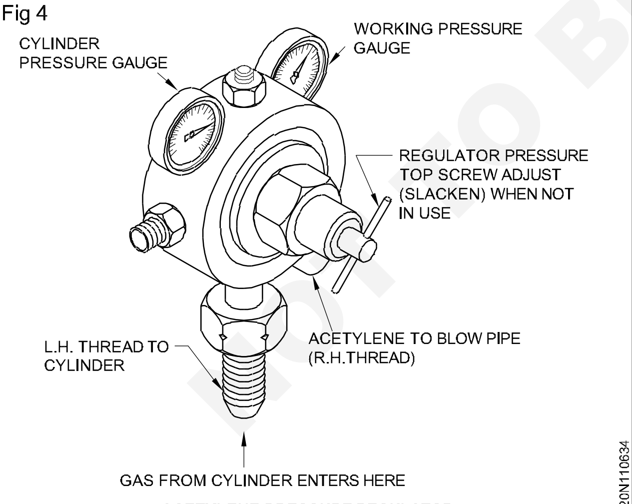
Oxygen pressure regulator: This is used to reduce the oxygen cylinder gas pressure according to the required working pressure and to control the flow of oxygen at a constant rate to the blowpipe. The threaded connections are right hand threaded. (Fig 3)

Fig 3



Acetylene regulator: As with the case of oxygen regulator this also is used to reduce the cylinder gas pressure to the required working pressure and to control the flow of acetylene gas at a constant rate to the blowpipe. The threaded connections are left handed, for quickly identifying the acetylene regulator, a groove is cut at the corners of the but. (Fig 4)

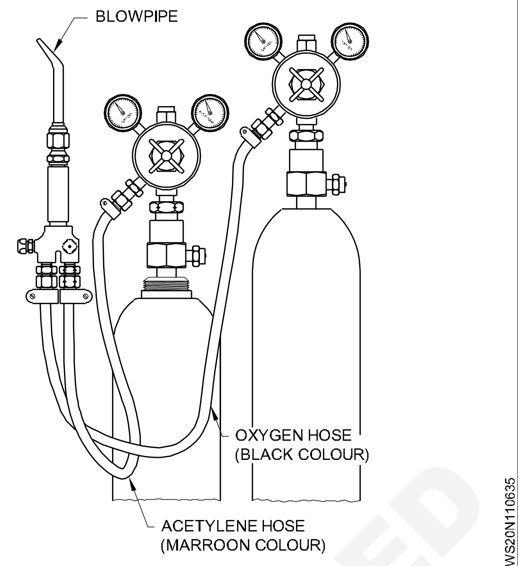
Fig 4



ACETYLENE PRESSURE REGULATOR

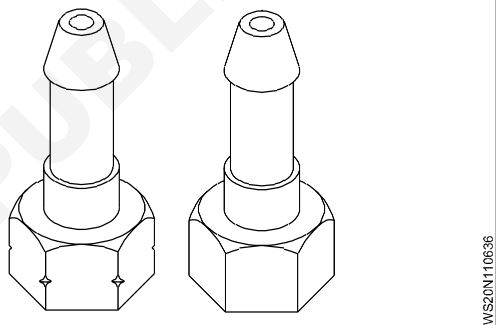
Rubber hose-pipes and connections: These are used to carry gas from the regulator to the blowpipe. These are made of strong canvas rubber having good flexibility. Hosepipes which carry oxygen are black in colour and the acetylene hoses are of maroon colour (Fig 5)

Fig 5



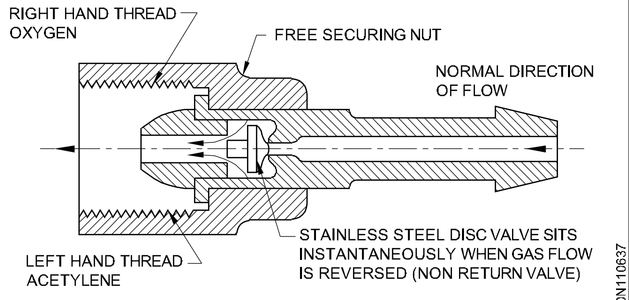
Rubber hoses are connected to regulators with the help of unions. These unions are right hand threaded for oxygen and left hand threaded for acetylene. Acetylene hose unions have a groove cut on the corners. (Fig 6)

Fig 6



At the blowpipe end of the rubber hoses-protectors are fitted. The hose protectors are in the shape of a connecting union and have a non-return disc fitted inside to protect from flashback and backfire during welding. (Fig 7)

Fig 7



HOSE PROTECTOR

Blowpipe and nozzle: Blowpipe are used to control and mix the oxygen and acetylene gases to the required proportion. (Fig 8)

A set of interchangeable nozzles/tips of different sizes is available to produce smaller bigger flames. (Fig 9)

Fig 8

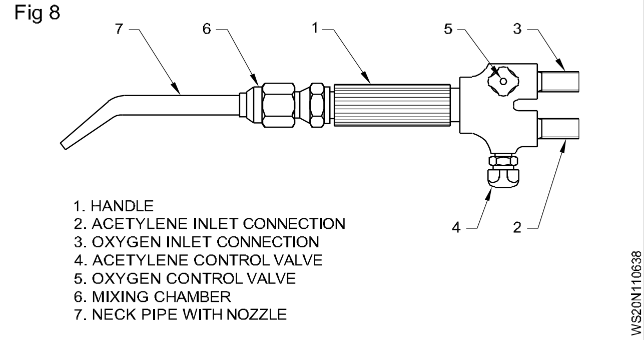
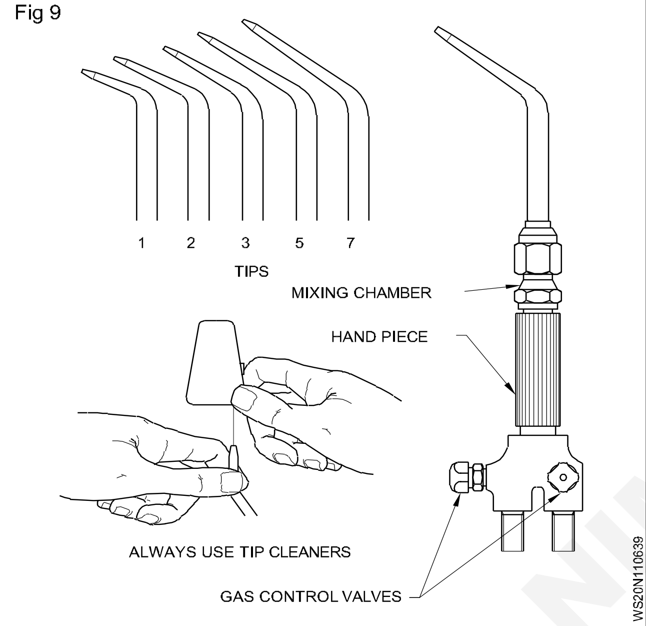


Fig 9



The size of the nozzle varies according to the thickness of the plates to be welded. (Table)

Table 1

plate thickness	Nozzle size
mm	Number
0.8	1
1.2	2
1.6	3
2.4	5
3.0	7
4.0	10
5.0	13
6.0	18
8.0	25
10.0	35
12.0	45
19.0	55
25.0	70
Over 25 .0	90

Gas welding hand tools

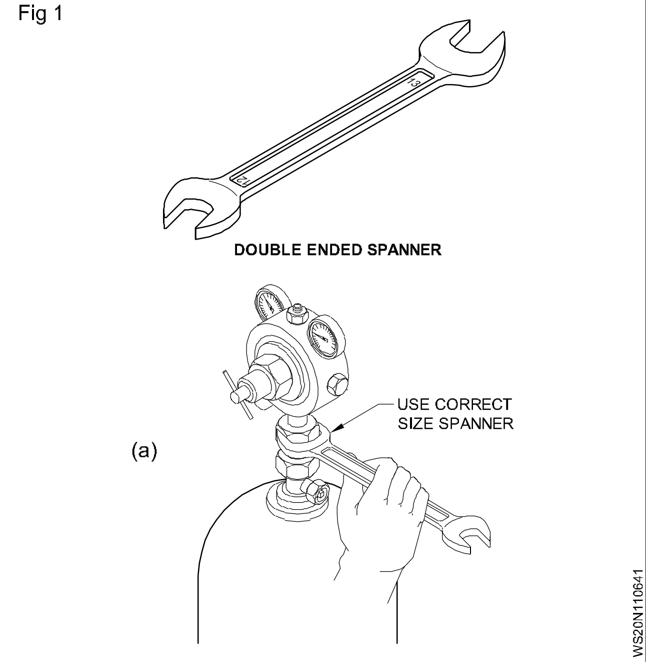
Objectives: At the end of this lesson you shall be able to
- **identify and name the hand tools used by a welder**
- **state their uses**
- **state the care and maintenance to keep the hand tool in good working condition.**

The following are the details of different hand tools used by a welder.

Double ended spanner: A double ended spanner is shown in Fig.1 and 1a. It is made of forged chrome vanadium steel. It is used to loosen or tighten nuts, bolts with hexagonal or square heads. The size of the spanner is marked on it as shown in Fig 1. In welding practice the spanners are used to fix the regulator onto the gas cylinder valves, hose connector and protector to the regulator and blow pipe, fix the cable lugs to the arc welding machine output terminals, etc.

Do not use any size of hammer; use the correct size of spanner to avoid damage to the nut/bolt head,

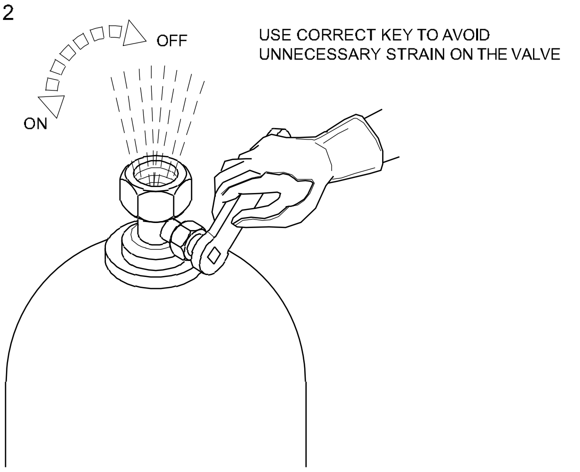
Fig 1



Cylinder Key: A cylinder key is shown in Fig 2. It is used to open or close the gas cylinder valve socket to permit or stop the gas flow from the cylinder to the regulator.

Always use correct size key to avoid damage to the square rod used to operate the valve. The key must always be left on the valve socket-itself so that the gas flow can be stopped immediately in case of flash back/back fire.

Fig 2

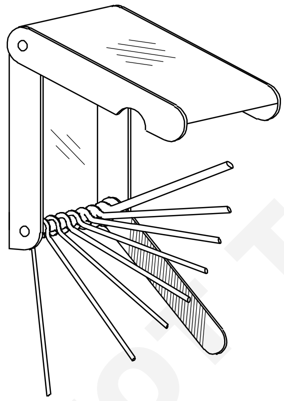


Nozzle or tip cleaner

Cleaning the tip: All welding torch tips are made of copper. They can be damaged by the slightest rough handling. Dropping, tapping or chopping with the tip on the work may damage the tip beyond repair.

Tip cleaner: A Special tip cleaner is supplied with the torch container. For each tip there is a kind of drill and a smooth file Fig 3.

Fig 3



Before cleaning the tip, select the correct drill and move it, without turning, up and down through the tip Fig 4.

The smooth file is then used to clean the surface of the tip Fig 5. While cleaning, leave the oxygen valve partly open to blow out the dust.

Spark lighter: The spark lighter, as illustrated in Fig 6 & 7 is used for igniting the torch. While welding, form the habit of always employing a spark lighter to light a torch. Never use matches. The use of matches for this purpose is very dangerous because the puff of the flame produced by the ignition of the acetylene flowing from the tip is likely to burn your hand.

Fig 4

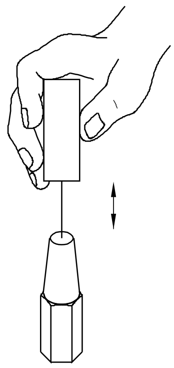


Fig 5

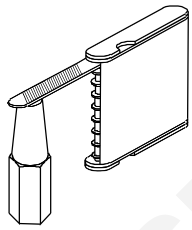


Fig 6

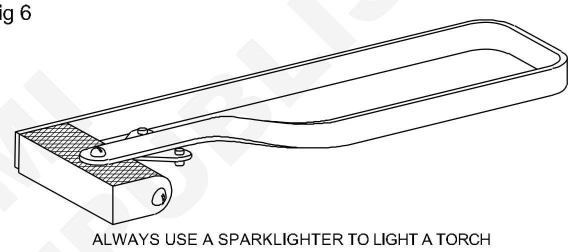
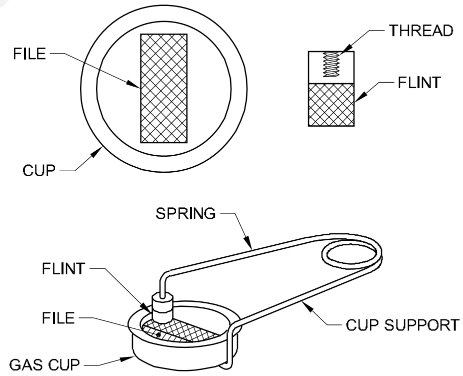


Fig 7



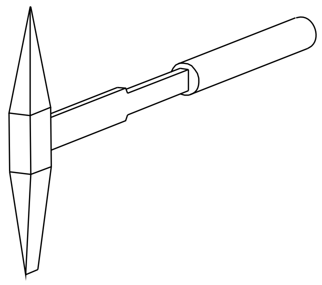
Chipping hammer: The chipping hammer (Fig 8) Is used to remove the slag which covers the deposited weld bead. It is made of medium carbon steel with a mild steel handle. It is provided with a chisel edge on one end and a point on the other end for chipping off slag in any position.

Care should be taken to maintain the sharp chisel edge and the point for effective chipping of slag.

Carbon steel wire brush: A carbon steel wire brush is shown in Fig 9. It is used for

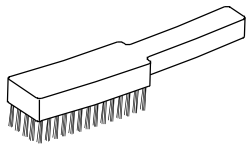
- Cleaning the work surface from rust, oxide and other dirt etc. prior to welding.

Fig 8



CHIPPING HAMMER

Fig 9



WIRE BRUSH

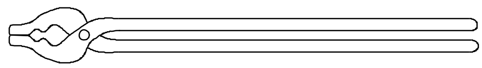
- Cleaning the inter bead weld deposits after chipping off the slag
- General cleaning of the weldment.

A stainless steel wire brush is used for cleaning a non ferrous and stainless steel welded joint.

It is made of bunch of steel wires fitted in three to five rows on a wooden piece with handle. The wires are hardened and tempered for long life and to ensure good cleaning action.

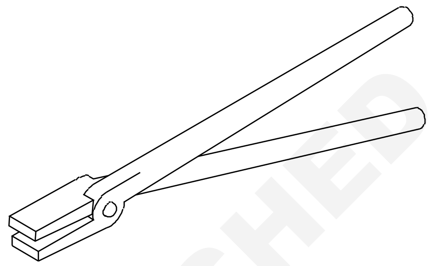
Tongs: Fig.10 and Fig.11 show a pair of tongs used to hold hot work pieces and to hold the job in position.

Fig 10



TONGS

Fig 11



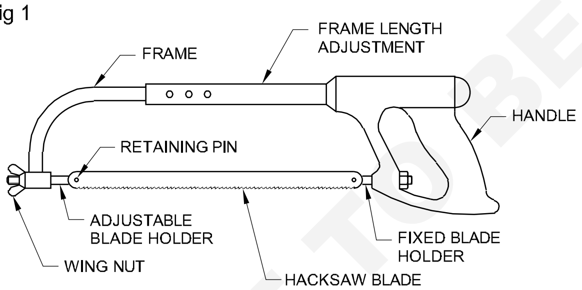
TONGS

Hacksaw frames and blades

Objectives: At the end of this lesson you shall be able to
- **state the different types of hacksaw frames and their uses.**

The hand hacksaw is used along with a blade to cut metals of different sections. It is also used to cut slots and contours. See fig 1 to identify the parts.

Fig 1



Types of hacksaw frames: The two different types of hacksaw frames are solid frames and adjustable frames.

Solid frame: Only a particular standard length of blade can be fitted to this frame.

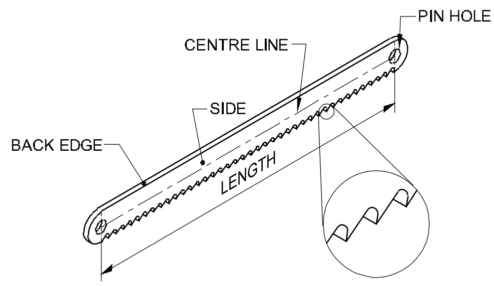
Adjustable frame (Flat type): Different standard lengths of blades can be fitted to this frame.

Adjustable frame (Tubular type): This is the most commonly used type. It gives a better grip and control, while sawing. Fig 1

For proper working, it is necessary to have frames of rigid construction.

Hacksaw blades (Fig 2): A hacksaw blade is a thin narrow steel band with teeth cut on one edge and two pin holes at the ends. It is used along with a hacksaw frame. The blade is made of either low alloy steel or high speed steel and is available in standard lengths of 250 mm and 300 mm.

Fig 2



Type of Hacksaw Blades: Two types of hacksaw blades are available - all hard blades and flexible blades.

All hard blades: The full blade is hardened between the pin holes.

Flexible blades: For these types of blades, only the teeth are hardened. Because of their flexibility, these blades are useful for cutting along curved lines.

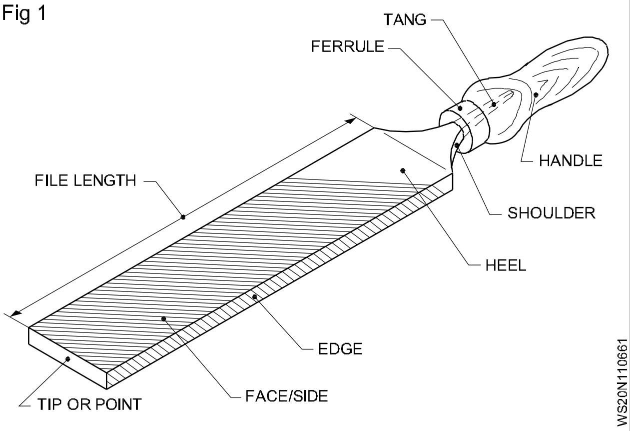
Files - Grades and specification

Objective: At the end of this lesson you shall be able to
- **identify the parts of a file.**

Parts of a file (Fig 1): **The parts of a file as can be seen in fig 1, are**

Tip or point: The end opposite to tang.

Fig 1



Face or side: The broad part of the file with teeth cut on its surface.

Edge The thin part of the file with a Single row of parallel teeth.

Heel: The portion of the broad part without teeth near the tang.

Shoulder: The curved part of the file joining tang from the body.

Tang; The narrow and thin part of a file which fits into the handle

Handle: The part fitted to the tang for holding the file

Ferrule; A protective metal ring to prevent cracking of the handle.

Materials: Generally files are made of high carbon or high grade cast steel. The body portion is hardened and tempered. The tang is, however, not hardened.

Cut of files

Objectives: At the end of this lesson you shall be able to
- **name the different cuts of files**
- **state the uses of each type of cut.**

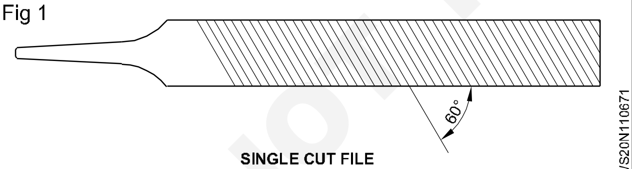
The teeth of a file is formed by cuts made on its face. Files have cuts of different types. Files with different cuts have different uses.

Type of cuts: Basically there are four types.

Single cut, double cut, Rasp cut and curved cut.

Single cut File (Fig. 1): 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 center line. It can cut chips as wide as the cut of the file. Files with this cut are useful for filing soft metals like brass, aluminium, bronze and copper.

Fig 1

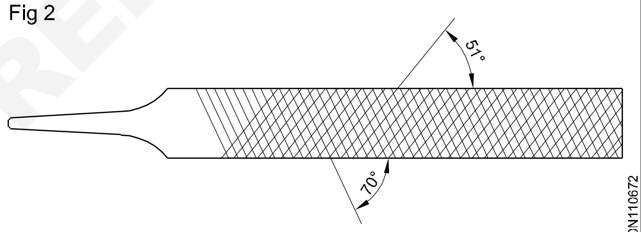


SINGLE CUT FILE

Single cut files do not remove stock as fast as double cut files, but the surface finish obtained is much smoother.

Double cut file (Fig 2): A double cut file has two rows of teeth cut diagonal to each other. The first row of teeth is known as OVERCUT and they are cut at an angle of 70° The other cut, made diagonal to this, is known as UPCUT, and is at an angle of 51°. This removes stock faster than the single cut file.

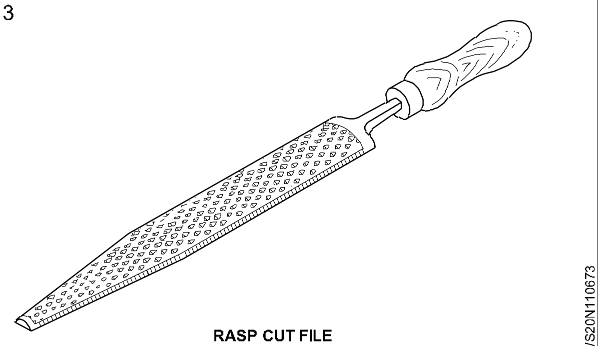
Fig 2



DOUBLE CUT FILE

Rasp cut file (Fig 3): The rasp cut has individual, sharp, pointed teeth in a line, and is useful for filing wood, leather and other soft materials. These files are available only in half round shape.

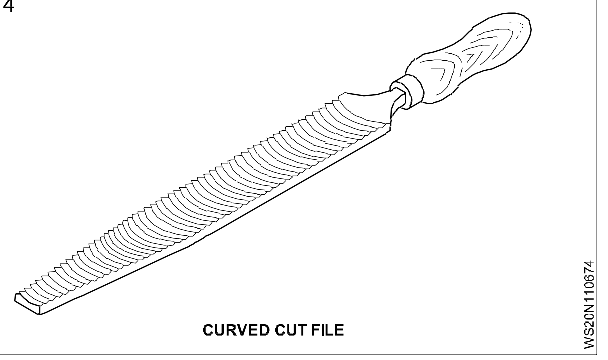
Fig 3



RASP CUT FILE

Curved cut file (Fig 4): These files have deeper cutting action and are useful for filing soft materials like-aluminium, tin, copper and plastic. The curved cut are available only in a flat shape.

Fig 4



CURVED CUT FILE

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.

File specifications and grades

Objectives: At the end of this lesson you shall be able to
- **state how files are specified**
- **name the different grades of files**
- **state the application of each grade of file.**

Files are manufactured in different types and grades to meet the various needs.

Files are specified according to their length, grade, cut and shape.

Length is the distance from the tip of a file to the heel. Fig1 under lesson parts of a File.

File grades are determined by the spacing of the teeth.

A rough file is used for removing rapidly a larger quantity of metal. It is mostly used for trimming the rough edges of soft metal castings.

A bastard file is used in cases where there is a heavy reduction of material.

A second cut file is used to give a good finish on metals, It is excellent to file hard metals. It is useful for bringing the jobs close to the finishing size.

A smooth file is used to remove small quantity of material and to give a good finish.

A dead smooth file is used to bring to accurate size with a high degree of finish.

The most used grades of files are bastard, second cut, smooth and dead smooth. These are the grades recommended by the Bureau of Indian Standards. (BIS)

Different sizes of files with the same grade will have varying sizes of teeth. In longer files, the teeth will be coarser.

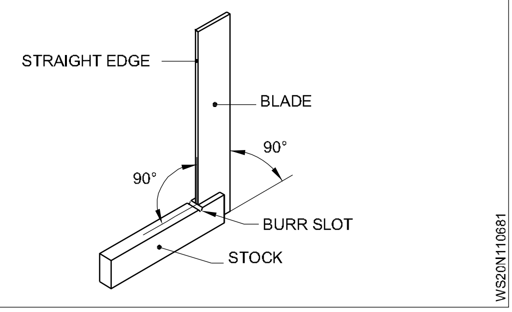
Try square

Objectives: At the end of this lesson you shall be able to
- **name the parts of the try square**
- **state the uses of the try square.**

Try square Fig 1 is a precision instrument which is used to check the squares and the flatness of surfaces very accurately.

The try square has a blade with parallel edges. This blade is fixed to the stock at 90°. Burr slot is provided on the stock at meeting point of blade to accommodate the burr, if present on the component, to avoid inaccuracy in measuring squares.

Fig 1



Uses: The try square is used to check the squares of machined of filed surfaces (Fig 2) and check flatness of surfaces (Fig 3), mark line at 90° to the edges of work pieces (Fig 4) and set work pieces at right angles on work holding devices. (Bench vice) Fig 5

Try squares are made of hardened steel. Try squares are specified according to the length of the blade i.e. 100mm, 150mm, 200mm.

Fig 2

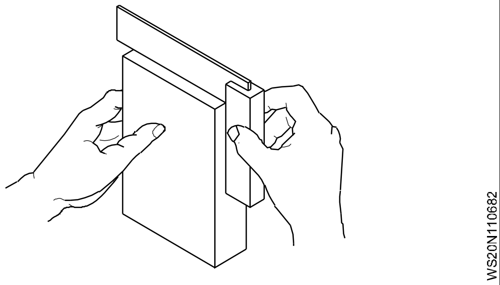


Fig 3

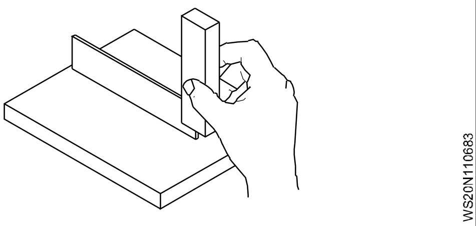


Fig 4

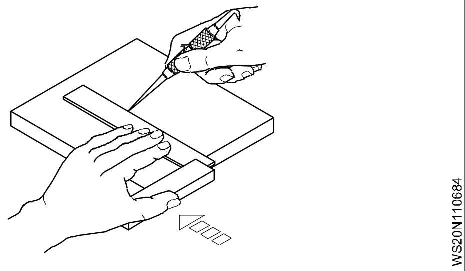
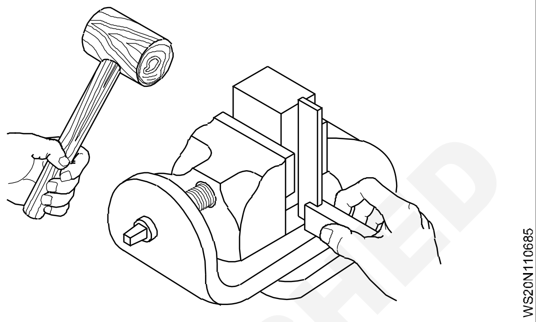


Fig 5



Mallets

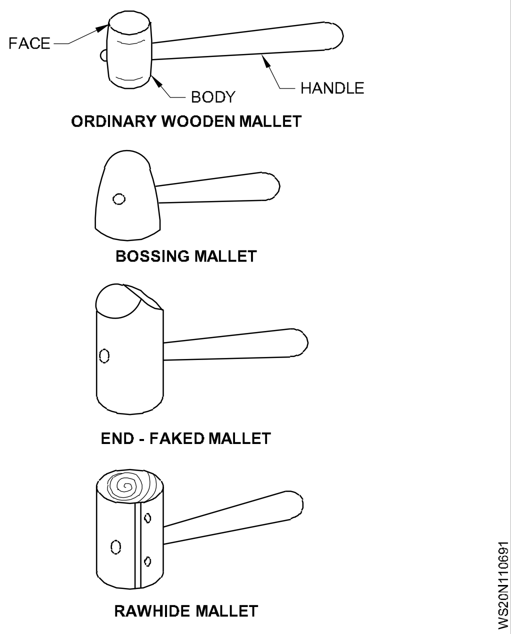
Objectives: At the end of this lesson you shall be able to
- **state the different types of mallets**
- **state the uses of mallets**
- **state the care and maintenance.**

Mallet is a shaping tool used for general purpose work like flattening, bending and forming to required shape of sheet metal.

These are made of hard wood

When using any metal hammer for flattening the sheet metal, the face of the hammer may damage or leave impression in the sheet more than what is required for the job. To avoid such damage and a impression, mallets are used.

Fig 1



Types (Fig 1)

- Ordinary mallet

- Bossing mallet

- End-faked mallet

- Raw hide mallet,

Ordinary mallet: Both the faces of the mallets, are provided a little convexity. If the face is not in convex shape the edges of the mallet face will get broken while beating the job.

Mallets are specified by the dia and the shape of the face. Mallets are available in 50mm, 75mm and 100 mm dia

Avoid using the mallet as hammer for doing chipping and to drive nails and work on the sharp corners. If the mallet is used for the above work its face will get damaged.

Bench vice

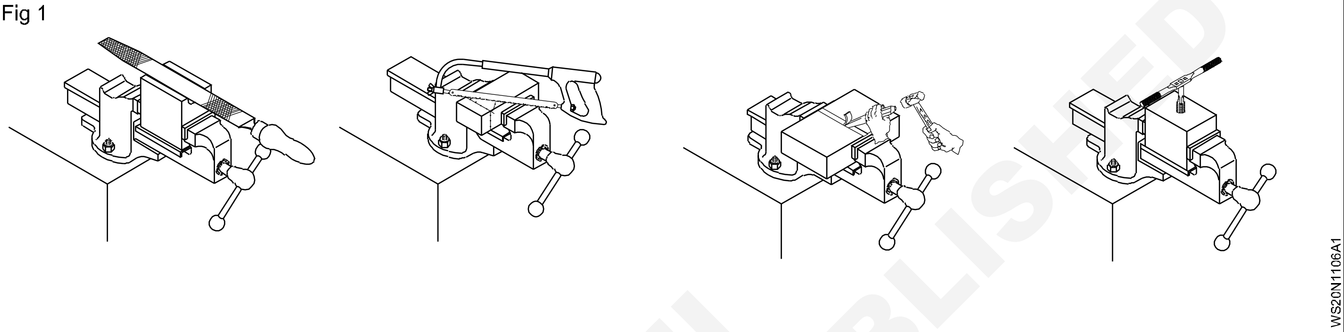
Objectives: At the end of this lesson you shall be able to
- **name the parts and uses of a bench vice**
- **specify the size of a bench vice**
- **state the uses of vice clamps.**

These are used for holding work pieces. They are available in different types. The vice used for bench work is bench vice. (Engineer's vice)

Bench vice is made of cast iron or cast steel and it is used to hold work for filing, sawing, threading and other hand operations. (Fig 1)

The size of the vice is stated by the width of the jaws.

Fig 1



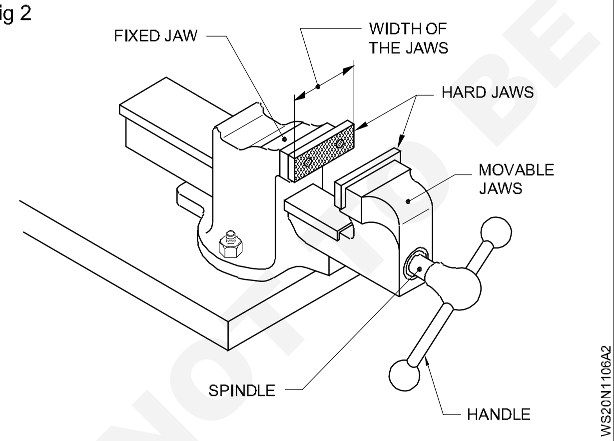
Parts of a bench vice (Fig 2)

The following are the parts of vice:

Fixed jaw, Movable jaw, Hard jaws, Spindle, Handle, Box nut and Spring.

The box nut and the spring are the internal parts.

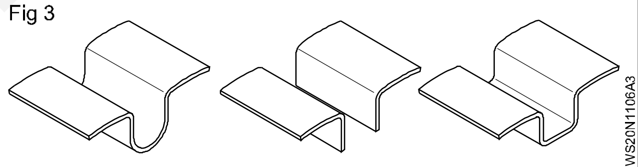
Fig 2



Vice clamp or soft jaws (Fig 3)

To hold a finished work use soft jaws (Vice claps) made of aluminium over the regular hard jaws. This will protect the work surface from damage.

Fig 3



Do not over-tighten the vice, otherwise, the spindle may be damaged.

Length measurement

Objectives: At the end of this lesson you shall be able to
- **name the base unit of length measurement as per the International System of units of measurement (SI)**
- **state the multiples of a meter and their values.**

When we measure an object, we are actually comparing it with a known standard of measurement.

The base unit of length as per SI is the METRE.

Length - SI UNITS and MULTIPLES

Base unit: The base unit of length as per the Systems International is the meter. The table given below lists some multiples of a metre.

METRE (m)	= 1000 mm
CENTIMETRE(cm)	= 10 mm
MILLIMETRE (mm)	= 1000u
MICROMETRE (um)	= 0.001 mm

Measurement in engineering practice: Usually, in engineering practice, the preferred unit of length measurement is the millimetre. (Fig 1)

Both large and small dimensions are stated in millimetres. (Fig 2)

The British system of length measurement: An alternative system of length measurement is the British system. In this system, the base unit is the Imperial Standard Yard. Most countries, including Great Britain itself, have, however, in the last few years, switched over to SI units.

Fig 1

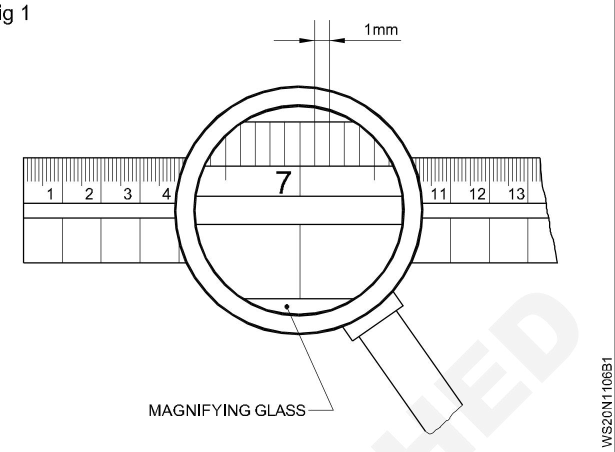
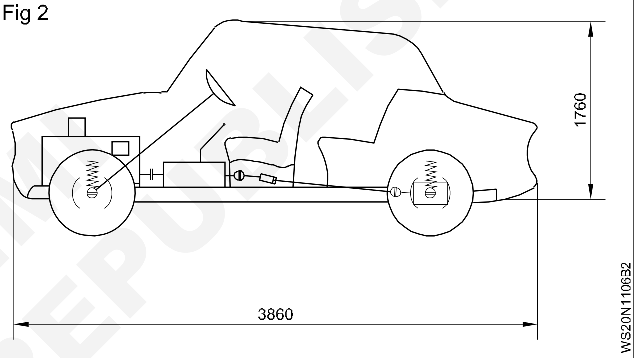


Fig 2



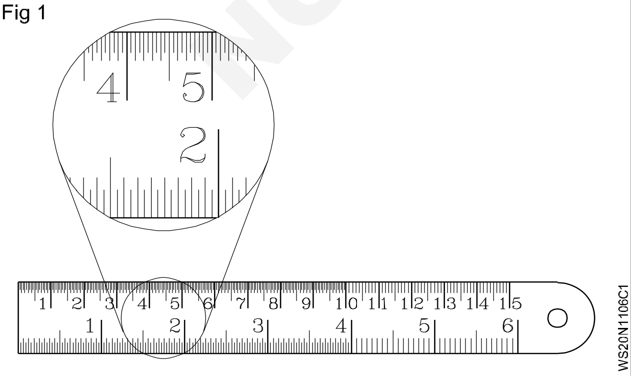
Steel rule

Objectives: At the end of this lesson you shall be able to
- **state the purpose of steel rule**
- **state the types of steel rule.**

Engineer's steel rule (Fig 1) is used to measure the dimensions of work pieces.

Steel rules are made of spring steel or stainless steel. These rules are available in length 150mm, 300mm and 600mm. The reading accuracy of steel rule is 0.5 mm and 1/64 inch.

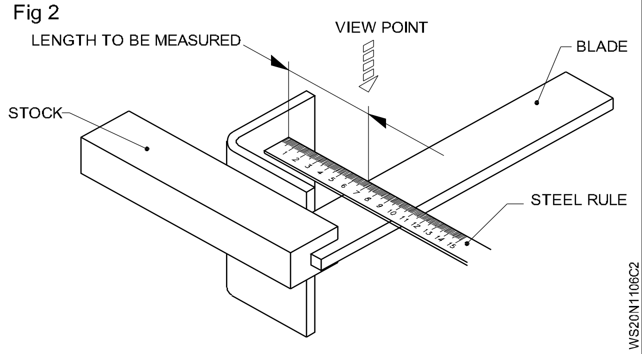
Fig 1



For accurate reading it is necessary to read vertically to avoid errors arising out of parallax. (Fig1)

Steel rule in English measure, they can also be furnished with metric and English graduation in a complete range of size 150, 300, 500 and 1000 mm. (Fig 2)

Fig 2



Marking media

Objectives: At the end of this lesson you shall be able to
- **name the common type of marking media**
- **state the Correct marking media for different applications.**

Different marking media: The different marking media are Whitewash, Prussian Blue, Copper Sulphate and Cellulose Lacquer.

Whitewash: White wash is prepared in many ways

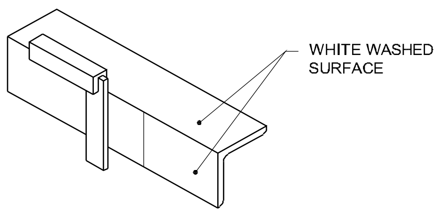
Chalk powder mixed with water

Chalk mixed with mentholated spirit

White lead powder mixed with turpentine.

Whitewash is applied to rough forgings and castings with oxidised surfaces. (Fig 1)

Fig 1



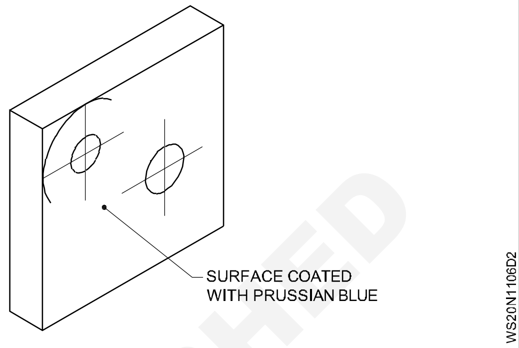
Whitewash is not recommended for work pieces of high accuracy.

Prussian Blue: This is used on file or machine-finished surfaces. This will give very clear lines but takes more time for drying than the other marking media. (Fig 2)

Copper Sulphate: The solution is prepared by mixing copper sulphate in water and a few drops of nitric acid.

The copper sulphate is used on filed or machine-finished surfaces. Copper sulphate sticks to the finished surfaces well.

Fig 2



Copper sulphate needs to be handled carefully as it is poisonous. Copper sulphate coating should be dried well before commencing marking as, otherwise, the solution may stick on the instruments used for marking.

Cellulose Lacquer: This is a commercially available marking medium. It is made in different colours, and dries very quickly.

> **The selection of marking medium for a particular job depends on the surface roughness and the accuracy of the workpiece.**

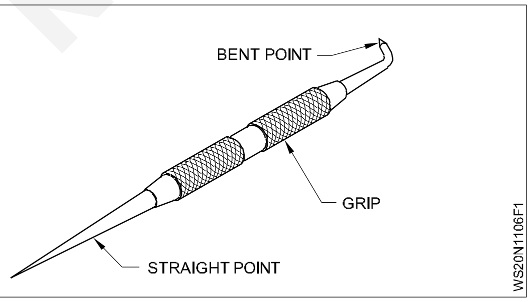
Scribers

Objectives: At the end of this lesson you shall be able to
- **state the Features of scribers**
- **state the uses of scribers.**

In lay out work it is necessary to scribe lines to indicate the dimensions of the work piece to be filed or machined. The scriber is a tool used for this purpose. It is made of high carbon steel and is hardened. For drawing clear and sharp lines, the point should be ground and used frequently for maintaining its sharpness.

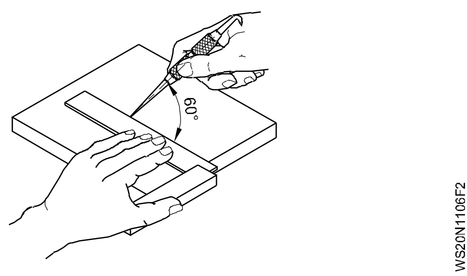
Scribers are available in different shapes and sizes. The most commonly used one is the plain scriber. (Fig 1)

Fig 1



While scribing lines, the scriber is used like a pencil so that the lines drawn are close to the straight edge. (Fig 2)

Fig 2



scriber points are very sharp: therefore, do not put the plain scriber in your pocket.

> **Place a cork on the point when not in use to prevent accidents.**

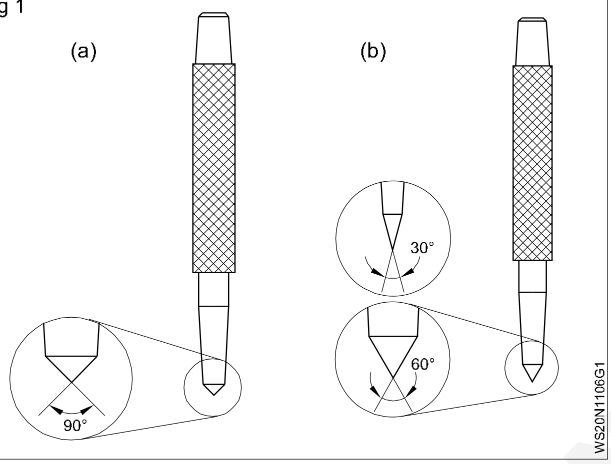
Types of marking punches

Objectives: At the end of this lesson you shall be able to
- **name the different punches in marking**
- **state the features of each punch and its uses.**

Punches are used in order to make certain dimensional features of the layout permanently. There are two types of punches. They are center punch and prick punch made up of high carbon steel, hardened and ground.

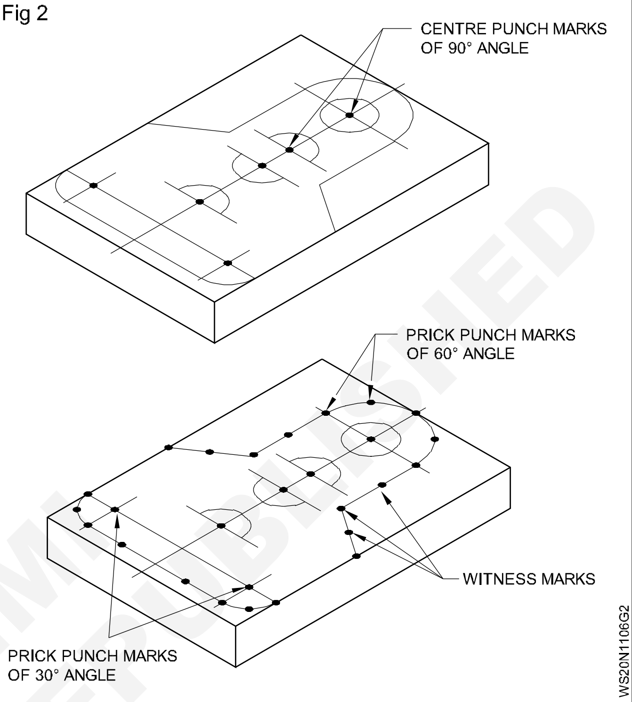
Centre punch: The angle of the point is 90° in a centre punch. The punch mark made by this is wide and not very deep. This punch is used for locating centre of the holes. The wide punch mark gives a good seating for starting the drill. (Fig 1a)

Fig 1



Prick punch/Dot punch: The angle of the prick punch is 30° or 60°. (Fig 1b) The 30° point punch is used for marking light punch marks needed to position dividers. The divider point will get a proper seating in the punch mark. The 60° punch is used for marking witness marks and called as dot punch (Fig 2)

Fig 2



The witness marks should not be too close to one another.

Hammer

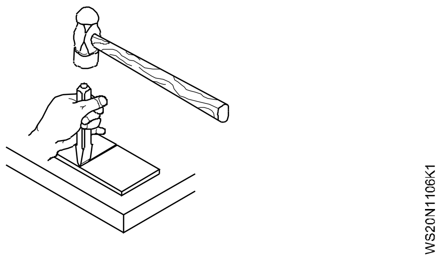
Objectives: At the end of this lesson you shall be able to
- **state the uses of an engineer's hammer**
- **identify the parts of an engineer's hammer and state their functions**
- **name the types of engineer's hammers**
- **specify the engineer's hammer.**

An engineer's hammer is a hand tool used for striking purposes while

- punching
- bending
- straightening
- chipping
- forging
- riveting.

(See Fig 1)

Fig 1



Major parts of a hammer

The major parts of a hammer are a head and handle.

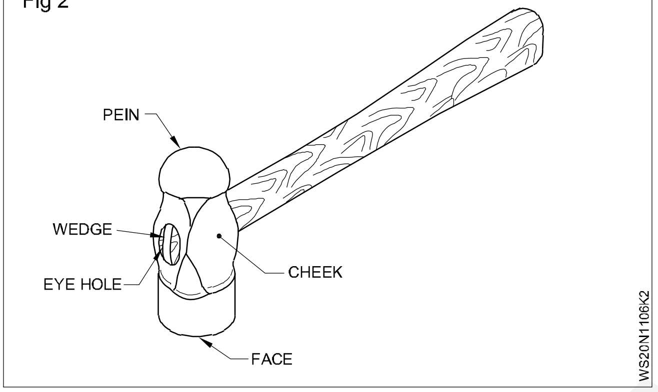
The head is made of drop-forged carbon steel, while the wooden handle must be capable of absorbing shock.

The parts of a hammer-head are the

- face
- pein
- cheek
- eye hole.

(See Fig 2)

Fig 2



Face

The face is the striking portion. Slight convexity is given to it to avoid digging of the edge.

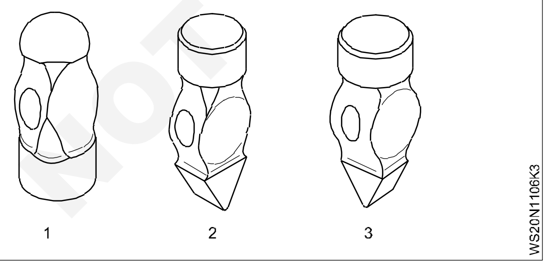
Pein

The pein is the other end of the head. It is used for shaping and forming work like riveting and bending. The pein is of different shapes like the

- ball pein
- cross pein
- straight pein. (Fig 3)

The face and the pein are hardened.

Fig 3



Cheek

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

Eye hole

An eye hole is meat for fixing the handle; Eye is shaped to fit the handle rigidly. The wedges fix the handle in the eye hole. (See figs 4 and 5.)

Fig 4

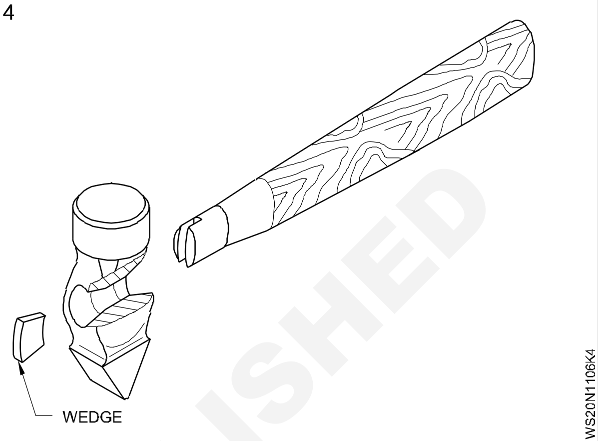
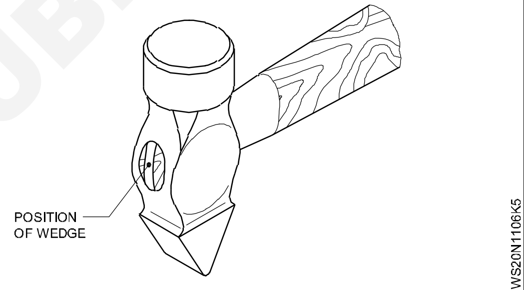


Fig 5



Specification

An engineer's hammer is specified by their weight and the shape of the pein. Their weight varies from 125 gms to 1500 gms.

The weight of an engineer's hammer used for marking purposes, is 250 gms.

The ball pein hammers are used for general work in a machine/fitting shop.

Before using a hammer

Make sure the handle is properly fixed and select a hammer with correct weight suitable for the job

Check the head and handle for any cracks and ensure the face of the hammer is free from ail or grease.

Various welding processes and it's application

Objectives: At the end of this lesson you shall be able to
- **state and classify the electric welding processes**
- **state and classify the gas welding processes**
- **name and classify the other welding processes**
- **state the applications of various welding processes.**

According to the sources of heat, welding processes can be broadly classified as:

- Electric welding processes (heat source is electricity)
- Gas welding processes (heat source is gas flame)
- Other welding processes (heat source is neither electricity nor gas flame)

Electric welding processes can be classified as:-

- Electric arc welding
- Electric resistance welding
- Laser welding
- Electron beam welding
- induction welding

Electric arc welding can be further classified as:

- Shielded Metal Arc Welding/Manual Metal Arc Welding
- Carbon arc welding
- Atomic hydrogen arc welding
- Gas Tungsten Arc Welding / TIG Welding
- Gas Metal Arc Welding / MIG/MAG Welding
- Flux cored arc welding
- Submerged arc welding
- Electro-slag welding
- Plasma arc welding

Electric resistance welding can be further classified as:

- Spot welding
- Seam welding
- Butt welding
- Flash butt welding
- Projection welding.

Gas welding processes can be classified as:

- Oxy-acetylene gas welding
- Oxy-hydrogen gas welding
- Oxy-coal gas welding
- Oxy-liquified petroleum gas welding
- Air acetylene gas welding.

The other welding processes are:

- Thermit welding
- Forge welding
- Friction welding
- Ultrasonic welding
- Explosive welding
- Cold pressure welding
- Plastic welding.

Code	Welding process
AAW	Air Acetylene
AHW	Atomic Hydrogen
BMAW	Bare Metal Arc
CAW	Carbon Arc
EBW	Electron Beam
EGW	Electro Gas
ESM	Electro slag
FCAW	Flux Cored Arc
FW	Flash
FLOW	Flow
GCAW	Gas Carbon Arc
GMAW	Gas Metal Arc
GTAW	Gas Tungsten Arc
IW	Induction
LBW	Laser Beam
OAW	Oxy-Acetylene
OHW	Oxy-Hydrogen
PAW	Plasma Arc
PGW	Pressure Gas
RPW	Resistance Projection
RSEW	Resistance Seam
RSW	Resistance Spot
SAW	Submerged Arc
SMAW	Shielded Metal Arc

SCAW	Shielded Carbon Arc
SW	Stud Arc
TW	Thermit
UW	Ultrasonic

Applications of Various welding processes

Forge welding: It is used in olden days for joining metals as a lap and butt joint.

Shielded Metal arc welding is used for welding all ferrous and non-ferrous metals using consumable stick electrodes,

Carbon arc welding is used for welding all ferrous and non-ferrous metals using carbon electrodes and separate filler metal. But this is a slow welding process and so not used now-a-days.

Submerged arc welding is used for welding ferrous metals, thicker plates and for more production.

Co_2 Welding (Gas Metal Arc Welding) is used for welding ferrous metals using continuously fed filler wire and shielding the weld metal and the arc by carbon-di-oxide gas.

TIG welding (Gas Tungsten Arc Welding) Is used for welding ferrous metals, stainless steel, aluminium and thin sheet metal welding.

Atomic hydrogen welding is used for welding all ferrous and non-ferrous metals and the arc has a higher temperature than other arc welding processes.

Electro slag welding is used for welding very thick steel plates in one pass using the resistance property of the flux material.

Plasma arc welding: The arc has a very deep penetrating ability into the metals welded and also the fusion is taking place in a very narrow zone of the joint.

Spot weding is used for welding thin sheet metal as a lap joint in small spots by using the resistance property of the metals being welded.

Seam welding is used for welding thin sheets similar to spot welding. But the adjacent weld spots will be overlapping each other to get a continuous weld seam.

Projection welding is used to weld two plates one over the other on their surfaces instead of the edges by making projection on one plate and pressing it over the other flat surface. Each projection acts as a spot weld during welding.

Butt welding is used to join the ends of two heavy section rods/blocks together to lengthen it using the resistance property of the rods under contact.

Flash butt welding is used o join heavy sections of rods/blocks similar to butt welding except that arc flashes are produced at the joining ends to melt them before applying heavy pressure to join them.

Oxy -acetylene welding is used to join different ferrous and non ferrous metals, generally of 3mm thickness and below.

Oxy-other fuel gases welding: Fuel gases like hydrogen, coal gas, liquified petroleum gas (LPG) are used along with oxygen to get a flame and melt the base metal and filler rod. Since the temperature of these flames are lower than the oxy-acetylene flame, these welding are used to weld metals where less heat input is required.

Air-acetylene gas welding is used for soldering, heating the job etc.

Induction welding is used to weld parts that are heated by electrical induction coils like brazing of tool tips to the shank, joining flat rings, etc.

Thermit welding is used for joining thick, heavy, irregularly shaped rods, like rails, etc using chemical heating process.

Friction welding is used to join the ends of large diameter shafts, etc by generating the required heat using the friction between their ends in contact with each other by rotating one rod against the other rod.

Arc and Gas Welding terms and definitions

Objectives: At the end of this lesson you shall be able to
- **state the welding terms and definitions.**

1 **Butt Weld:** joining of two pieces placed in 180° (surface level) & the welding performed is called as Butt weld.

2 **Fillet weld:** joining of two pieces placed in 90° (surface level / one surface & another edge surface/both edge surface) & the welding performed is called as fillet weld.

3 **Weld reinforcement:** the material which is above the place surface/miter surface is called as weld reinforcement.

4 **Miter line:** the straight line which is bisecting two toe points is known as miter line.

5 **Toe of weld:** the point at which the weld reinforcement is resting on base metal surface is known as toe point.

6 **Toe Line:** the line on which the weld reinforcement is resting on base metal surface.

7 **Concave bead:** the weld metal below the miter line is known as concave bead.

8 **Convex bead:** the weld metal above the miter line is known as convex bead.

9 **Miter bead:** If the weld bead is up to the level of miter line it is known as miter bead.

10 **Gas welding torch:** A device which is used for mixing, carrying, flow control and flame igniting of gases is known as gas welding torch.

11 **Gas cutting torch;** A device which is used for mixing, carrying, flow control and flame igniting of gases is known as gas cutting torch.

12 **Gas pressure regulator:** A device which monitors content of gas pressure in cylinder and regulates drawing/working gas pressure.

13 **Gas Rubber hose pipe:** A rubber hose which carries gases from gas pressure regulators and supplies to gas welding/cutting torches.

14 **Back fire:** If gas flame is snapped out due to wrong gas pressure setting is known as back fire.

15 **Flash back:** When the gas flame is snapped out and starts reverse burning towards cylinder with hissing sound which is very hazardous is known as flash back,

16 **Flash back arrestor:** Sometimes during backfire, the flame goes off and the burning acetylene gas travels backward in the blowpipe, towards the regulator or cylinder. At the time in between the device which has to be arrested the backfire.

17 **Electrode holder:** A device by which electricity provided by cable will be carried to the electrode and which holds the electrode in desired angles. (This device is available with different capacities and type i.e. 300 Amps, 400 Amps and 600 Amps partly, semi and fully insulated).

18 **Earth clamp:** A device by which electricity will carry provided by cable will be carried to the job table. (This device is available with different capacities and type i.e. 300 Amps, 400 Amps and 600 Ams. It is prepared by brass casting, G.I. Coated in spring or fixed form.

19 **Arc welding cable:** This is made of copper/aluminium strands to carry electricity from welding machine to electrode holder and earth cable.

20 **Cable Lug:** This is available with different capacities and type i.e. 300Amps, 400Amps and 600Amps. This is preferably made of copper metal.

21 **SMAW:** Shielded Metal Arc Welding. Also known as manual metal arc welding and stick welding. (In this process the electrode is consumable).

22 **GMAW:** Gas Metal Arc welding covers CO2 welding (MAG), metal inter gas arc welding (MIG) & flux cored arc welding. (In these processes the electrode is consumable).

23 **GTAW:** Gas Tungsten Arc welding. (In this process the electrode is consumable).

24 **FCAW:** Flux cored Arc welding. Flux cored arc welding. (In the process the electrode is consumable).

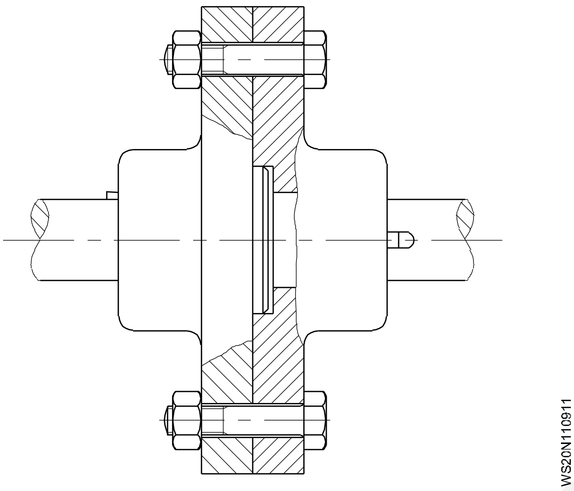
25 **Electrode** (Flux coated) A metal stick which is coated with flux and having parts indicated as stub end, tip, bare/core wire and flux coating. The size of this is determined by size of bare/core wire diameter. (This is used in shielded Metal Arc welding as consumable material).

Different process of metal joining methods bolting,riveting, soldering brazing

Objectives: At the end of this lesson you shall be able to
- **state the situations in which bolts and nuts are used**
- **state the advantages of using bolts and nuts.**

Bolts and nuts (Fig 1)

Fig 1



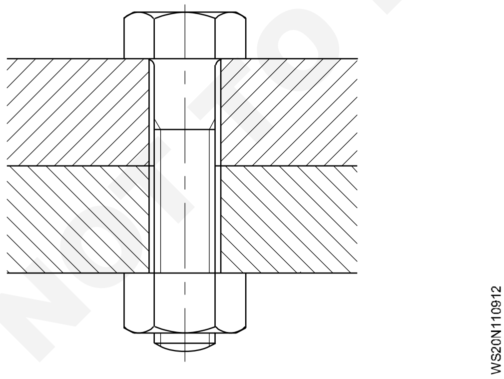
These are generally used to clamp two parts together.

When bolts and nuts are used, if the thread is stripped, a new bolt and nut can be used. But in the case of a screw directly fitted in the component, when threads are damaged, the component may need extensive repair or replacement.

Depending on the type of application, different types of bolts are used.

Bolts with clearance hole (Fig 2)

Fig 2

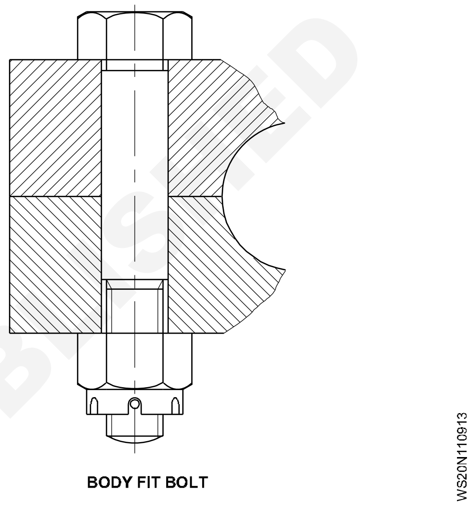


This is the most common type of fastening arrangement using bolts. The size of the hole is slightly larger than the belt (Clearance hole).

Slight misalignment in the matching hole will not affect the assembly.

Body fit bolt (Fig 3)

Fig 3

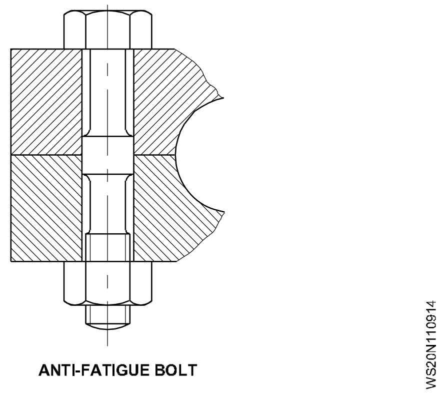


This type of bolt assembly is used when the relative movement between the work pieces has to be prevented. The diameter of the threaded portion is slightly smaller than the shank diameter of the bolt.

The bolt shank and the hole are accurately machined for achieving perfect mating.

Anti-fatigue bolt (Fig 4)

Fig 4

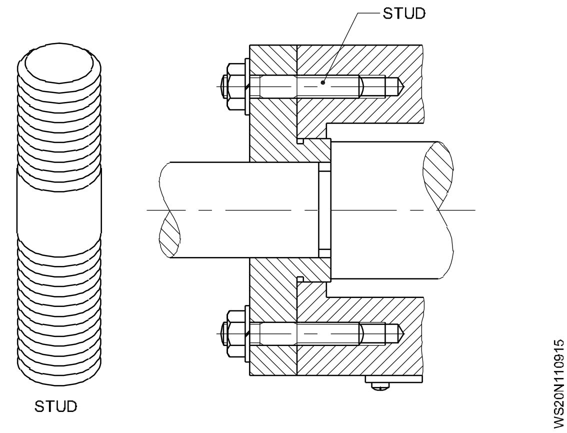


This type of bolt is used when the assembly is subjected to alternating load conditions continuously. Connecting rod with big ends in engine assembly are examples of this application.

The shank diameter is in contact with the hole in a few places and other portions are relieved to give clearances.

Studs (Fig 5)

Fig 5



Studs are used in assemblies which are to be separated frequently.

When excessively tightened, the variation in the thread pitch allows the fine thread or nut end to strip. This prevents damage to the casting.

Designation of bolts as per B.I.S. specifications

Hexagonal head bolts shall be designated by name, thread size, nominal length, property class and number of the Indian Standard.

Example

A hexagonal head bolt of size M10, nominal length 60mm and property class 4.8 shall be designated as:

Hexagonal head bolt M10 60 - 4.8 - IS: 1363 (Part)

Explanation about property class.

The part of the specification 4.8 indicates the property class (mechanical properties). In this case it is made of steel with minimum tensile strength - 40 kgf/mm^2 and having a ratio of minimum yield stress to minimum tensile strength = 0.8.

NOTE

Indian standard bolts and screws are made of three product grades - A, B, & C and 'A' being precision and the others, of lesser grades of accuracy and finish.

(For more details on the designation system, refer to IS: 1367, Part XVI 1979.)

While there are many parameters given in the B.I.S. Specification, the designation need not cover all the aspects and it actually depends on the functional requirement of the bolt or other threaded fasteners.

Rivet joines

Objectives: At the end of this lesson you shall be able to
- **state the purpose of rivets**
- **identify the different types of rivets**
- **name the different types of riveted joints**
- **name the materials from which rivets are made**
- **calculate the length of rivets.**

Rivets are used to join together two or more sheets of metal permanently. In sheet metal work riveting is done where;

- brazing is not suitable,
- the structure changes owing to welding heat,
- the distortion due to welding cannot be easily removed etc.

Specification of rivets

Rivets are specified by their length, material, size and shape of head.

Rivets

There are various kinds of rivets as shown in Fig 1. Snap head rivets, countersink rivets and thin bevel head rivets are widely used in sheet metal work.

The materials used for rivets are mild steel, copper yellow brass, aluminium and heir alloys.

The length of the rivets 'L' is indicated by the shank length. (Fig 1)

Rivet joints (Fig 2)

Rivet joints are classified as lap joints and butt joints.

In the case of butt joints, a plate called a butt strap is used.

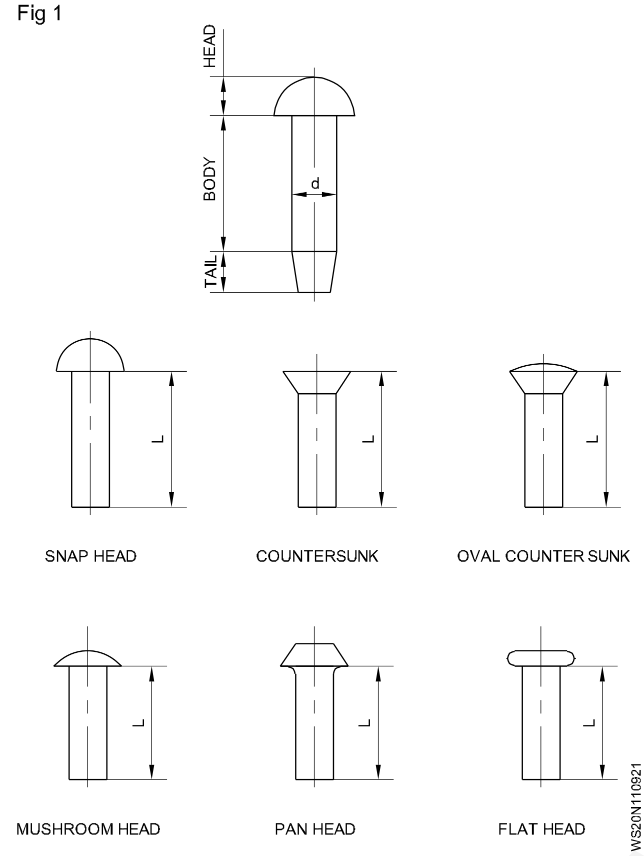
Rivet interference

The length required to form the head in riveting is called rivet interference.

When forming a round head (Fig 3) the interference X is given as

X = d X (1.3, -- 1.6)

Fig 1



where = rivet interference(mm)

d = rivet diameter (mm)

Therefore, the length of the rivet (L mm) to form a round head when the total thickness of the piled plates is T mm will be, as given below.

L = T + d (1.3 - 1.6)

When forming a flat head (Fig 4) the length of the rivet (L'mm) will be as given below.

L' = T + d (0.8 - 1.2)

When the appropriate values of the rivet diameter and the length for the plate thickness are found out, choose the rivets with the standard size close to the calculated values.

Fig 3

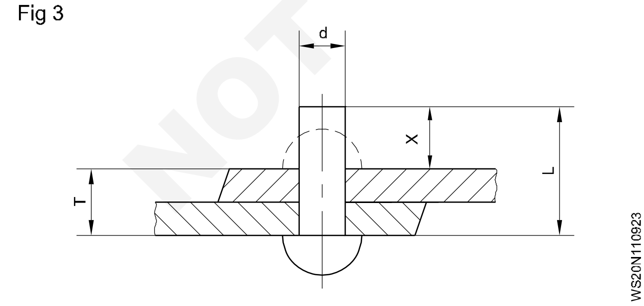


Fig 2

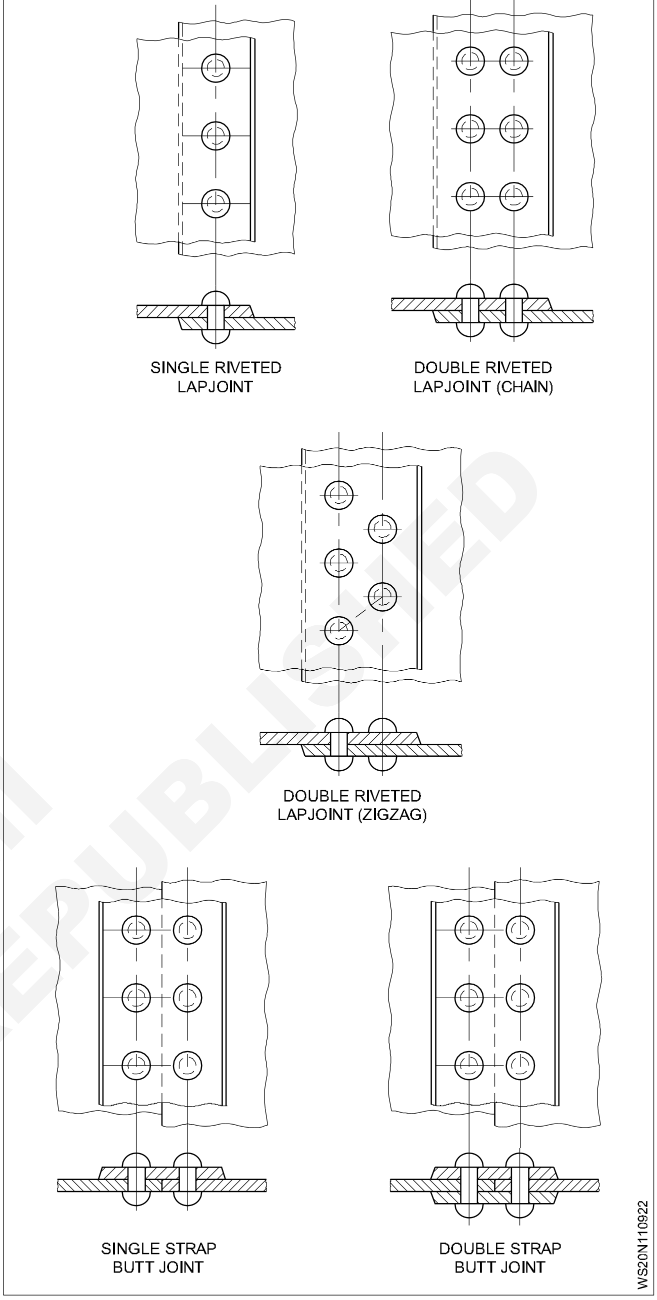
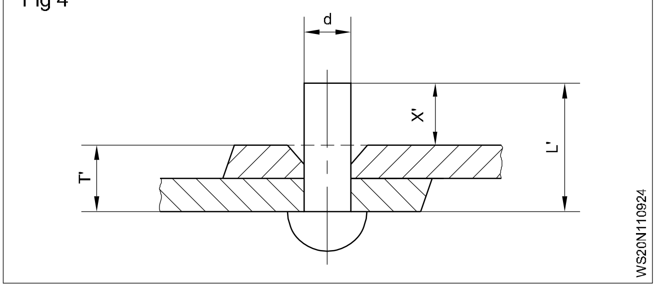


Fig 4



Soldering

Objectives: At the end of this lesson you shall be able to
- **define 'soldering'**
- **state the different types of soldering processes.**

Soldering method: There are different methods of joining metallic sheets. Soldering is one of them.

Soldering is the process by which metals are joined with the help of another alloy called solder without heating the base metal to be joined. The melting point of the solder is lower than that of the materials being joined.

The molten solder wets the base material which helps in binding the base metal to form a joint.

Soldering should not be done on joints subjected to heat and vibration and where more strength is required.

Soldering can be classified as soft soldering and hard soldering. Hard soldering is further divided as (a) brazing (b) sliver brazing.

The process of joining metals using tin and lead as a soldering alloy which melts below 420°C is known as soft soldering.

The process of joining metals using copper. zinc and tin alloy as filler material in which the base metal is heated above 420°C below 850°C is called brazing.

Silver brazing is similar to brazing except that the filler material used is a silver-copper alloy and the flux used is also different.

Soldering iron (soldering bit)

Objectives: At the end of this lesson you shall be able to
- **state the purpose of soldering iron**
- **describe constructional features of soldering iron**
- **state different types of copper bits and there uses.**

Soldering iron: The soldering iron is used to melt the solder and heat metal that are joined together.

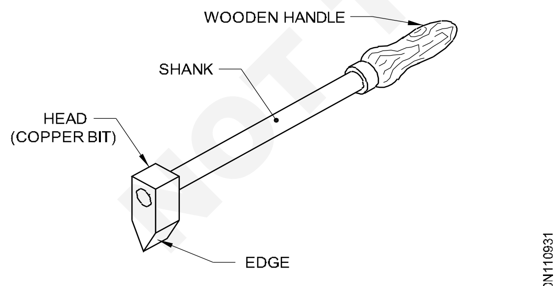
Soldering irons are normally made of copper or copper alloys. So they are also called as copper bits.

Copper is the preferred material for soldering bit because

- it is a very good conductor of heat
- it has affinity for tin lead alloy
- it is easy to maintain in serviceable condition
- it can be easily forged to the required shape.

A soldering iron has the following parts. (Fig 1)

Fig 1



SOLDERING IRON (HATCHET TYPE)

- Head (copper bit)
- Shank
- Wooden handle
- Edge

SOLDERING COPPER BIT

Type of soldering copper bits: There are 7 types of soldering copper bits in general use,

They are

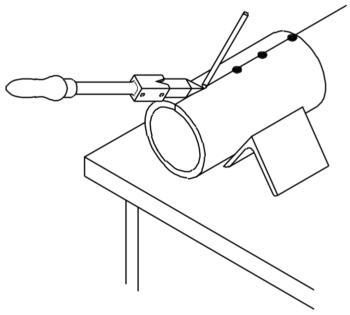
- The pointed soldering copper bit.
- The electric soldering copper bit.
- The gas heated soldering copper bit .
- Straight soldering copper bit.
- Hatchet soldering copper bit.
- Adjustable copper bit
- Handy soldering copper bit.

The bits of soldering irons are made in various shapes and sizes to suit the particular job. They should be large enough to carry adequate heat to avoid too frequent reheating and not too big to be awkward to manipulate.

Soldering bits are specified by the weight of the copper head. For general soldering process, the shape of the head is a square pyramid but for repetition, or awkward placed, other shapes are designated.

Point soldering copper bit: This is also called a square pointed soldering iron, The edge is shaped to an angle on four sides to from a pyramid. This is used for tacking and soldering. (Fig 2)

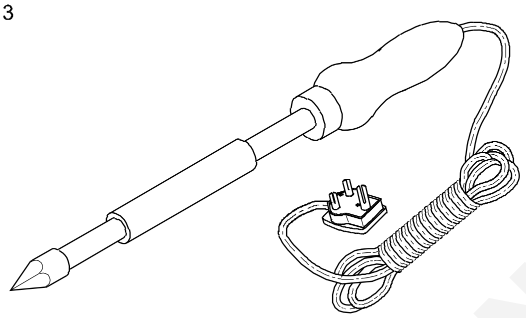
Fig 2



WS20N110932

Electric soldering copper bit: The bit of the electric soldering iron is heated by an element. This type is preferred, if current is available because it maintains uniform heat. Electric soldering irons are available for different voltages and are usually supplied with a number of interchangeable tips. They can be made quite small and are generally used on electrical or radio assembly work (Fig 3)

Fig 3

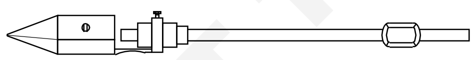


ELECTRIC COPPER SOLDERING

WS20N110933

Gas heated soldering copper bit: A gas heated soldering copper bit is heated by a gas flame which ignites on the back of the head. High pressure gas is used and the bit is large enough to have a good heat storage capacity. Liquified petroleum gas (L.P.G) flame is used extensively for this purpose. Soldering kit normally includes many sizes and shapes of bits which can be used to make most kinds of soldering connections. (Fig 4)

Fig 4



GAS HEATED SOLDERING COPPER BIT

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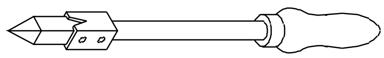
Straight soldering copper bit: This type of soldering iron is suitable for soldering the inside bottom of a round job. (Fig 5)

Fig 5

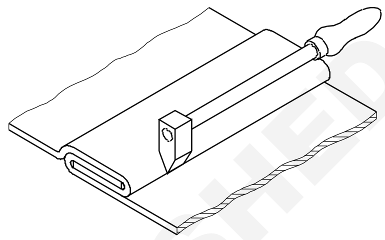


STRAIGHT SOLDERING COPPER WITH HANDLE

WS20N110935

Hatchet soldering copper bit: This type of soldering iron is very much suitable for soldering on flat position hp or grooved joint outside round or square bottom. (Fig 6)

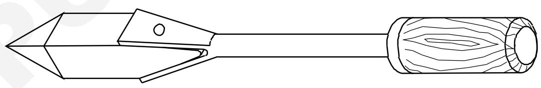
Fig 6



WS20N110936

Adjustable soldering copper bit: This type of soldering iron is used for soldering where straight or Hatchet bit cannot be used for soldering. Adjustable soldering bit can be adjusted in any position for soldering. (Fig 7)

Fig 7

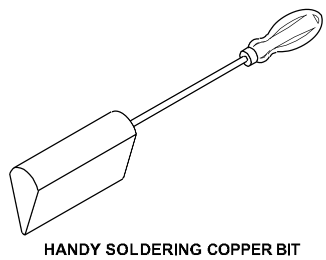


ADJUSTABLE SOLDERING BIT

WS20N110937

Handy soldering copper bit: It is like a hatchet type but bigger in size than the hatchet. It is used for soldering heavy gauges of metal because additional heat will cause the metal to buckle. (Fig 8)

Fig 8



HANDY SOLDERING COPPER BIT

WS20N110938

Solder

Objectives: At the end of this lesson you shall be able to
- **define a solder**
- **state the types of solders**
- **state the constituents of soft and hard solders.**

Solder is a bonding filler metal used in soldering process.

Pure metals or alloys are used as solders. Solders are applied in the form of wires, sticks ingots, rods, threads, tapes, formed sections, powder, pastes etc.

Types of solders

There are two types of solders.

- Soft solder
- Hard solder

Soft solders: Soft solders are alloys of tin and lead in varying proportions. They are called soft solders because of their comparatively low melting point. One distinguishes between soft solder whose melting points are 450°C and hard solders whose melting points lie above 450°C These are alloys of the materials tin, lead, anitimony, copper, cadmium and zinc and are used for soldering heavy (thick) metals. Table shows different compositions of solder and their application.

Warning

For cooking utensils, do not use solder containing lead. This could cause poisoning. Use pure tin only.

Hard solder: These are alloys of copper, tin, silver, zinc, cadmium and phosphorus and are used for soldering heavy metals.

Sl.No.	Types of solder	Tin	Lead	Application
1	Common solder	50	50	General sheet metal applications
2	Fine solder	60	40	Because of quick setting properties and higher strength, they are used for copper water electrical work.
3	Fine Solder	70	30	
4	Coarse solder	40	60	Used on glavanised iron sheets
5	Extra fine solder	66	34	Soldering brass, copper and jewellery
6	Eutectic alloy	63	37	Similar to fine solder

Soldering flux

Objectives: At the end of this lesson you shall be able to
- **state the functions of soldering fluxes**
- **state the criteria for the selection of fluxes**
- **distinguish between corrosive and non-corrosive fluxes**
- **state the different types of fluxes and their applications.**

All metal rust to some extent, when exposed to the atmosphere because of oxidation. The layer of the rust must be removed before soldering. For this, a chemical compound applied to the joint is called flux.

Function of the fluxes:

1 Fluxes remove oxides from the soldering surface. It prevents corrosion.

2 It forms a liquid cover over the work piece and prevents further oxidation.

3 It helps molten solder to flow easily in the required place by lowering the surface tension of the molten solder.

Selection of flux: The following criteria's are important for selecting a flux.

- Working temperature of the solder
- Soldering process
- Material to be joined

Different types of fluxes: Flux can be classified as (1) Inorganic or corrosive (Active) & (2) Organic or noncorrosive (Passive.)

Inorganic fluxes are acidic and chemically active and remove oxides by chemically dissolving them. They are applied by brush directly on to the surface to be soldered and should be washed immediately after the soldering operation is completed.

organic fluxes are chemically inactive. These fluxes coat the surface of the metals to be joined and exclude the air from the surface, to avoid further oxidation. They are applied only to the metal surfaces which have been previously cleaned, by mechanical abrasion. They are in the form of lump, powder, paste or liquid.

Brazing: Brazing is a metal joining process which is done at a temperature of above 450°C as compared to soldering which is done at below 450°C

So brazing is a process in which the following steps are followed.

- Clean the area of the joint thoroughly by wire brushing, emerging and by chemical solutions for removing oil, grease, paints etc.
- Fit the joints tightly using proper clamping. (Maximum gap permitted between the two joining surfaces is only 0.08 mm)
- Apply the flux in paste form (for brazing iron and steel a mixture of 75% borax powder with 25% boric acid (liquid form) to form a paste is used). Usually the brazing flux contains chlorides, fluorides, borax, borates, flurodorates, boric acid, wetting agents and water. So suitable flux combination is selected based on metal being used.

Brazing is employed where a ductile joints is required.

Brazing filler rods/ metals melt at temperature from 860°C to 950°C and are used to braze iron and its alloys.

Brazing fluxes: Fused borax is the general purpose flux for most metals.

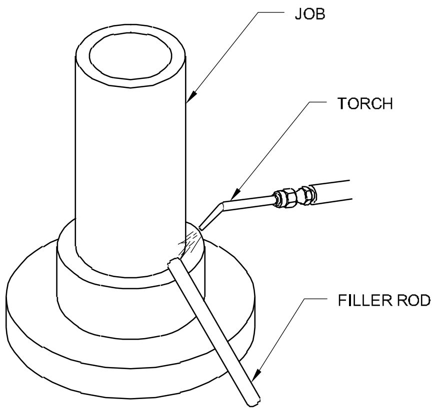
It is applied on the joint in the form of a paste made by mixing up with water.

If brazing is to be done at a lower temperature, fluorides of alkali materials are commonly used. These fluxes will remove refractory oxides of aluminium, chromium, silicon and beryllium.

Various methods of brazing

Torch brazing: The base metal is heated to the required temperature by the application of the oxy-acetylene flame. (Fig 1)

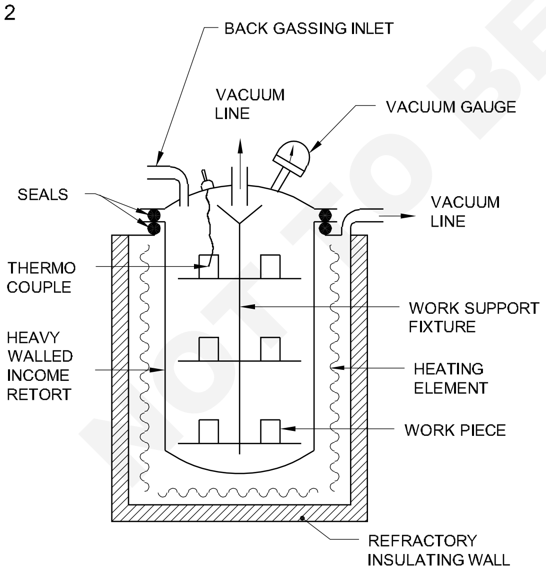
Fig 1



TORCH BRAZING

Furnace brazing: The parts to be brazed are aligned with the brazing material placed in the joint. The assembly is kept in the furnace. The temperature is controlled to provide uniform heating. (Fig 2)

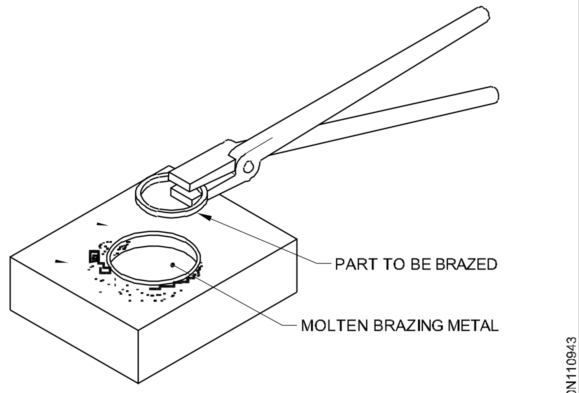
Fig 2



VACUUM FURNACE FOR BRAZING

Dip brazing: The parts to be brazed are submerged in a molten metal or chemical bath (Fig 3) of brazing filler metal.

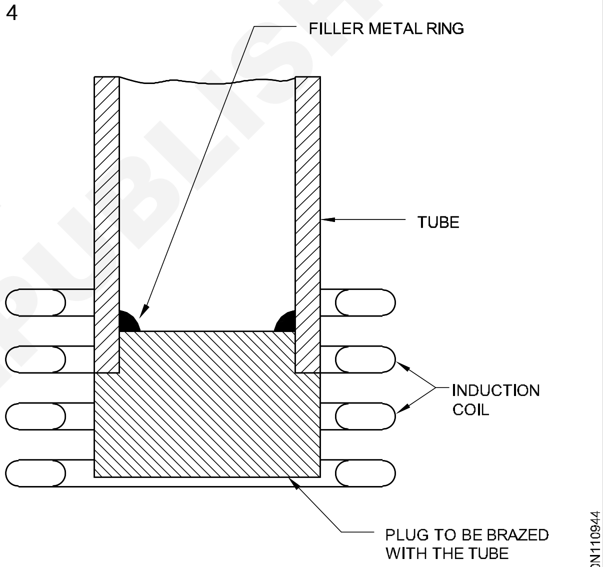
Fig 3



DIP BRAZING PROCESS

Induction brazing: The parts to be brazed are heated to the melting point of the brazing material by means of a high frequency electric current. This is done by encircling the joint with a water cooled induction coil (Fig 4).

Fig 4



INDUCTION BRAZING

Conditions to obtain satisfactory brazed or soldered joint

Wet the base metal.

Spread the filler metal and make contact with the joint surfaces. The solder will be drawn into the joint by capillary action.

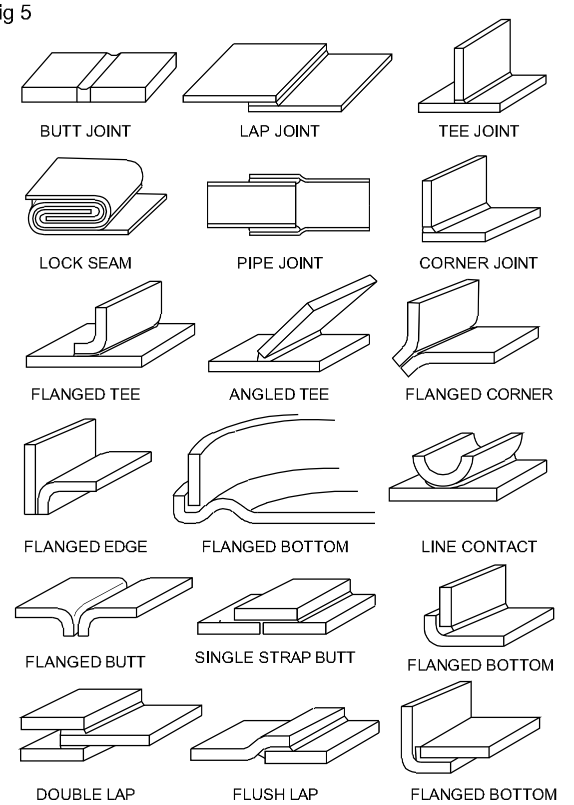
Suggested joint designs for soldering and brazing are shown in Fig 5

Advantages of brazing

The completed joint requires little or no finishing.

The relatively low temperature at which the joint made minimizes distortion.

Fig 5



SUGGESTED JOINT DESIGNS FOR SOLDERED AND BRAZED JOINTS

WS20N110945

There is no flash or weld spatter.

The brazing technique does not require as much skill as the technique for fusion welding.

The process can be easily mechanised.

The process is economical owing to the above advantages.

Disadvantages of brazing

If the joint is exposed to corrosive media, the filler metal used may not have the required corrosive resistance.

All the brazing alloys loose strength at an elevated temperature

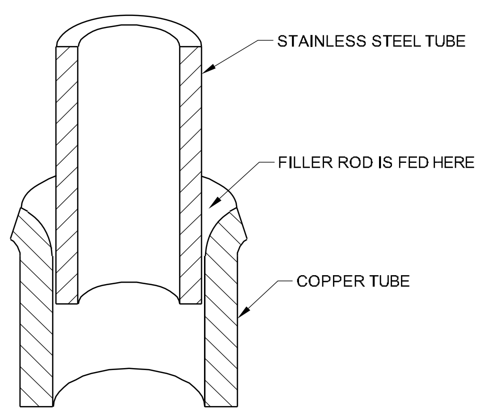
The colour of the brazing alloy which ranges from silver white to copper red may not match the base metal very closely.

Brazing: Problems and remedies

Problem	Remedy
Filler metal 'balls up', does not melt and flow into the joint.	Use more flux. Pickling or additional mechanical cleaning to remove oxides, oils, or other surface coatings must be done, Add fresh flux. Also check for contaminated pickling acid or 'dirty' grinder wheels that could spread impurities instead of removing them.
Filler metal melts but does not flow completely through joint.	Longer preheating period required. the base metal may not be hot enough. More thorough cleaning required. A wider or narrower joint gap should be provided. Joint must not be too tight or too loose. Also check for gaps or spaces where capillarity is interrupted. Apply more flux to both filler and base metal. Use a different flux compound. Improper flux may be breaking down due to too much heat. Eliminate this fault.
Filler metal runs out, instead of running into the joint.	Re-position (tilt) the joint so that gravity helps the filler metal to run into the joint. Making a small reservoir in the joint to start the capillary action will help. Feeding the filler metal into the joint from above rather than horizontally or from below is recommended.
Filler metal melts but will not flow.	Additional cleaning of filler metal to remove oxides is required. More flux on both filler and base metal is required.

Silver brazing: Silver brazing is also sometimes called silver soldering. It is one of the best methods used to connect/join parts which are to be leak proof and has to give maximum strength of the joint. It is a very useful and easy process for joining copper brass, bronze parts as well as for joining dissimilar metal tubes like copper to stainless steel tubes etc. The melting point of silver brazing alloy filler rods will be around 600 to 800°C which is always less than that of the base metals joined. Fig 6 shows silver brazing of stainless steel tube to be with a copper tube.

Fig 6



SILVER BRAZING OF STAINLESS STEEL TUBE WITH COPPER TUBE

The process is similar to other brazing processes. The points to be remembered while silver soldering are:

- The joint must be thoroughly cleaned both mechanically and chemically.
- Fit the joint closely/tightly without any gap and support the joint. (The maximum permissible gap between the parts to be silver brazing is 0.08mm).

Apply proper flux at the joint and on the filler rod.

Heat the joint to the brazing temperature depending on the composition of the silver brazing filler rod. The brazing temperature may vary from 600°C to 800°. Use an oxy-acetylene blow pipe for heating.

Apply the silver brazing filler rod coated with the pasty flux at the joint using leftward technique. Heat the filler rod to the "flow temperature" which is usually 10 to 15° more than its melting temperature. i.e, for the filler metal to flow easily into the joint and for getting the wetting and capillary action, it is necessary to heat the molten filler metal to 10 or 15° more than its melting temperature.

Allow the joint to cool without removing the support given to the joint.

Clean the joint throughly to remove all residual flux.

Fluxes used for silver brazing may be chlorides or borax made into a paste with water.

Brazing and braze welding; Both brazing and braze welding are metal joining processes which are performed at temperatures above 840°F (450°C) as compared to soldering which is performed temperatures below 840°F (450°C)

The American Welding society defines these processes as follows:

Brazing-" A group of welding processes which produces coalescence of materials by heating them o a suitable temperature and by using a filler metal having a liquids above 840°F (450°C) and below the solidus of the base metal . The filler metal is distributed between the closely fitted surfaces of the joint by capillary action" coalescence is a joining or uniting of materials.

Braze welding-" A welding process variation in which a filler metal, having a liquids above 840°F (450°C) and below the solidus of the base metal, is used. Unlike brazing, in braze welding the filler is not distributed in the joint by capillary action"

Brazing has been used for centuries. Blacksmiths, jewelers, armourers and other crafters used the process on large and small articles before recorded history. This joining method has grown steadily both in volume and popularity. It is an important industrial process, as well as jewelery making and repair process. The art of brazing has become more of a science as the knowledge of chemistry, physics and metallurgy has increased.

The usual terms Brazing and Braze welding imply the use of a nonferrous alloy. These nonferrous alloys consist of alloys of copper. tin, zinc, aluminum, beryllium, magnesium, silver, gold and others.

Brass is an alloy consisting chief of copper and zinc. Bronze is an alloy consisting chiefly of copper and tin. Most rods used in both brazing and braze welding on ferrous metals are brass alloys rather than bronze. The brands which are called bronze usually contain a small percent (about one percent) of tin.

Brazing and braze welding principles: Brazing is an adhesion process in which the metals being joined are heated but not melted: the brazing filler metal melts and flows at temperatures above 840°F (450°C). Adhesion is the molecular attraction exerted between surfaces.

A brazed joint is stronger than a soldered joint because of the strength of the alloys used. In some instances it is as strong as a welded joint. It is used where mechanical strength and leap roof joints are desired. Brazing and braze welding are superior to welding in some applications, since they do not affect the heat treatment of the original metals as much as welding.

Brazing and braze welding wrap the original metals less and it is possible to joint dissimilar metals. For example, steel tubing may be brazed to cast iron, copper tubing brazed to steel and tool steel brazed to low carbon steel.

Brazing is done on metals which fit together tightly. The metal is drawn into the joint by capillary action. (A liquid will be drawn between two tightly fitted surfaces. This drawing action is known as capillary action). Very thin layers of filler metal are used when brazing. The joints and the material being brazed must be specially designed for the purpose. When brazing, poor fit and alignment result in poor joints and in inefficient use of brazing filler metal.

In braze welding, joint designs used for oxyfuel gas or arc welding are satisfactory. When braze welding, thick layers of the brazing filler metal is used.

Type of welding joints and its applications edge preparation & fluid for different thickness

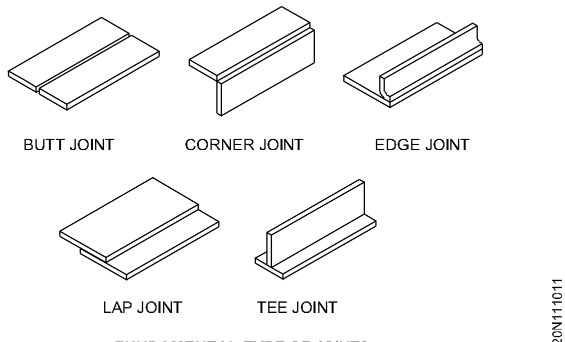
Objectives: At the end of this lesson you shall be able to
- **illustrate and name the basic welding joints.**
- **explain the nomenclature of butt and fillet welds.**

Basic welding joints (Fig. 1)

The various basic welding joints are shown in Fig. 1.

The above types mean the shape of the joint, that is, how the joining edges of the parts are placed together.

Fig 1

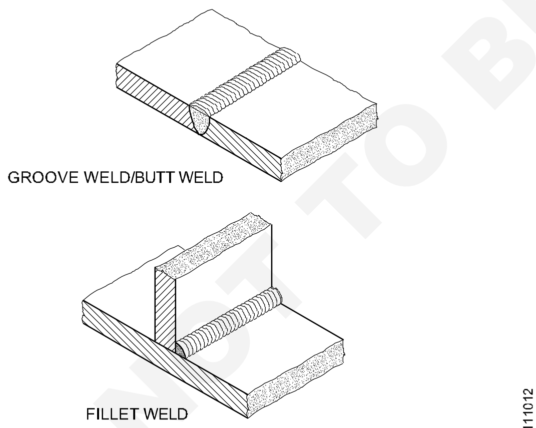


FUNDAMENTAL TYPE OF JOINTS

Types of weld: There are two types of weld. (Fig .2)

- Groove weld/butt weld
- Fillet weld
- Application of welding joints to the included

Fig 2



TYPE OF WELD

Nomenclature of butt nd fillet weld (Figs 3 and 4)

Root gap: It is the distance between the parts to be joined. (Fig 3)

Heat affected zone: Metallurgical properties have been changed by the welding heat adjacent to weld.

Leg length: The distance between the junction of the metals and the point where the weld metal touches the base metal 'toe' (Fig 5)

Fig 3

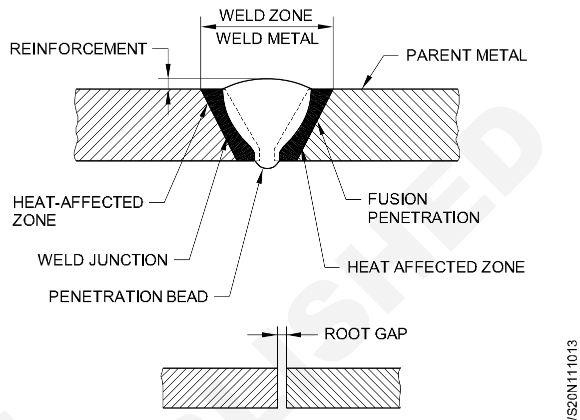


Fig 4

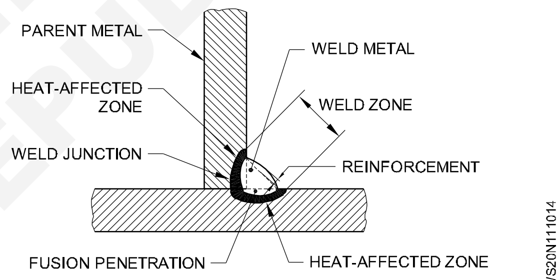
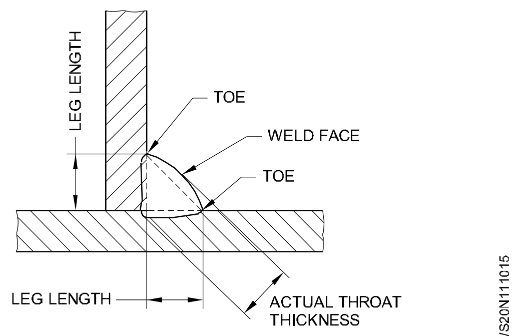


Fig 5

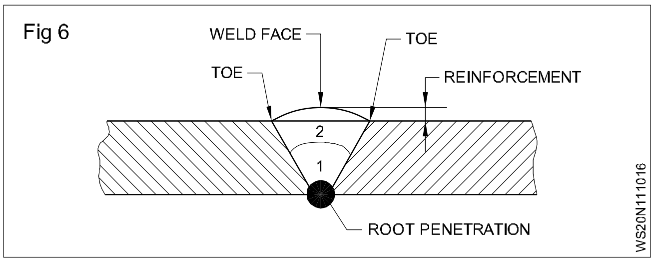


Parent metal: The material or the part to be welded.

Fusion penetration: The depth of fusion Zone in the parent metal. (Fig 3 and 4)

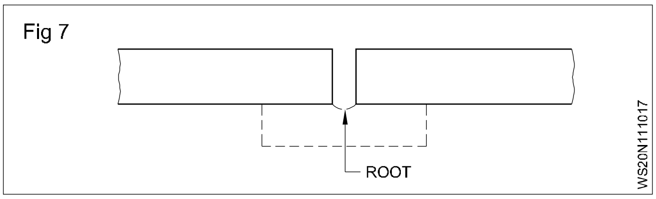
Reinforcement: Metal deposited on the surface of the parent metal of the excess metal over the line joining the two toes. (Fig 6)

Fig 6



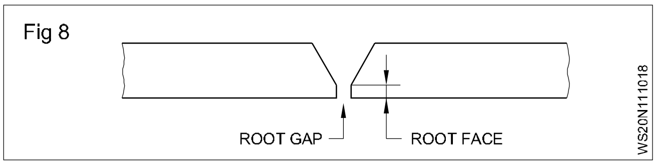
Root: The parts to be joined that are nearest together. (Fig 7)

Fig 7



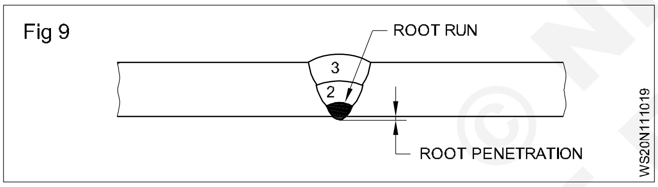
Root face: The surface formed by squaring off the root edge of the fusion face to avoid a sharp edge at the root. (Fig 8)

Fig 8



Root run: The first run deposited in the root of a joint (Fig 9)

Fig 9



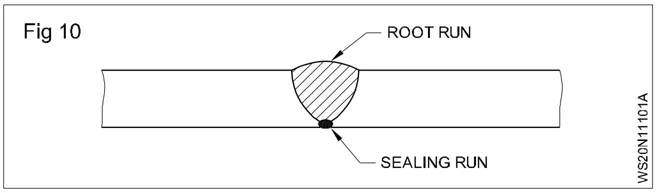
Root penetration: It is the projection of the root run at the bottom of the joint (Fig. 6 and 9)

Run: The metal deposited during one pass. Fig. 9.

The second run is marked as 2 which is deposited over the root run. The third run is marked as 3 which is deposited over the second run.

Sealing run: A small weld deposited on the root side of a butt or corner joint (after completion of the weld joint). (Fig 10)

Fig 10



Backing run: A small weld deposited on the root side of butt or corner joint (before welding the joint.) Fig. 6

Throat thickness: The distance between the junction of metals and the midpoint on the line joining the two toes. (Fig 5.)

Toe of weld: The point where the weld face joins the parent metal. (Fig 5&6.)

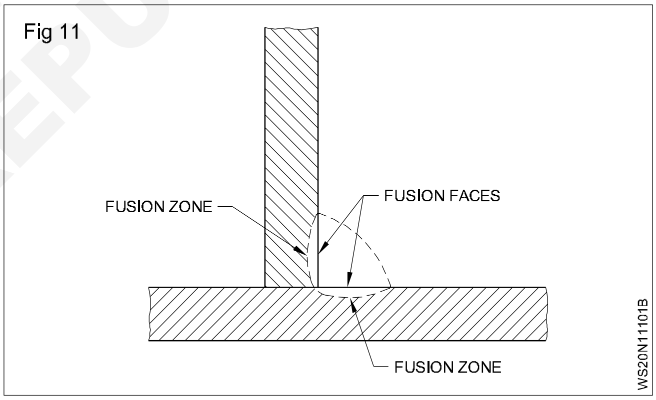
Weld face: The surface of a weld seen from the side from which the weld was made. (Fig 5&6.)

Weld Junction: The boundary between the fusion zone and the heat affected zone. (Fig 3&4)

Fusion face: The portion of a surface which is to be fused on making the weld. (Fig 11)

Fusion zone: The depth to which the parent metal has been fused. (Fig 11)

Fig 11



Material preparation method

Objectives: At the end of this lesson you shall be able to
- **state the necessity of preparing the materials to be welded**
- **state different methods used to cut mild steel sheets and plates to the required size before welding**
- **identify different tools and equipments used to prepare the mild steel sheets and plates.**

Necessity of materials preparation for welding: While fabricating (producing or making) different components/parts by welding, different sizes of plates, sheets pipes, angles, channels with different dimensions are joined together to get the final objects. For example, a railway compartment, an aeroplane, an oil or water pipe line, a gate, a window grill, a stainless steel milk tank, etc. So these objects can be made to the required dimensions only by cutting them from the larger size sheets, plates, pipes etc, which are available in standard sizes, thickness, diameters and lengths in the market. Hence cutting and preparing the base metal to the required dimensions from the original material available in many stores is necessary before welding them.

Also the base metals before cutting them to size will have impurities like dirt, oil, paint, water and surface oxides, due to long storage.

These impurities will affect the welding and will create some defects in the welded joint. These defects will make the joint weak and it is possible that the welded joint will break, if the weld defects are present in the welded joints.

So in order to get a strong welded joint, it is necessary to clean the surfaces to be joined and remove the dirt, oil paint, water, surface oxide etc. from the joining surfaces before welding.

Different methods used to cut metals

1 By chiseling the sheets

2 By hack sawing

3 By shearing using hand lever shear

4 By using guillotine shear

5 By gas cutting

For thin sheets the first 4 methods are used. For thick materials method 2,4 and 5 are used.

Tools and equipments used to cut metals

1 Cold chisel

2 Hacksaw with frame

3 Hand lever shear

4 Guillotine shear

5 Oxy-acetylene cutting torch

The cut edges of the sheet or plate are to be filed to remove burrs and to make the edges to be square (at 90° angle) with each other. For ferrous metal plates, which are more than 3mm thick, the edges can be prepared by grinding them on a bench/pedestal grinding machine.

Edge preparation

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of edge preparation**
- **describe the edge preparation for butt and fillet welds.**

Necessity of edge preparation: Joints are prepared to weld metals at less cost. The preparation of edges are also necessary prior to welding in order to obtain the required strength to the joint. The following factors are to be taken into consideration for the edge preparation.

- The welding process like SMAW, oxy-acetylene welds, $Co_{2,}$ electro-slag etc.
- The type of metal to be joined, (i.e) mild steel, stainless steel, aluminum, cast iron etc.
- The thickness of metal to be joined.
- The type of weld (groove and fillet weld)
- Economic factors

The square butt weld is the most economical to use, since this weld requires no chamfering, provided satisfactory strength is attained. The joints have to be beveled when the parts to be welded are thick so that the root of the joints have to be made accessible for welding in order to obtain the required strength.

In the interest of economy, bevel butt welds should be selected with minimum root opening and groove angles such that the amount of weld metal to be deposited is the smallest. “J” and “U” butt joints may be used to further minimise weld metal when the savings are sufficient to justify the more difficult and costly chamfering operations. The “J” joint is usually used in fillet welds.

A root gap is recommended since the spacing allows the shrinking weld to draw the plates freely together in the butt joint. Thus, it is possible to reduce weld cracking and minimise distortion and increase penetration, by providing a root gap for some welded joints.

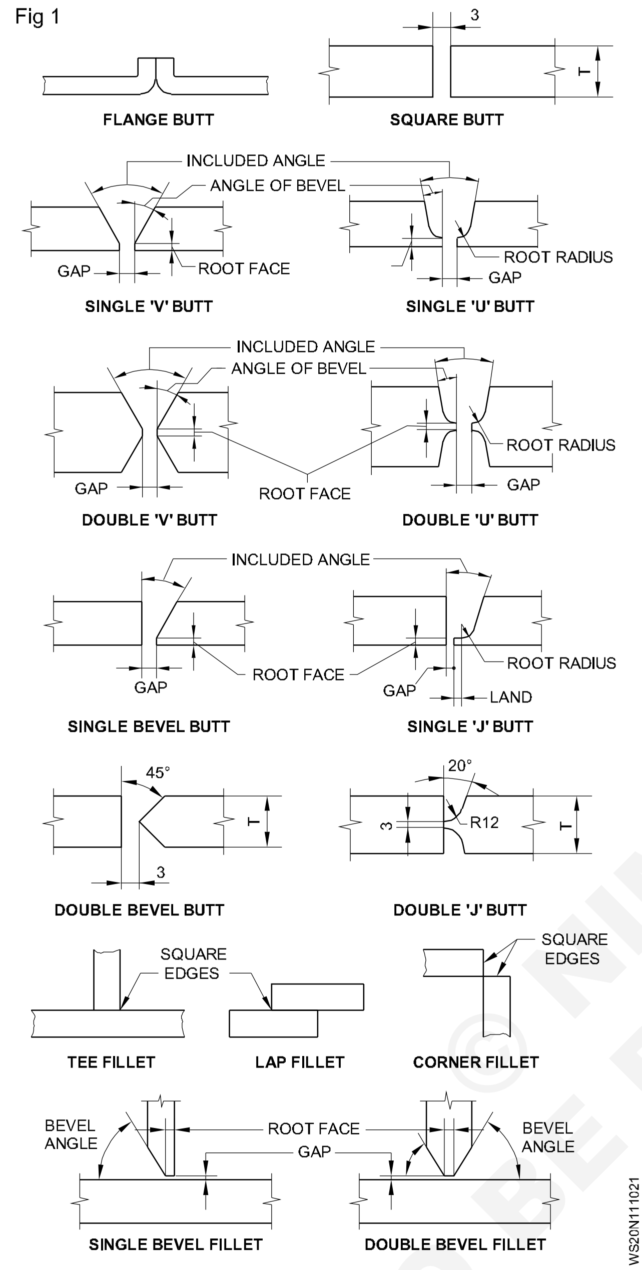
Method of edge preparation: The joining edges may be prepared for welding by any one of the methods mentioned below.

- Flame cutting
- Machine tool cutting
- Machine grinding or hand grinding
- Filing, chipping

Types of edge preparation and setup

Different preparation generally used in arc welding are shown in Fig 1 below.

Fig 1


3
T
FLANGE BUTT
SQUARE BUTT
INCLUDED ANGLE
ANGLE OF BEVEL
GAP
ROOT FACE
ROOT RADIUS
GAP
SINGLE 'V' BUTT
SINGLE 'U' BUTT
INCLUDED ANGLE
ANGLE OF BEVEL
ROOT RADIUS
GAP
ROOT FACE
GAP
DOUBLE 'V' BUTT
DOUBLE 'U' BUTT
INCLUDED ANGLE
ROOT FACE
ROOT RADIUS
GAP
GAP
LAND
SINGLE BEVEL BUTT
SINGLE 'J' BUTT
45°
T
3
20°
3
R12
T
DOUBLE BEVEL BUTT
DOUBLE 'J' BUTT
SQUARE EDGES
SQUARE EDGES
TEE FILLET
LAP FILLET
CORNER FILLET
BEVEL ANGLE
ROOT FACE
GAP
BEVEL ANGLE
SINGLE BEVEL FILLET
DOUBLE BEVEL FILLET
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Surface Cleaning

Objectives: At the end of this lesson you shall be able to
- **importance of cleaning**
- **describe the cleaning method**

Every joint must be cleaned before welding to obtain a sound weld.

Importance of cleaning: The basic requirement of any welding process is to clean the joining edges before welding. The joining edges of surface may have oil, paint, grease, rust, moisture, scale or any other foreign matter. If these contaminants are not removed the weld will become porous, brittle and weak. The success of welding depends largely on the conditions of the surface to be joined before welding. The oil, grease, paints and moisture of the sheets to be welded will give out gases while heated by arc or flame and these gases will get into the molten metal. They will come out of the metal when the molten metal cools to form the bead and create small pin holes on the surface of the bead. This is known as porosity and it weakens the joint.

Methods of cleaning: Chemical cleaning includes washing the joining surface with solvents of diluted hydrochloric acid to remove oil, grease, paint etc (Fig. 1)

Mechanical cleaning includes wire brushing, grinding, filing, sand blasting, scraping, machining or rubbing with emery paper. (Fig 2)

For cleaning ferrous metals a carbon steel wire brush is used. For cleaning stainless and non-ferrous metals, a stainless steel wire brush is used.

Fig 1

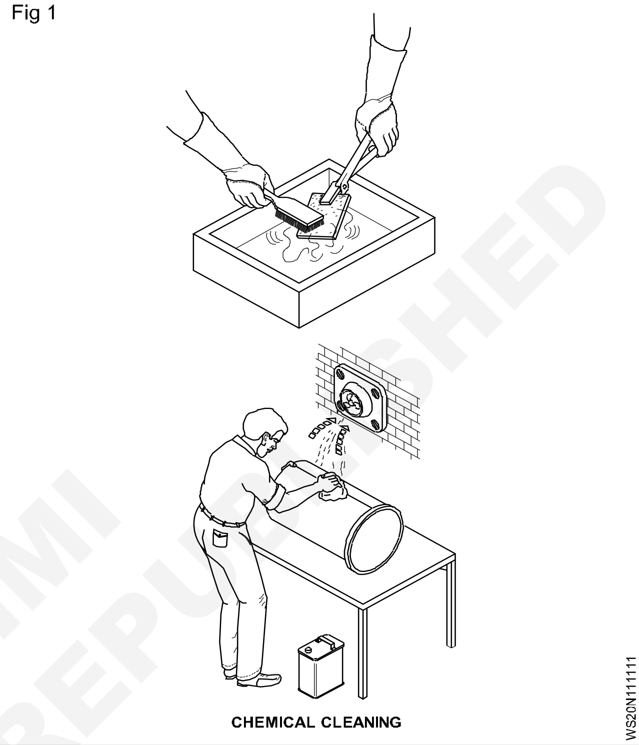
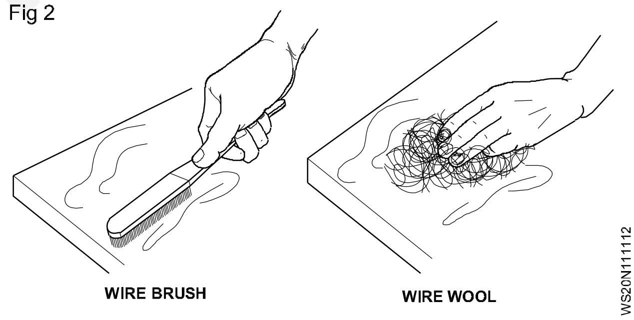


Fig 2



Basic electricity applicable to arc welding and related electrical terms & definitions

Objectives : At the end of this lesson you shall be able to
- **define simple electrical terms**
- **differentiate between electric current, pressure and resistance**
- **state AC and DC**
- **explain open circuit and arc voltage**
- **state OHM's law and its application**

Electricity is a kind of invisible energy which is capable of doing work such as:

- burning of lamps
- running of fans, motors, machines etc.
- producing heat.
- by creating an arc
- by electrical resistance of materials

It is dangerous to play with electricity.

Electric current: Electrons in motion is called current. The rate of flow of electrons is measured in amperes (A). The measuring instrument is called ampere meter, or ammeter.

Electric pressure/voltage: It is the pressure which makes the electric current to flow.

It is called voltage or electromotive force (emf). Its measuring unit is volt(V). The measuring instrument is called voltmeter.

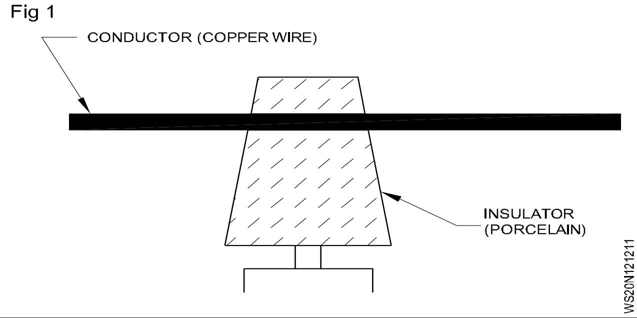
Electric resistance; It is the property of a substance to oppose the flow of electric current passing through it.

Its measuring unit is ohm and the measuring instrument is ohmmeter or megger.

- Resistance of a metal changes as given below:
- If the length is more the resistance will also be more.
- if the diameter is more the resistance will be less.
- the resistance will increase or decrease depending on the nature of the material.

Conductors: Those substances through which electricity passes are called conductors. (Fig 1)

Fig 1



Copper, aluminium, steel, carbon, etc, are examples of conductors. The resistance of these materials is low.

Insulators: Those substances through which electricity does not pass are called insulators. (Fig 1)

Glass, mica, rubber. Bakelite, plastic dry wood, dry cotton, porcelain and varnish are examples of insulators. The resistance of these materials is high.

Electric circuits: It is the path taken by the electric current during its flow. Every electrical circuit comprises current, resistance and voltage.

The fundamental types of circuit are:

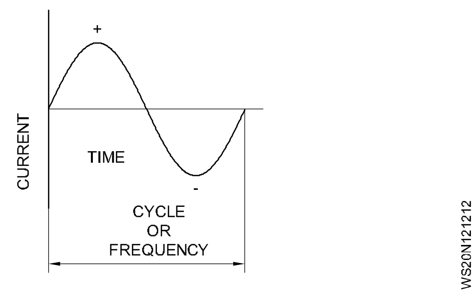
- series circuit
- parallel circuit.

Series circuit: The resistances of a circuit are connected in a series end-to-end making only one path in which the current flows.

Parallel circuit: The resistances are connected side by side to each other with the ends connected to power source.

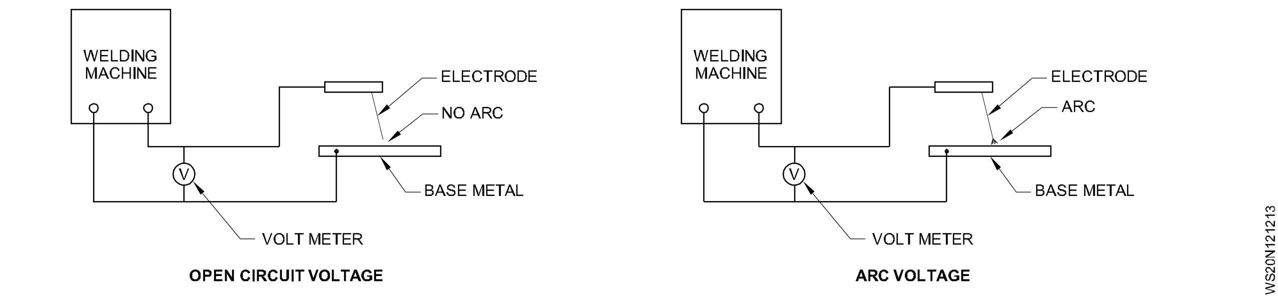
Alternating current (AC): Electric current which changes its direction of flow and magnitude at a certain number of times per second is called alternating current. E.g. 50 cycles means it changes its direction 50 times per second. Its rate of change is called frequency i.e. hertz (Hz). (Fig.2)

Fig 2



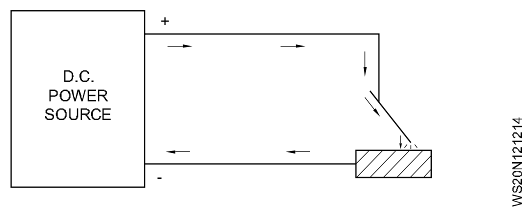
Direct current (DC) (Fig. 4): Electric current which always flows in a particular direction is known as direct current. (i.e) Negative to positive (electronic direction). Positive to negative (conventional direction).

Fig 3



Ohm's law: It is one of the most widely applied laws of electrical science.

Fig 4



It is the relationship of current, voltage and resistance, which was studied in 1827 by George. S.Ohm, a mathematician.

The law states:

In an electrical circuit, at constant temperature, the current varies directly as the voltage, and inversely as the resistance. i.e. current increases when voltage increases.

V=IR

Where V = Voltage

I = Current

R = Resistance

Current decreases when resistance increases.

Application of Ohm's law: The importance of this law lies in its practical use for finding any one value when the other two values are known.

The three forms in which ohm's law may be written are shown below.

$$I = \frac{V}{R} \text{ Where } I = \text{current in amps}$$

$$V = I \times R \text{ Where } V = \text{Voltage in volts}$$

$$R = \frac{V}{R} \text{ Where } R = \text{Resistance ohms}$$

Open circuit voltage and arc voltage: Fig 3 shows an electric circuit used in arc welding. After switching on the welding machine, when there is no arc created/struck between the electrode tip and the base metal then the voltage "V" shown by the voltmeter in the circuit is called "Open circuit voltage".

The value of this open circuit voltage will very from 60V to 110V depending on the type of machine.

After switching on the welding machine, if the arc is struck/created between the tip of the electrode and the base metal then the voltage "V' shown by the voltmeter in the circuit is called "Arc voltage".

The value of this arc voltage will vary from 18V to 55V depending on the type of machine.

Heat and temperature and its terms related to welding

Objectives : At the end of this lesson you shall be able to
- **state the units of heat and temperature measurement.**

Heat and temperature: Heat is a form of energy, capable of flowing between two bodies which are at different temperatures. The addition of heat energy to a body increases the kinetic energy of motion of its molecules. Temperature is the degree of hotness or coldness of a body measured, usually in centigrade of Fahrenheit. Temperature is a measure of the intensity of heat.

Example: If we ask, 'how hot is a substance', the answer will be, 'it is so many degrees hot'. i.e. 40°C, 50°C, 150°F etc.

Temperature measurement: there are two basic scales for measuring temperature.

- Centigrade scale
- Fahrenheit scale

In both systems there are two fixed points which indicate:

- the temperature at which ice melts (Water freezes)
- the temperature at which pure water boils at standard pressure.

Temperature is measured by a unit called 'degree'.

Centigrade scale: This is a system for measuring changes in temperature in which the interval of temperature between the freezing and boiling points of pure water at standard pressure is divided into 100 equal parts. There freezing point is made zero of the scale (°0 C) and the boiling point is fixed at 100 degrees (100° C), each division part is called one centigrade degree (°C). Degree centigrade is also called as degree celsius.

Fahrenheit scale: A system for measuring changes in temperature in which the interval of temperature between the freezing and boiling points of pure water at standard pressure is divided into 180 equal parts. The freezing point is made 32 degree of the scale (32°F). The boiling point is fixed at 212 degree (212°F).

Each division part is called one Fahrenheit a degree (°F).

Conversion of temperature from °C to °F

The formula used for temperature conversion is

$$C = (F - 32) \times \frac{5}{9} \text{ and } F = \left[c \times \frac{9}{5} \right] \pm 32$$

To check this, a reading of 100°C may be changed to the Fahrenheit scale by substituting the value of (C) as given below.

$$F = (100\,c \times \frac{9}{5}) \pm 32 = 212^\circ$$

A reading of 122°F can be converted to centigrade scale by substituting the value of 122°F given below.

$$c = (122 - 32) \times \frac{5}{9}$$

Application of heat, temperature and their units (terms) in welding

Heat and temperature should not be confused with each other.

The temperature of oxy-acetylene flame is app. 3200°C.

Flames produced by small and large nozzles have the same temperatures but the large nozzle flame gives off more heat than the small nozzle flame. More volume of mixed gases comes out through larger size nozzles and so more heat is produced. Refer the chart given below.

Example

A thin piece of steel sheet 1.5 mm thick can be melted quickly with a small oxy-acetylene flame.

A thicker piece of steel plate (6 mm) will take a longer time to melt with the same oxy-acetylene flame.

Both pieces of steel have the same melting points of 1530°C.

To speed up the melting of the thicker plate, use bigger nozzles which will give a larger flame and more heat in less time.

Refer to the chart given below which gives different nozzle sizes and the corresponding volume of gasses flowing out of them per hour

When the nozzle size increases, the quantity of gas flow per hour (rate of gas flow) increases. So more heat is given out by larger nozzles and less heat by smaller size nozzles.

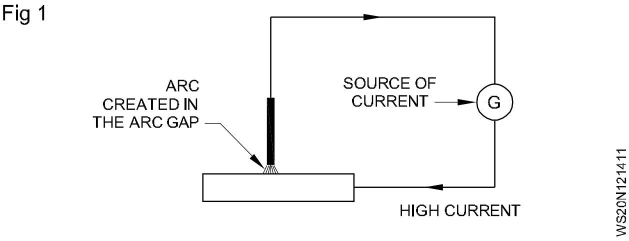
Plate thickness (in mm)	Nozzle size	Approximate consumption of each gas litres per hour
0.8	1	28
1.2	2	56
1.6	3	85
2.0 to 2.5	5	142
3.0 to 3.5	7	200
4.0	10	280
5.0	13	370
6.0 to 6.5	18	510
8.0	25	710
10.0	35	990
12.0	45	1280

Principle of arc welding and characteristics of arc

Objectives : At the end of this lesson you shall be able to
- **state principle of arc welding and characteristics of arc.**

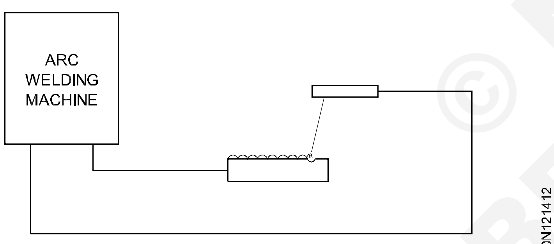
When high current passes through an air gap from one conductor to another, it produces very intense and concentrated heat in the form of a spark. The temperature of this spark (or arc) is app. 3600°C, which can melt and fuse the metal very quickly to produce a homogeneous weld. (Fig 1)

Fig 1



Shielded metal arc welding (Fig 2**):** This is an arc welding process in which the welding heat is obtained from an arc, formed between a metallic (consumable) electrode and welding job.

Fig 2



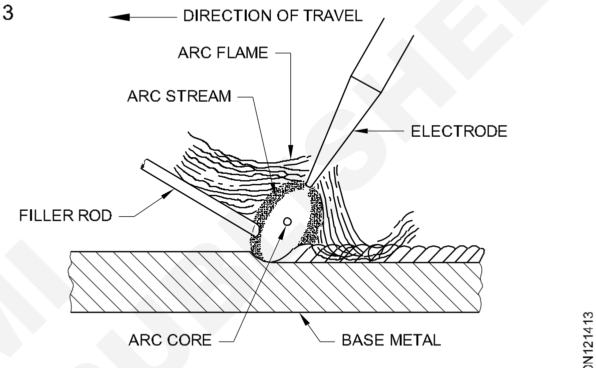
ARC WELDING

The metal electrode itself melts and acts as a filler metal.

Carbon arc welding (Fig 3): Here the arc is formed between a carbon electrode (non-consumable) and the welding job.

A separate filler rod is usd since the carbon electrode is a non-metal and will not melt.

Fig 3



CARBON ARC WELDING

Metal transfer across the arc characteristics of arc

Objectives: At the end of this lesson you shall be able to
- **explain the factors involved in the transfer of metal across the arc due to arc characteristics.**

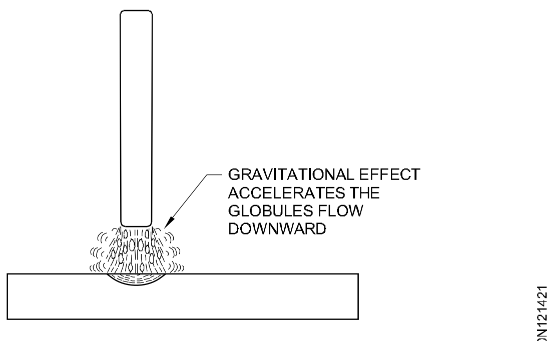
The electric arc has different arc characteristics which help in the transfer of metal across the arc. They are:

- gravity force
- gas expansion force
- surface tension
- electromagnetic force.

Gravity force (Fig 1): Molten globules formed at the arcing end of the electrode travel downwards towards the job in the molten pool.

Gravitational force helps the transfer of metal flat or down hand position and thus the deposition rate of weld metal is increased.

Fig 1

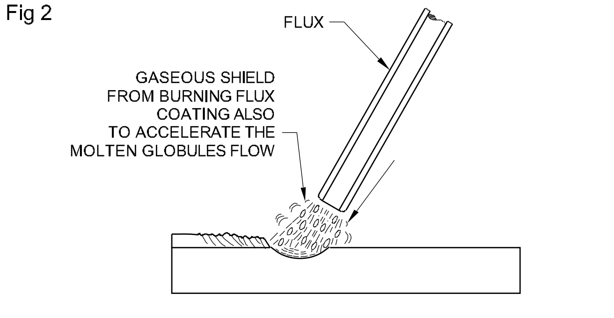


GRAVITY FORCE

Gas expansion force (Fig 2): Flux coating on the electrode melts due to the arc heat, resulting in the:

- Production of carbon monoxide and hydrogen mainly
- Formation of a sleeve of the flux at the arcing end due to a little higher melting point of the flux coating than the core wire.

Fig 2



GAS EXPANSION EFFECT

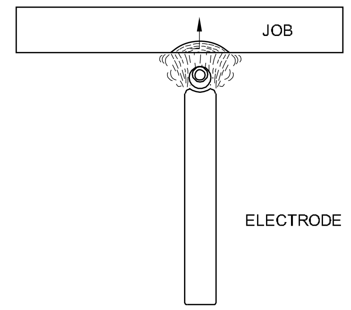
These gases expand and gain velocity. The flux sleeve direct these gases to flow in the direction of the molten metal. The gases flowing from the tip of the electrode have a pushing effect. Thus the metal globules are carried deep into the weld pool and influence penetration.

This effect of expanded gases is more useful in positional welding in metal transfer and influences penetration

Surface tension (Fig 3): It is the characteristic (Force) of the base metal to attract and retain the molten metal in it. This effect is more useful in the case of positional welding.

The short arc promotes more surface tension effect.

Fig 3

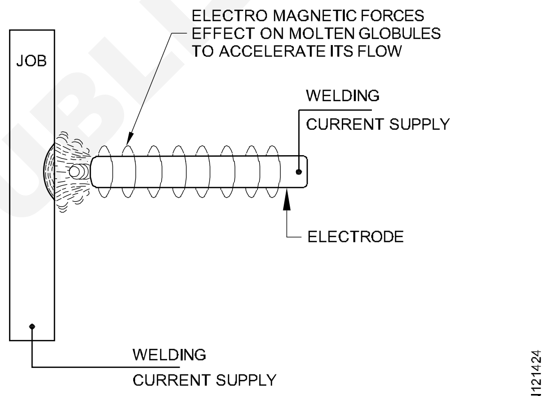


SURFACE TENSION EFFECT

Electromagnetic force (Fig 4): The current passing through the electrode forms magnetic lines of force in the form of concentric circles. This force exerts a pinch effect on the molten metal globule formed at the arcing end of the electrode. The globule is detached from the electrode and reaches the molten pool under the influence of the magnetic force.

This effect is more useful in positional welding.

Fig 4



ELECTRO MAGNETIC EFFECT

Common gases used for welding and cutting flame temperature and uses

Objectives: At the end of this lesson you shall be able to
- **name the different types of gases used for welding**
- **state the temperatures and uses of the different gas flame combinations.**

In the gas welding process, the welding heat is obtained from the combustion of fuel gases in the presence of a supporter of combustion (oxygen).

(Oxy-acetylene gas flame combination is used in most gas welding processes because of the high temperature and heat intensity.)

Comparison of different gas flame combinations and their uses

Sl. No	Fuel gas	Supporter of combustion	Name of the gas flame	Temperature	Application/uses
1	Acetylene	Oxygen	Oxy-acetylene flame	3100 to 3300°C (Highest temperature)	To weld all ferrous and non-ferrous metals and their alloys; gas cutting & gouging of steel;brazing bronze welding; metal spraying and hard facing.
2	Hydrogen	Oxygen	Oxy-hydrogen flame	2400 to 2700°C (Medium temperature)	Only used for brazing, silver soldering and underwater gas cutting of steel.
3	Coal gas	Oxygen	Oxy-coal gas flame	1800 to 2200°C (Low temperature)	Used for silver soldering underwater gas cutting of steel.
4	Liquid petroleum gas (LPG)	Oxygen	Oxy-liquid petroleum gas flame	2700 to 2800°C (Medium tempeature)	Used for gas cutting steel heating purposes. (Has moisture and carbon effect in the flame.)
5	Acetylene	Air	Air-acetylene flame	1825 to 1875°C (Low temperature)	Used only for soldering, brazing, heating purposes and lead burning.

Types of oxy - acetylene flames and uses

Objectives: At the end of this lesson you shall be able to
- **name the different types of oxy-acetylene flames**
- **state the characteristics of each type of flame**
- **explain the uses of each type of flame.**

The oxy-acetylene gas flame is used for gas welding because

- it has a well controlled flame with high temperature
- the flame can be easily manipulated for proper melting of the base metal
- it does not change the chemical composition of the base metal /weld.

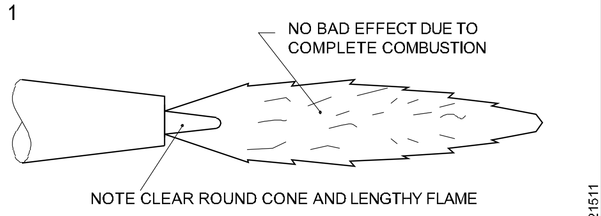
Three different types of oxy-acetylene flames as given below can be set.

- Neutral flame
- Oxidising flame
- Carburising flame.

Characteristics and uses

Neutral flame (Fig 1): Oxygen and acetylene are mixed in equal proportion in the blowpipe.

Fig 1



NEUTRAL FLAME
(EQUAL QUANTITIES OF OXYGEN AND ACETYLENE)

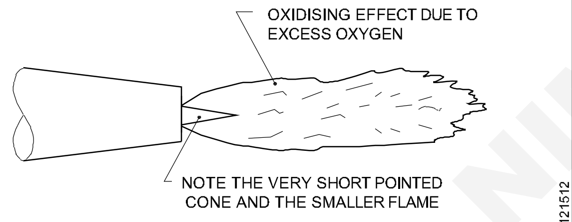
Complete combustion takes place in this flame.

This flame does not have a bad effect on the base metal/ weld i.e. the metal is not oxidised and no carbon is available for reacting with the metal.

Uses: It is used to weld most of the common metals, i.e. mild steel, cast iron, stainless steel, copper and aluminium.

Oxidising flame (Fig 2): It contains excess of oxygen over acetylene as the gases come out of the nozzle.

Fig 2



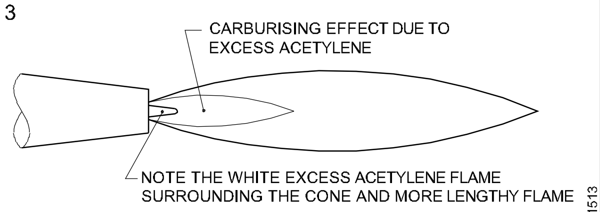
OXIDISING FLAME
(EXCESS OXYGEN)

The flame has an oxidising effect on metals which prevents evaporation of zinc/tin in brass welding/brazing.

Uses: Useful for welding of brass and for brazing of ferrous metals.

Carburising flame (Fig 3): It receives an excess of acetylene over oxygen from the blowpipe.

Fig 3



CARBURISING FLAME
(EXCESS ACETYLENE)

Uses : Useful for stelliting (hard facing), 'Linde' welding of steel pipes, and flame cleaning.

The selection of the flame is based on the metal to be welded

The neutral flame is the most commonly used flame. (See the chart given below.)

	Metal	**Flame**
1	Mild steel	Neutral
2	Copper (de-oxidised)	Neutral
3	Brass	Oxidising
4	Cast iron	Neutral
5	Stainless steel	Neutral
6	Aluminium (Pure)	Neutral
7	Stellite	Carburising

Oxy-Acetylene cutting equipment principle, parameters and application.

Objectives : At the end of this lesson you shall be able to
- **explain the principle of gas cutting**
- **equipment and its parameter and application.**

Introduction to gas cutting: The most common method of cutting mild steel is by an oxy-acetylene cutting process. With an oxy-acetylene cutting torch, the cutting (Oxidation) can be confined to a narrow strip and with little effect of heat on the adjoining metal. The cut appears like a saw-cut on a wooden plank. The method can be successfully used to cut ferrous metals i.e. mild steel.

Non-ferrous metals and their alloys cannot be cut by this process.

Principle of gas cutting: When a ferrous metal is heated to red hot condition and then exposed to pure oxygen, a chemical reaction takes place between the heated metal and oxygen. Due to this oxidation reaction, a large amount of heat is produced and cutting action takes place.

Oxy-acetylene cutting equipment

Objectives: At the end of this lesson you shall be able to
- **explain the features of the oxy-acetylene cutting equipment, its parts and cutting torch**
- **describe the oxy-acetylene cutting procedure**
- **differentiate between cutting and welding blowpipes**.

Cutting equipment: The oxy-acetylene cutting equipment is similar to the welding equipment, except that instead of using a welding blowpipe, a cutting blowpipe is used. The cutting equipment consists of the following.

- Acetylene gas cylinder
- Oxygen gas cylinder
- Acetylene gas regulator
- Oxygen gas regulator (Heavy cutting requires higher pressure oxygen regulator.)
- Rubber hose-pipes for acetylene and oxygen
- Cutting blowpipe

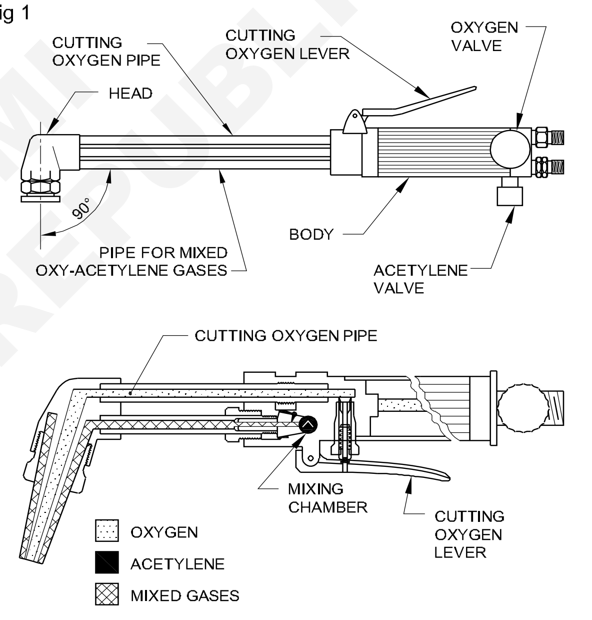
(Cutting accessories i.e. cylinder key, spark lighter, cylinder trolley and other safety appliances are the same as are used for gas welding.)

The cutting torch (Fig 1): The cutting torch differs from the regular welding blowpipe in most cases: it has an additional lever for the control of the cutting oxygen used to cut the metal. The torch has the oxygen and acetylene control valves to control the oxygen and acetylene gases while preheating the metal.

The cutting tip is made with an orifice in the centre surrounded by five smaller holes. The centre opening permits the flow of the cutting oxygen and the smaller holes are for the preheating flame. Usually different tip sizes are provided for cutting metals of different thicknesses.

Oxy-acetylene cutting procedure: Fix a suitable size cutting nozzle in the cutting blowpipe. lignite the cutting torch the same way as was done in the case of the welding blowpipe. Set the neutral flame for preheating. To start the cut, hold the cutting nozzle at angle 90° with the plate surface, and the inner cone of the heating flame 3 mm above the metal. Preheat the metal to bright red before pressing the cutting oxygen lever. If the cut is proceeding correctly, a shower of sparks will be seen to fall from the punched line. If the edge of the cut appears to be too ragged, the torch is being moved too slowly. For a bevel cut, hold the cutting torch at the desired angle and proceed as is done in making a straight line cut. At the end of the cut, release the cutting oxygen lever and close the control valves of the oxygen and acetylene. Clean the cut and inspect.

Fig 1



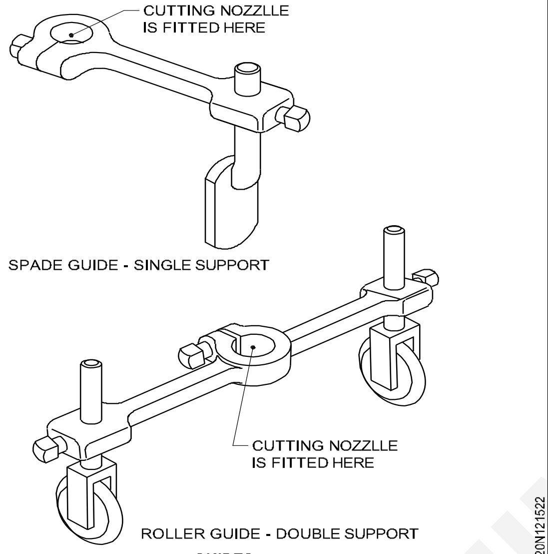
Parameters

Cutting nozzle size-mm	Thickness of plate (mm)	Cutting oxygen Pressure kgf/cm^2
0.8	3-6	1.0 - 1.4
1.2	6-9	1.4 - 2.1
1.6	19-100	2.1 - 4.2
2.0	100-150	4.2 - 4.6
2.4	150-200	4.6 - 4.9
2.8	200-250	4.9 - 5.5
3.2	250-300	5.5 - 5.6

Application of cutting torch: Oxy-acetylene cutting torch is used to cut mild steel plates above 4mm thickness. The M.S plate can be cut to its full length in straight line either parallel to the edge or at any angle to the edge of the plate. Beveling the edges of a plate to any required angle can also be done by tilting the torch. Circles and any other curved profile can also be cut using the cutting torch by using a suitable guide or template.

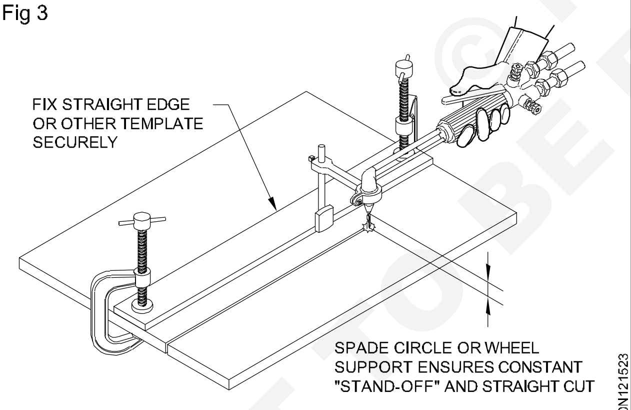
Fig 2 to Fig 6 Shows the guides used to cut straight lines, bevel and small circles.

Fig 2



GUIDES

Fig 3



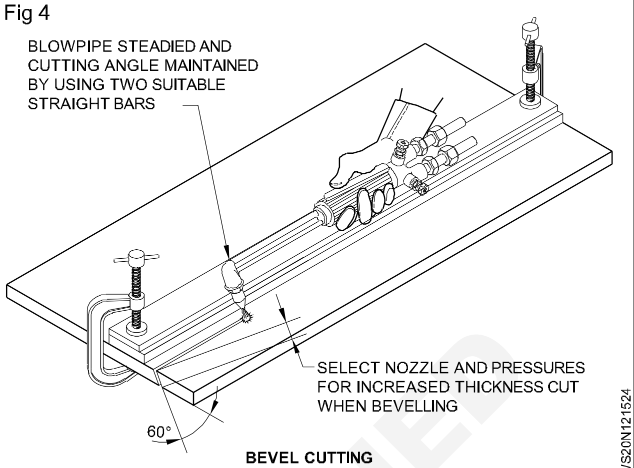
CUTTING WITH STRAIGHT EDGE AND SINGLE SUPPORT

Cutting torch guides: Guides are sometimes used during oxy acetylene cutting.

They can be either a roller guide, double support or spade guide with single support.

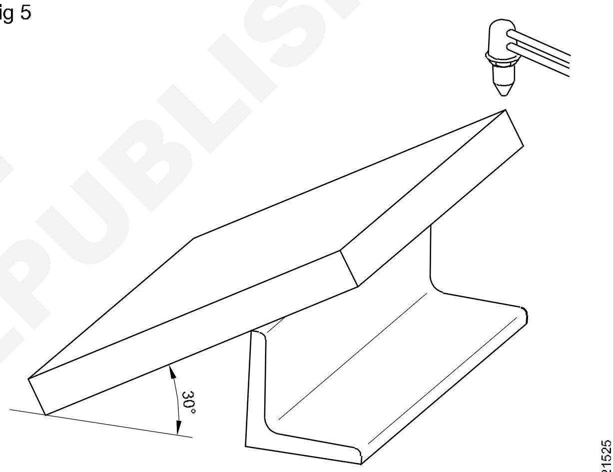
Cutting guides are held onto the nozzle of the cutting torch by tightening a clamp bolt. the clamps, where they are fitted, are adjusted so the inner cones of the preheat flames are approximately 2-3mm above the surface of the metal to be cut. The tip of the cutting nozzle is held at distance of 5-6mm above surface of the plate being cut.

Fig 4



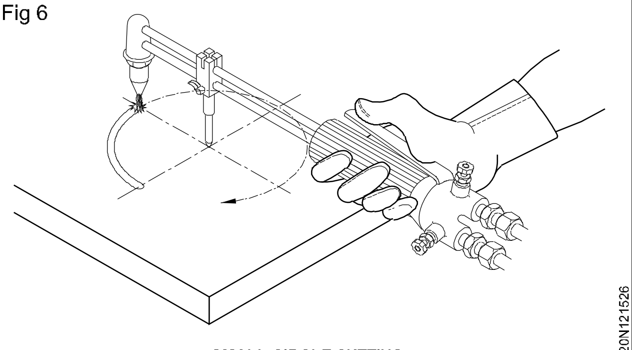
BEVEL CUTTING

Fig 5



ALTERNATIVE METHOD OF CUTTING
BEVELLED EDGE ON INCLINE

Fig 6



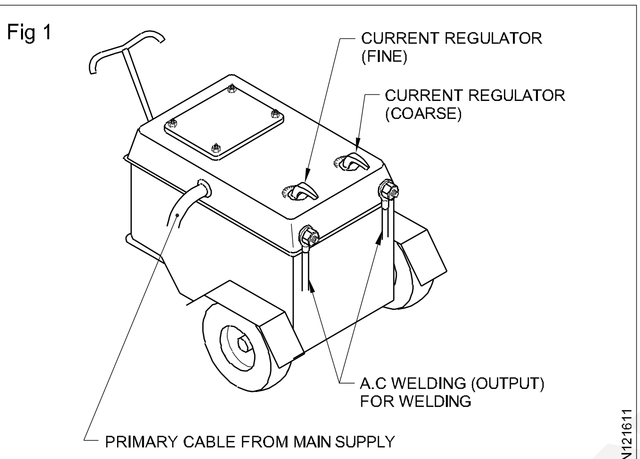
SMALL CIRCLE CUTTING

Arc welding power sources: Transformer, Rectifier and Inverter type welding machines and its care & maintenance

Objectives: At the end of this lesson you shall be able to
- **identify the features of an AC welding transformer, and welding rectifier**
- **explain the working principle of the above welding machines**
- **compare the advantages and disadvantages of an AC and a DC welding machine**
- **explain the care and maintenance of welding machines.**

AC welding transformer: This is a type of AC welding machine which converts AC main supply into AC welding supply. (Fig 1)

Fig 1



AC WELDING TRANSFORMER

AC main supply has high voltage-low ampere. AC welding supply has high ampere-low voltage.

It is a step down transformer, which:

- reduces the main supply voltage (220 or 440 volts) to welding supply open circuit voltage (OCV), between 40 and 100 volts
- increases the main supply low current to the required high output welding current in hundreds of amperes.

An AC welding transformer cannot be operated without AC main supply.

Constructional features: It consists of an iron core made out of a special alloy thin iron sheet stampings. Two coils of wire are wound over the iron core without any interconnection between them.

One coil, called primary winding, consists of a thin conductor and has more turns which receive energy from the mains. The second coil, called secondary winding consists of a thick conductor and less turns which supply energy for welding.

A current regulator is attached to the secondary output supply to adjust the amperes for welding suitable to the various sizes of electrodes.

Two welding cables are attached with the output terminals.

One is for the electrode and the other is for earth or job.

The transformer may be air-cooled or oil-cooled.

Working principle: The AC main supply (220-440 volts) is connected to the primary winding which produces a magnetic lines of force in the iron core.

The magnetic lines of force affects the secondary winding and induces high ampere-low voltage welding supply in it.

This action is called the principle of mutual induction.

The voltage at the primary coil is reduced in the secondary coil depending on the ratio of the No. of turns in the primary to that of the secondary.

Voltage at secondary coil =

$$\frac{\text{Voltage at primary coil} \times \text{No. of turns in the secondary}}{\text{No.of turns in the primary}}$$

Advantages

- Less initial cost
- Less maintenance cost
- Freedom from arc blow
- NO noise

The magnetic effect of DC disturbs the arc, the effect of which is called 'arc blow'.

Disadvantages

Not suitable for:

- welding of non-ferrous metals
- bare wire electrodes
- fine current setting in welding special jobs.

AC cannot be used without special precautions of safety.

Care and maintenance

Transformer body must be properly earthed.

Transformer oil must be changed after recommended period, in the oil cooled transformers.

Always follow the operating instruction manual to run and install the machine.

Do not run the machine continuously on its maximum capacity.

Switch off the main supply of the machine while cleaning internally or externally.

Do not change the current when welding is going on.

Always keep and install the machine on dry floor.

Give proper protection to the machine while working outside in rain or dust.

AC/DC welding rectifier its construction

Constructional features of AC/DC welding rectifier: A welding rectifier set is used to convert AC welding supply into DC welding supply. It consists of a step down transformer and welding current rectifier cell with a cooling fan. (Fig, 1) The rectifier cell consists of a supporting plate made of steel or aluminium (Fig.2) which is plated with a thin layer of nickel or bismuth, sprayed with SELENIUM or SILICON. It is finally covered with an alloyed film of CADMIUM, BISMITH and TIN.

The coating of nickel or bismuth over the supporting plate serves as one electrode (ANODE) of the rectifying cell. The alloyed film (of cadmium, bismuth and tin) serves as another electrode (CATHODE) of the rectifying cell. The rectifier acts as a non-return valve and allows current to flow one side of it as it offers very little resistance and on the other side it offers very high resistance to the flow of the current. Hence the current can flow in one direction only.

Fig 1

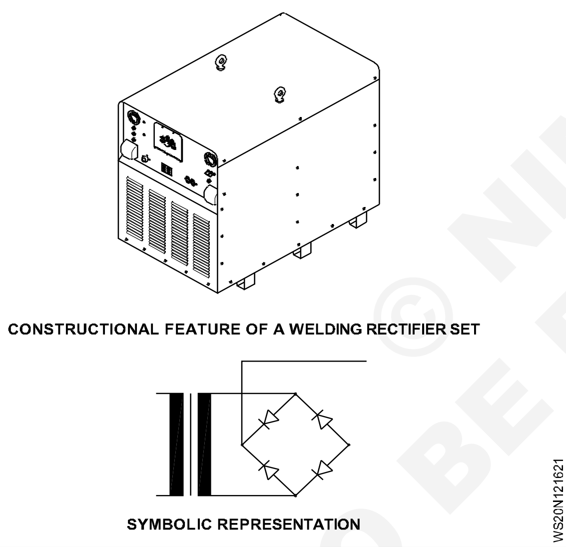
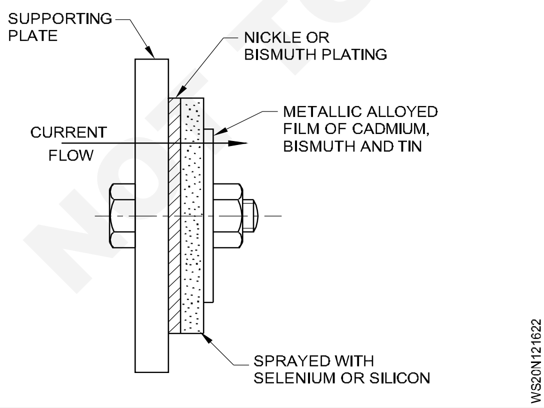


Fig 2



Working principle: The output of the step down transformer is connected to the rectifier unit, which converts AC to DC. The DC output is connected to positive and negative terminals, from where it is taken for welding purposes through welding cables. It can be designed to provide either AC or DC welding supply by operating a switch provided on the machine.

Care and maintenance of rectifier welding set

Keep all the connections in tight condition.

Lubricate the fan shaft once in 3 months.

Do not adjust the current or operate the AC/DC switch when the welding arc is 'on'.

Keep the rectifier plates clean.

Check and clean the set at least once in a month.

Keep the air ventilation system in good order.

Never run the machine without the fan.

Inverters

Basic principle

inverter basically converts DC to AC

DC derived by rectification of AC voltage with high value electrolytic capacitors as filters

These DC is converted to AC by high frequency solid state switching (in KHz)

A small ferrite core is sufficient for converting several kilowatts of power

Output of this ferrite transformer is rectified by high frequency diodes and smoothened by a DC choke

The output is controlled with Sensors & suitable closed loop electronic circuitry.

Working principle

1 Main voltage is rectified to DC
2 The inverter converts the DC to high frequency AC
3 The transformer changes the HF AC to suitable welding current.
4 The AC is rectified
5 Various filters remove the disturbing frequencies and ripples in the DC current. There is also a filter which protects against exterior high frequency disturbances.
6 The entire process is monitored by a control circuit. This gives the machine an ideal static and dynamic characteristics.
7 A DC voltage is available for welding purpose

Advantage

- Compact and light weight
- easy to set
- precise setting

Disadvantage

- expensive
- difficult to repair
- sensitive to high currents

Advantages and disadvantages of A.C. and D.C. welding machines.

Objectives: At the end of this lesson you shall be able to
- **compare the advantages and disadvantages of AC welding**
- **compare the advantages and disadvantages of DC welding.**

Advantages of AC welding

A welding transformer has:

- a low initial cost due to simple and easy construction
- a low operating cost due to less power consumption
- no effect of arc blows during welding due to AC
- low maintenance cost due to the absence of rotating parts
- higher working efficiency
- noiseless operation.

Disadvantages of AC welding

It is not suitable for bare and light coated electrodes.

It has more possibility for electrical shock because of higher open circuit voltage.

Welding of thin gauge sheets, cast iron and non-ferrous metals (in certain cases) will be difficult.

it can only be used where electrical mains supply is available.

Advantages of DC welding

Required heat distribution is possible between the electrode and the base metal due to the change of polarity (positive 2/3 and negative 1/3).

It can be used successfully to weld both ferrous and non-ferrous metals.

Bare wires and light coated electrodes can be easily used.

Positional welding is easy due to polarity advantage.

It can be run with the help of diesel or petrol engine where electrical mains supply is not available.

It can be used for welding thin sheet metal, cast iron and non-ferrous metals successfully due to polarity advantage.

It has less possibility for electrical shock because of less open circuit voltage.

It is easy to strike and maintain a stable arc.

Remote control of current adjustment is possible.

Disadvantages of DC welding

DC welding power source has:

- a higher initial cost
- a higher operating cost
- a higher maintenance cost
- trouble of arc blow during welding
- a lower working efficiency
- noisy operation in the case of a welding generator
- occupies more space.

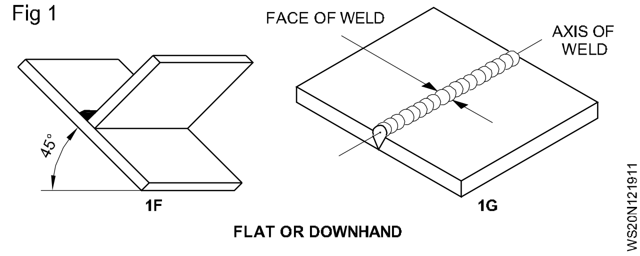
Welding positions as per EN & ASME : flat,horizontal,vertical and over head position

Objective : At the end of this lesson you shall be able to
- **name and illustrate the basic welding positions.**

Basic welding positions

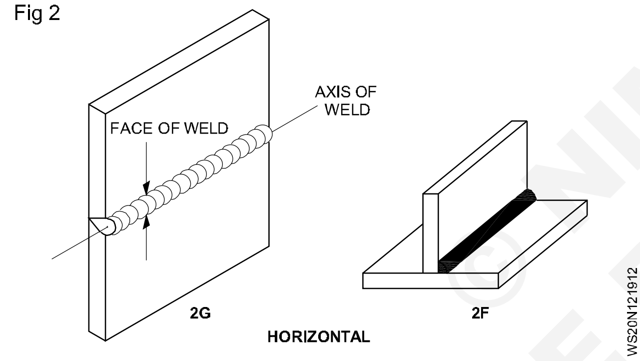
- Flat or down hand position (Fig 1)

Fig 1



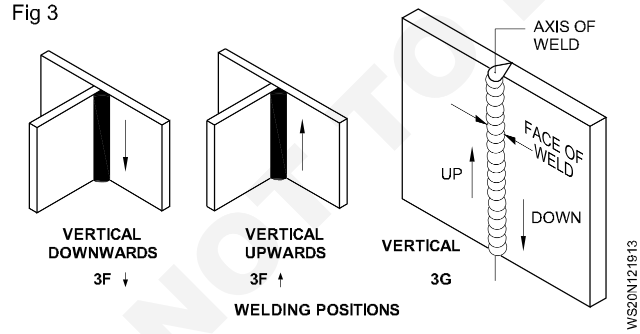
- Horizontal position (Fig 2)

Fig 2



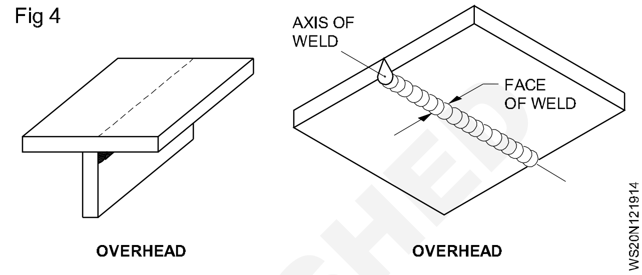
- Vertical position (Vertical up and down) (Fig 3)

Fig 3



- Overhead position (Fig 4)

Fig 4



All welding action takes place in the molten pool, formed in the welding joint/welding line.

The position of the welding joint line and the weld face in respect of ground axis indicates the welding position.

All joints may be welded in all positions.

Plate welding position:

Welding position	EN		ASME	
	Groove	Fillet	Groove	fillet
Flat	PA	PA	1G	1F
Horizontal	PC	PB	2G	2F
Vertical PG/PF	PG/PF	3G	3F	
Overhead	PE	PD	4G	4F

Pipe welding position:

Welding position	EN	ASME
	Groove	Groove
Flat	PA	1G
Horizontal	PC	2G
Multiple position	PF/PG	5G
Inclined (All position)	H-LO45	6G

Weld slope and rotation

Objectives : At the end of this lesson you shall be able to
- **define and explain weld slope and weld rotation with respect to butt and fillet joint**
- **illustrate the various weld positions with respect to slope and rotation as per I.S.**

Welding position: All welding is to be done in one of the four positions mentioned below.

1 Flat or down hand

2 Horizontal

3 Vertical

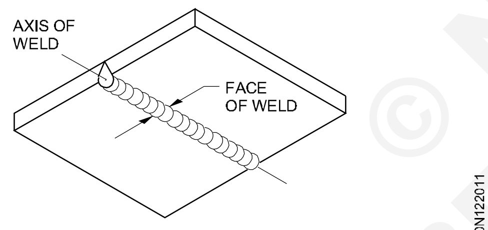
4 Overhead

Each of these positions can be decided by the angle formed by the axis of the weld and the weld face with the horizontal and vertical plane respectively.

Axis of weld: The imaginary line passing through the weld center lengthwise is known as axis of the weld. (Fig 1)

Face of weld: Face of weld is the exposed surface of a weld made in a welding process on the side from which the welding is done. (Fig 1)

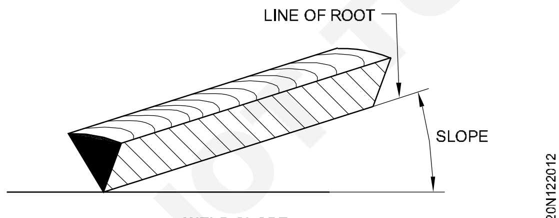
Fig 1



OVERHEAD

Weld slope (Fig 2): It is the angle formed between the upper portion of the vertical reference

Fig 2



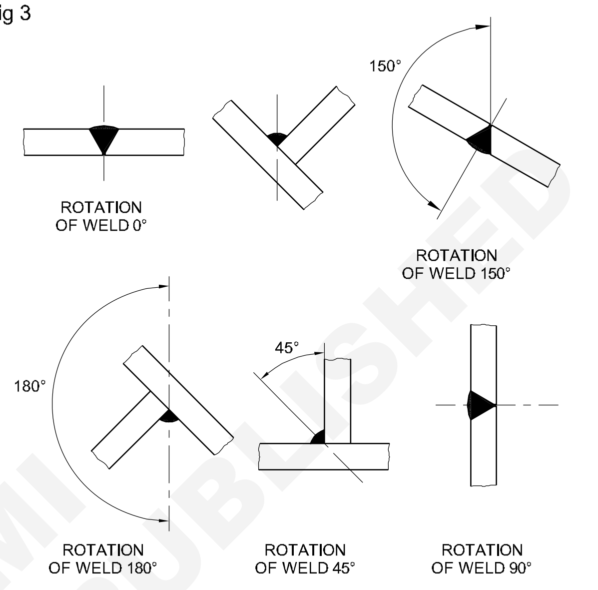
WELD SLOPE

Weld rotation (Fig 3): It is the angle formed between the upper portion of the vertical reference plane passing through the line of the weld root and that part of the plane passing through the weld root and a point on the face of the weld equidistant from both the edges of the weld.

Slope and rotation (Fig 4)

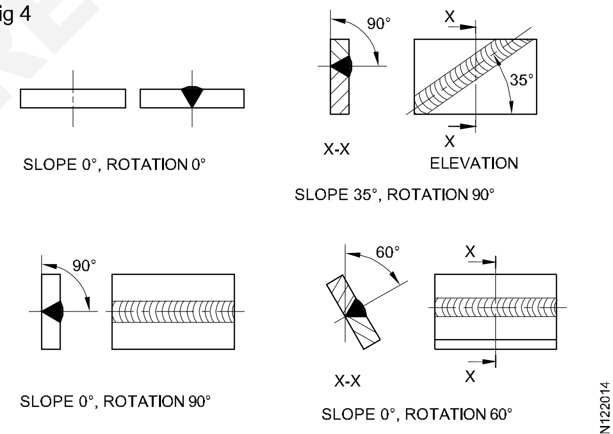
Weld in flat position. (Fig 5)

Fig 3



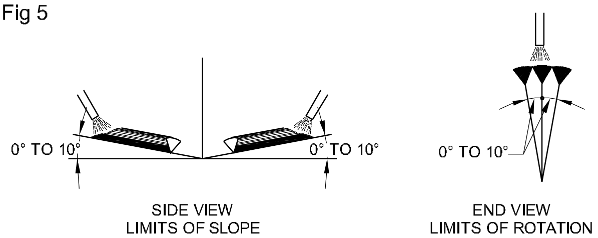
WELD ROTATION

Fig 4



SLOPE AND ROTATION

Fig 5



WELD IN FLAT POSITION

Weld in horizontal and vertical position. (Fig 6 & 7)

Fig 6

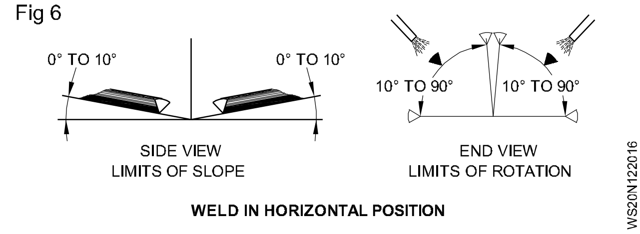
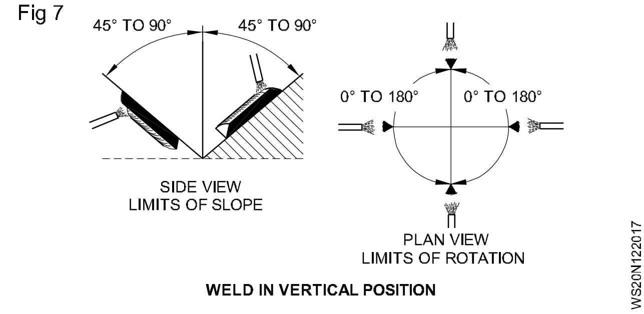


Fig 7

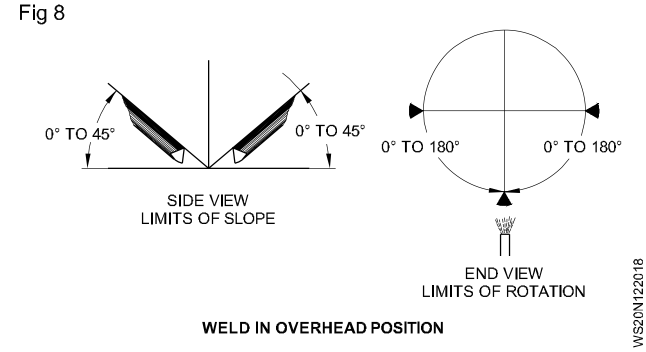


Weld in overhead position. (Fig 8)

Weld slope and weld rotation in respect of all the four positions are shown above.

Definitions of welding positions with respect to their slope and rotation angles a Table is given below.

Fig 8



Definition of welding position

Position	Symbol	Slope	Rotation
Flat or down hand	F	Not exceeding 10°	Not exceeding 10°
Horizontal	H	Not exceeding 10°	Exceeding 10° but not beyond 90°
Vertical	V	Exceeding 45°	Any.
Overhead	O	Not exceeding 45°.	Exceeding 90°.

Weld symbol and welding symbol - Description and uses

Objectives : At the end of this lesson you shall be able to
- **explain the necessity of weld symbol and welding symbol**
- **describe the elementary symbols and supplementary symbols**
- **describe the welding symbol and its application, as per symbol standard (BIS) and AWS.**

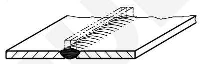
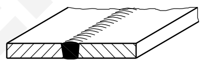
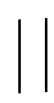
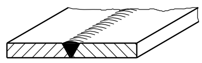
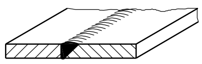
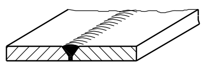
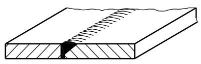
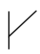
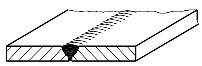
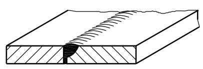
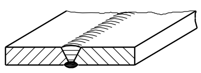
Necessity: For conveying the information required for welding for designers and welders, standard symbols are used. The symbols described below provide the means of placing on drawing the information concerning type, size, location of weldment.

Elementary symbols (As per IS 813 - 1986): The various categories of welds are characterized by a symbol which in general is similar to the shape of the weld to be made. (Table 1)

Supplementary symbols: Elementary symbols may be complemented by another set of symbols (supplementary) (Table 2) characterizing the shape of the external surface of the weld. Supplementary symbols on elementary symbols indicate the type of weld surface required. (Table 3)

TABLE 1

Elementary symbols

Sl. No.	Designation	Illustration	Symbol
1	Butt weld between plates with raised edges (the raised edges being melted down completely)		
2	Square butt weld		
3	Single V butt weld		
4	Single bevel butt weld		
5	Single V butt weld with broad root face		
6	Single bevel butt weld with broad root face		
7	Single U butt weld (Parallel or sloping sides)		
8	Single J butt weld		
9	Backing run; back or backing weld		

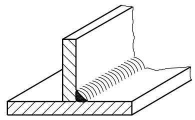
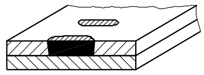
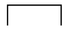
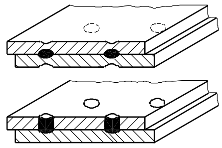
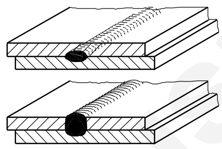
Sl. No.	Designation	Illustration	Symbol
10	Fillet weld		
11	Plug weld; Plug or slot weld/USA		
12	Spot weld		
13	Seam weld		

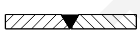
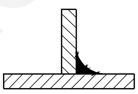
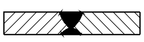
TABLE 2

Supplementary symbols

Shape of weld surface	Symbol
a) Flat (Usually finished flush) b) Convex c) Concave	

Table 3

Examples of application of supplementary symbols

Designation	Illustration	Symbol
Flat (flush) single V		
Convex double V butt weld		
Concave fillet weld		
Flat (flush) single V butt weld with flat (flush) backing run		

Weld symbol: It represents the type of weld made on a weld joint. It is also a miniature drawing of any metal edge preparation required prior to welding,

Welding symbol: The complete welding symbol will indicate to the welder how to prepare the base metal, the welding process to use, the method of finish and the required dimensions and other details with the basic weld symbol. They consist of 7 elements as mentioned below. (Fig 1)

1 Reference line

2 Arrow

3 Welding elementary symbols

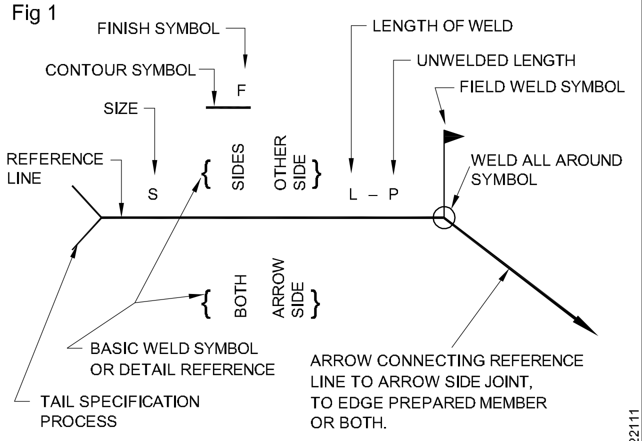
4 Dimensions and other details

5 Supplementary symbols

6 Finish symbols

7 Tail (Specification, process)

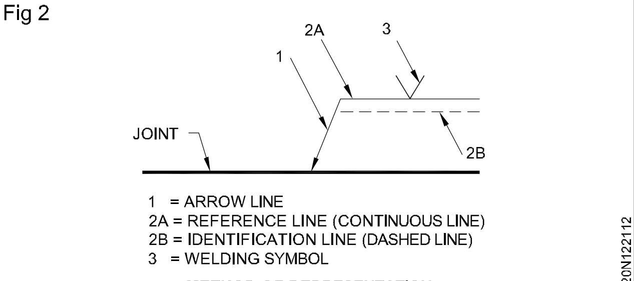
Fig 1



STANDARD LOCATION OF ELEMENTS OF A WELDING SYMBOL

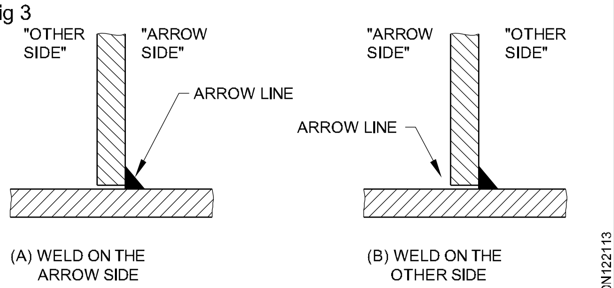
Methods of representation (Fig 2 and 3)

Fig 2



METHOD OF REPRESENTATION

Fig 3



T-JOINT WITH ONE FILLET WELD

The reference line, arrow-head and tail

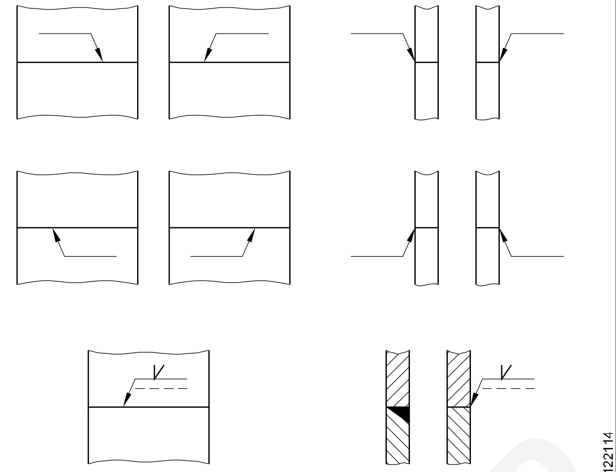
The reference line shown in Figs 1 and 5 is always drawn as horizontal line. It is placed on the drawing near the joint to be welded. All other information to be given on the welding symbols is shown above below the reference line.

Arrow: The arrow may be drawn from either end of the reference line. The arrow always touches the line which represents the welded joint.

On the welding symbol the arrow side weld information is always shown below the reference line. The other side weld information is always shown on the dash- line side. (Figs 2 and 4)

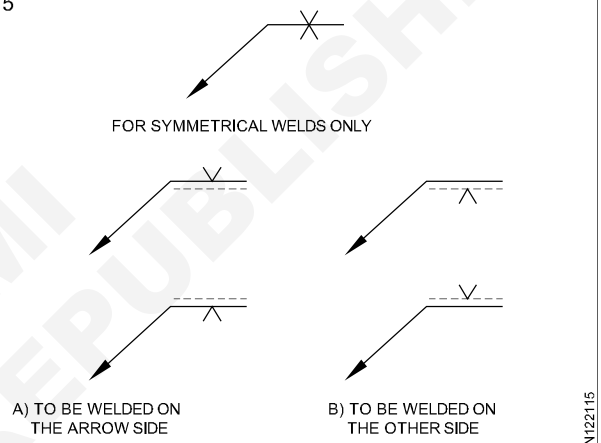
Tail: The tail is used only when necessary. If used it may give information on specification, the welding process used. or other details required which are not shown in the welding symbol.

Fig 4



POSITION OF THE ARROW LINE

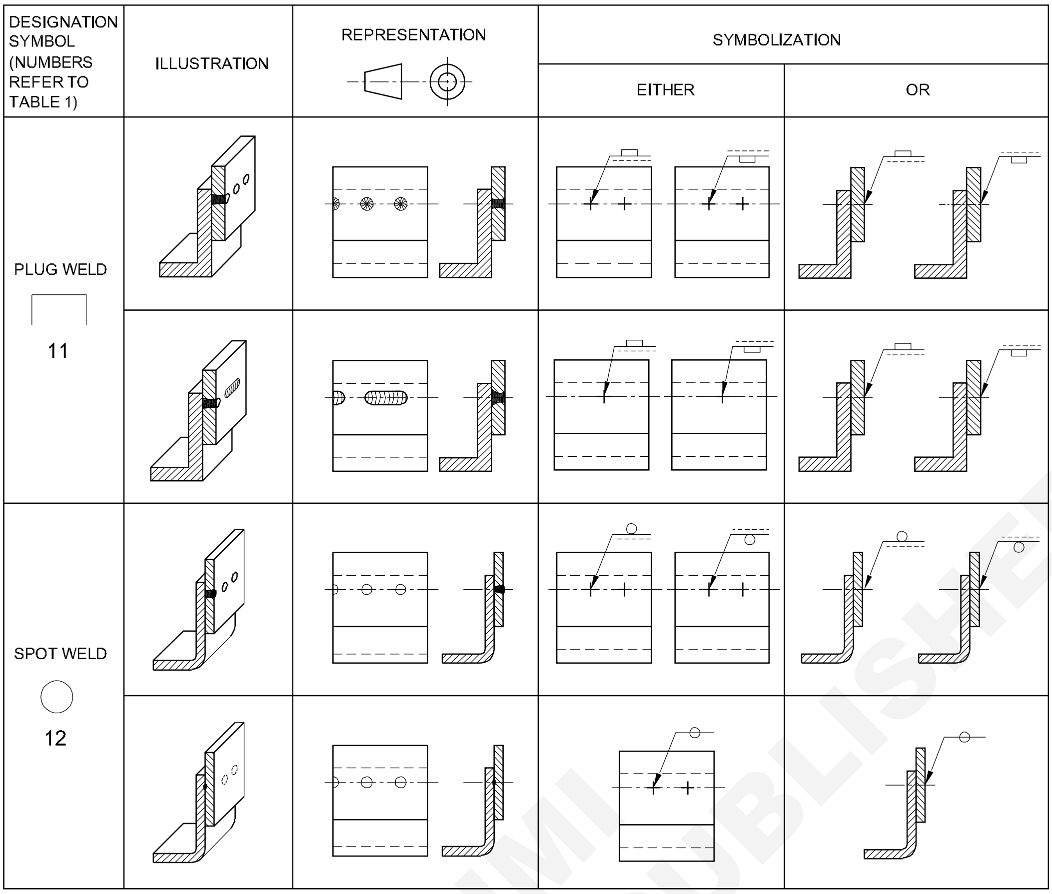
Fig 5



POSITION OF SYMBOLS ACCORDING TO THE REFERENCE LINE

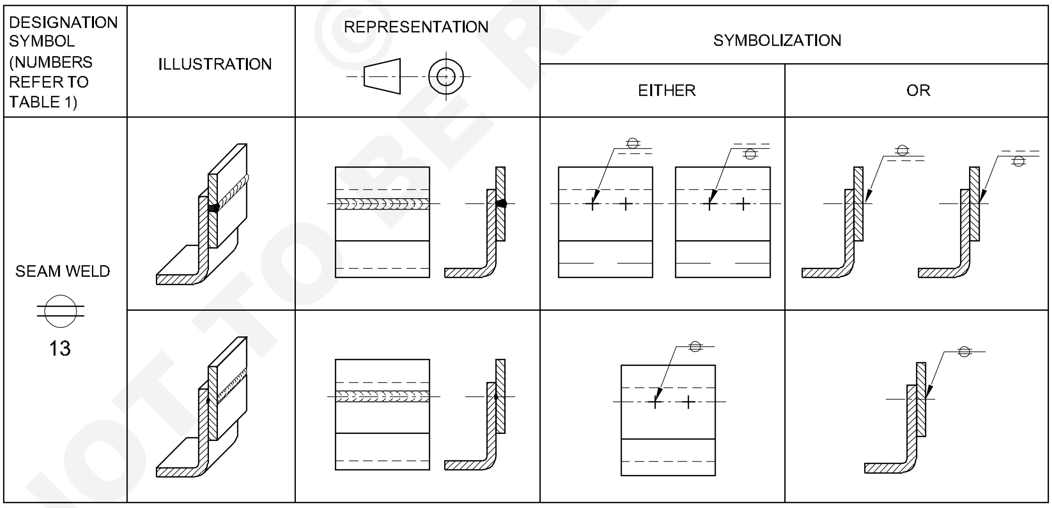
Welding/elementary symbol: Figs 6 and 7 illustrate how some of the various types of weld symbols are used in welding symbols.

Fig 6



EXAMPLES OF USE OF ELEMENTRY SYMBOLS

Fig 7

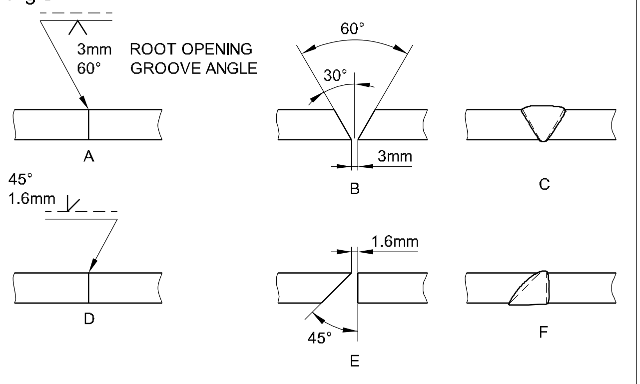


EXAMPLES OF USE OF ELEMENTRY SYMBILS

Root opening and groove angle: The root opening size appears inside the basic weld symbol on the complete welding symbol. The included angle or total angle of a groove weld is shown above the basic weld symbol. (Fig 8)

Contour and finish symbols: The shape or contour of the completed weld bead is shown on the welding symbol as a straight or curved line between the basic weld symbol and the finish symbol. The curved contour line indicates a normal convex or concave weld bead. (Fig 9)

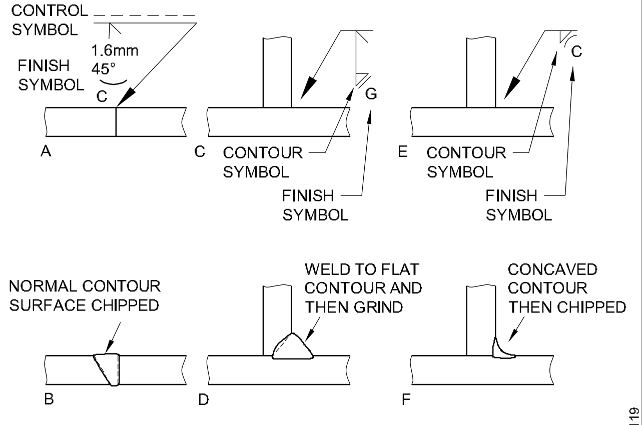
Fig 8



A AND D SHOW THE WELD SYMBOL FOR A GROOVE WELD
B AND E SHOW THE PIECES CUT AND SET UP FOR WELDING
C AND F SHOW THE COMPLEETED WELD

ROOT OPENING AND GROOVE ANGLE

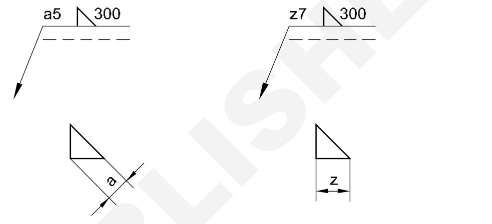
Fig 9



WELD CONTOUR AND FINISH SYMBOLS IN A,C AND FINISH E
CONTOUR AND FINISH SYMBOLS ARE SHOWN ON WELDING SYMBOL
B,D AND F ILLUSTRATE SHAPE AND FINISH OF COMPLETED WELD

Dimensions and other details: The size of a weld is important. The term 'size of weld' means different things for the fillet weld and butt weld. The dimensions of a fillet weld are shown to the left of the basic weld symbol. (Fig10) The number 300 indicates the length of the weld is 300mm; a5 indicates that the throat thickness is 5mm; Z7 indicates the leg length is 7mm.

Fig 10



METHOD OF INDICATING DIMENSIONS FOR FILLET WELDS

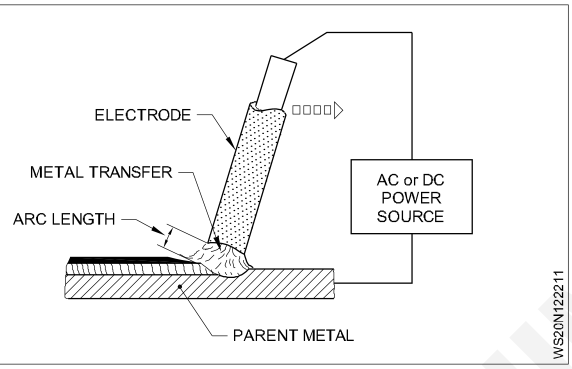
Arc length - types - effects of arc length.

Objectives : At the end of this lesson you shall be able to
- **define and identify the different types of arc lengths**
- **explain the effects and uses of different arc lengths.**

Arc length (Fig 1): It is the straight distance between the electrode tip and the job surface when the arc is formed. There are three of arc lengths.

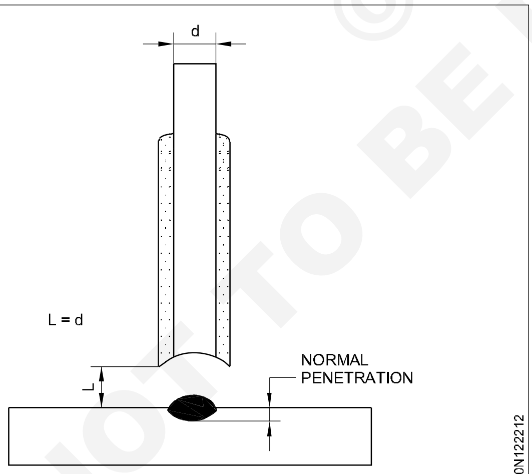
- Medium or normal
- Long
- Short

Fig 1



Medium, normal arc (Fig 2): The correct arc length or normal arc length is approximately equal to the diameter of the core wire of the electrode.

Fig 2

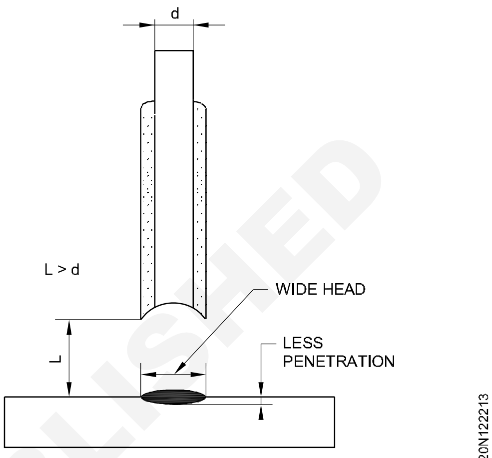


NORMAL ARC LENGTH

Long arc (Fig 3): If the distance between the tip of the electrode and the base metal is more than the diameter of the core wire it is called a long arc.

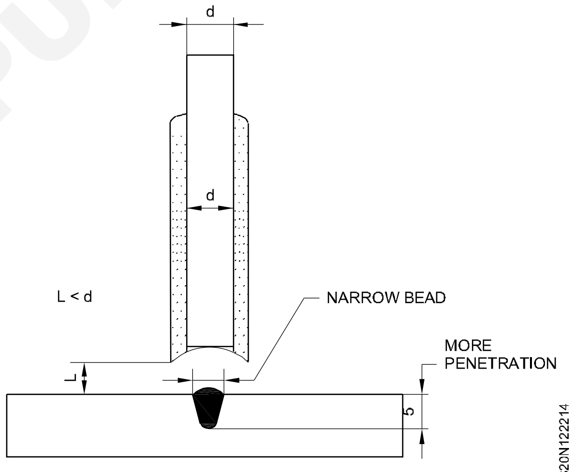
Short arc (Fig 4): If the distance between the tip of the electrode and the base metal is less than the dia. of the core wire it is called a Short arc.

Fig 3



LONG ARC LENGTH

Fig 4



SHORT ARC LENGTH

Effects of different arc length

Long arc

It makes a humming sound causing:

- Unstable arc
- Oxidation of weld metal
- Poor fusion and penetration
- Poor control of molten metal
- more spatters, indicating wastage of electrode metal.

Short arc: It makes a popping sound causing:

- the electrode melting fastly and trying to freeze with the job
- higher metal with narrow width bead
- less spatters
- more fusion and penetration.

Normal arc: This is a stable arc producing steady sharp crackling sound and causing:

- even burning of the electrode
- reduction in spatters
- correct fusion and penetration
- correct metal deposition.

Uses of different arc lengths

Medium or normal arc: It is used to weld mild steel using a medium coated electrode. It can be used for the final covering run to avoid undercut and excessive convex fillet/reinforcement.

Long arc: It is used in plug and slot welding. for restarting the arc and while withdrawing the electrode at the end of a bead after filling the crater. Generally long arc is to be avoided as it will give a defective weld.

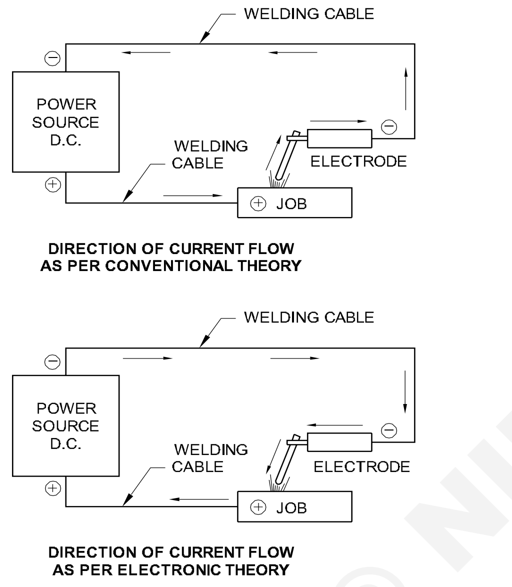
Short arc: It is used for root runs to get good root penetration, for positional welding and while using a heavy coated electrode, low hydrogen, iron, powder and deep penetration electrode.

Polarity types and applications

Objectives : At the end of this lesson you shall be able to
- **state the kinds and importance of polarity in arc welding**
- **describe the uses of straight and reverse polarity**
- **describe the methods of determining the polarity and explain the effects of using wrong polarity.**

Polarity in arc welding: Polarity indicates the direction of current flow in the welding circuit. (Fig 1)

Fig 1



Direct current (DC) Always flows from:

- the positive (higher potential) terminal to the negative (lower potential) terminal, as per the conventional theory
- negative terminal to positive terminal as per electronic theory.

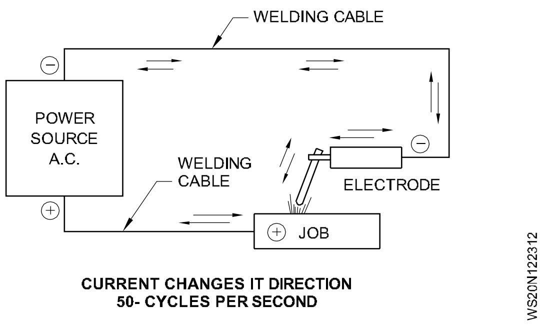
In older machines the electrode and earth cables are interchanged whenever the polarity has to be changed.

In the latest machines a polarity switch is used to change the polarity.

Flow of electrons is always from negative to the positive.

In AC we cannot utilize polarity as the power source changes its poles frequently. (Fig 2)

Fig 2



Importance of polarity in welding: In DC welding 2/3 of the heat is liberated from the positive end and 1/3 from the negative end.

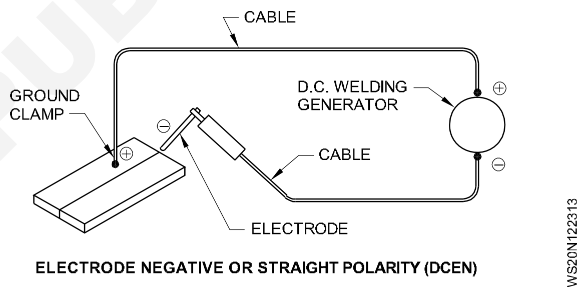
To have this advantage of unequal heat distribution in the electrode and base metal, the polarity is an important factor for successful welding.

Kinds of polarity - Types and applications

- Straight polarity or electrode negative (DCEN).
- Reverse polarity or electrode positive (DCEP).

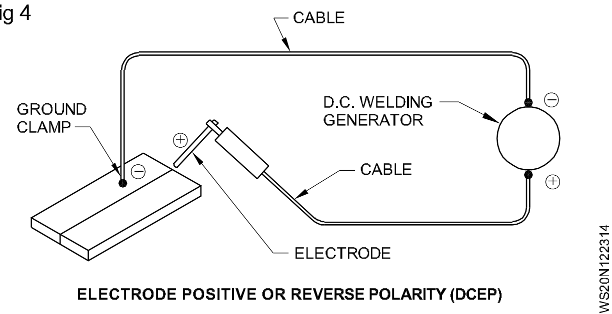
Straight polarity: In straight polarity the electrode is connected to the negative and the work to the positive terminal of the power source. (Fig 3)

Fig 3



Reverse Polarity: In reverse polarity the electrode is connected to the positive and the work to the negative terminal of the power source. (Fig 4)

Fig 4



Straight polarity is used for:

- welding with bare light coated and medium coated electrodes
- Welding the thicker sections in down hand position to obtain more base metal fusion and penetration.

Reverse polarity is used for:

- Welding of non-ferrous metals
- Welding of cast iron

- Welding with heavy and super-heavy coated electrodes
- Welding in horizontal, vertical and overhead positions
- Sheet metal welding.

DC is preferred to AC for hard facing and stainless steel welding.

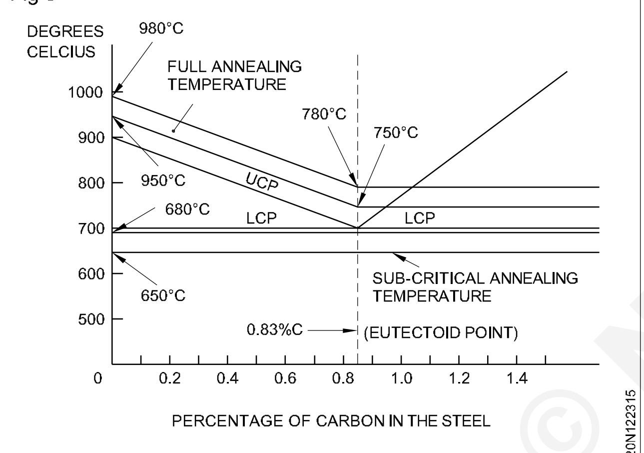
Choice of the polarity also depends on the instruction of the electrode manufacturers.

Determination of polarity: In order to get the best results it is essential to attach the electrode with the correct terminal of the welding machine.

Positive/negative terminals on a DC welding machine can be identified by the following tests.

Carbon electrode test (Fig 5): Strike an arc using normal range current with the help of a carbon electrode pointed at its end using DC.

Fig 5

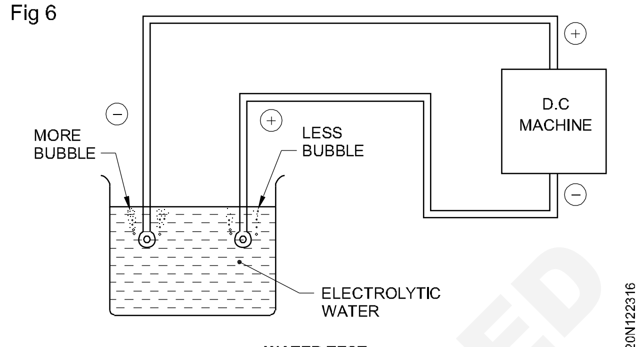


ANNEALING TEMPERATURES FOR PLAIN CARBON STEELS

The pointed end of carbon will become blunt soon if it is connected with the positive terminal, but there will be no change with the negative.

Water test (Fig 6): Put both terminals of the welding cable (connected with DC) in a container of electrolyte water separately.

Fig 6



WATER TEST

More and quick arising bubbles will indicate NEGATIVE while slow arising bubbles will indicate POSITIVE.

Indication of wrong polarity

If the electrode is used on wrong polarity it will result in:

- excess spatter and poor penetration
- improper fusion of the electrode
- heavy brownish deposition on the face of the weld metal
- difficulty in manipulation of the arc
- abnormal sound of the arc
- Poor weld bead appearance with surface defects and more spatter.

Calcium carbide uses and hazards

Objectives : At the end of this lesson you shall be able to
- **calcium carbide uses**
- **composition of calcium carbide**
- **calcium carbide hazards.**

Calcium carbide is a dark-grey stone like chemical compound which is used to produce acetylene gas.

Composition of calcium carbide: calcium carbide is a chemical compound consisting of:

- Calcium = 62.5%
- Carbon = 37.5%, by weight i.e., in 100g of calcium carbide, 62.5g will be calcium and 37.5g will be carbon.

its chemical symbol is $Ca\ C_2$

Calcium carbide hazards

Calcium carbide can irritate the skin casing a rash. redness and burning feeling on contact permanent damage (cornal opacities) exposures may cause a buildup of fluid in the lungs (pulmonary edema) a medical emergency.

Acetylene gas - Properties

Objectives : At the end of this lesson you shall be able to
- **explain the composition and properties of acetylene and oxygen gas**
- **describe the method of producing oxygen by air liquefaction process and by electrolysis of water.**

Acetylene is a fuel gas, which produces a very high temperature flame with the help of oxygen, because it has more amount of carbon (92.3%) than any other fuel gas. The temperature of oxy-acetylene flame is 3100°c - 3300°c.

Composition of acetylene gas: Acetylene is composed of:

- carbon 92.3% (24 parts)
- hydrogen 7.7% (2 parts)

Its chemical symbol is C_2H_2 which shows that two atoms of carbon are combined with two atoms of hydrogen.

Properties of acetylene gas: It is a colourless gas, lighter than air. It has a specific gravity of 0.9056 as compared with air. It is highly inflammable and burns with a brilliant flame. It is slightly soluble in water and alcohol. Impure acetylene has pungent (garlic like) odour. It can be easily detected by its peculiar smell. Acetylene dissolves in acetone liquid.

Impure acetylene reacts with copper and forms an explosive compound called copper acetylene. therefore, copper should not be used for acetylene pipeline. Acetylene gas can cause suffocation if mixed 40% or more in air. Acetylene mixed with air becomes explosive on ignition. It is unstable and unsafe when compressed to high pressure i.e. its safe storage pressure in free state is fixed as 1 kg/cm^2. The normal temperature pressure (N.T.P) is 1.091 kg/cm^2.The normal temperature is 20°C and the normal pressure 760mm of mercury or 1 kg/cm^2. It can be dissolved in liquid acetone. at high pressure. One volume of liquid acetone can dissolve 25 volumes of acetylene under N.T.P. It can dissolve 25X15=375 volume of acetylene cylinder if it is dissolved with a pressure of 15kg/cm^2 pressure. In an acetylene cylinder it is dissolved acetylene. For complete combustion one volume unit of acetylene requires two and a half volume units of oxygen.

Acetylene gas flash back arrestor

Objectives : At the end of this lesson you shall be able to
- **explain flash back arrestor parts**
- **explain working principle.**

Acetylene gas flash back arrestor

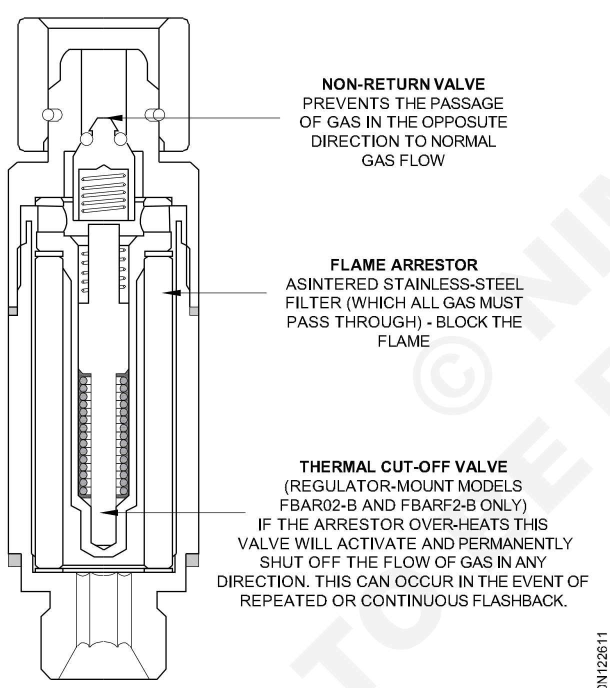
Introduction

It is a safety device and fitted with acetylene cylinder (generator low pressure system) it is made out of mild steel cylindrical body.

Parts: and working principle

High pressure system

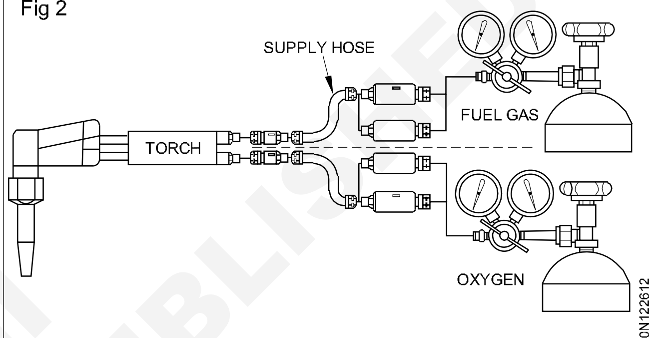
Fig 1



HIGH PRESSURE SYSYTEM

Working principle: A flash back arrester works in three ways stopping the fuel flow by a non-return valve stopping flame from passing towards the cylinder by filter arrangement stopping the gas mixture from backward travel by thermal low off valve (integrated plastic seal)

Fig 2



PROPER PLACEMENT OF FLASH-BACK ARRESTERS

Oxygen gas and it's properties and oxygen by air liquefaction

Objectives : At the end of this lesson you shall be able to
- **explain the composition and properties of oxygen gas**
- **describe the method of producing oxygen by air liquefaction process and by electrolysis of water.**

Oxygen gas: Oxygen is a supporter of combustion. Its chemical symbol is O_2

Properties of oxygen gas

- Oxygen is colourless, odourless and tasteless gas,
- It has atomic weight of 16.
- Its specific gravity at 32° F and at normal atmosphere pressure is 1.1053, as compared with air.
- It is slightly soluble in water.
- It does not burn itself. but readily supports combustion of fuels.

When compressed oxygen comes in contact with finely divided particles of combustible material (i.e., coal dust, mineral oil, grease) it will self-ignite them, leading to fire or explosion. Self-ignition in such cases may be initiated by the heat given up suddenly by compressed oxygen,

Oxygen becomes liquefied at a temperature of -182.962°C at normal atmospheric pressure.

Liquid oxygen has a pale blue colour.

Liquid oxygen becomes solid at - 218.4 C° at normal atmospheric pressure. It combines rapidly with most of the metals and forms oxide. i.e.,

Iron + oxygen = Iron oxide

Copper + oxygen = Cuprous oxide

Aluminium + oxygen = Aluminium oxide

The process of making oxide is called oxidation. Oxygen is found everywhere in nature, either in free state or in a combination with other elements. It is one of the chief constituents of atmosphere i.e., 21% oxygen 78% Nitrogen. Water is chemical compound of oxygen and hydrogen, in which approximately 89% is oxygen by weight and 1/3 by volume. One volume of liquid oxygen produces 860 volumes of oxygen gas. One kg of liquid oxygen produces 750 liters of gas. The weight of the container used to store liquid oxygen is several times less than the weight of cylinders required to store an equivalent quantity of gaseous oxygen.

Production of oxygen gas

Air liquefaction process: This method is based upon the idea of separating the various gases that constitute the air by liquefaction process.

This process is done in three stages.

- purification
- liquefaction
- Distillation

The composition of air and the boiling points of its components are given in Table 1.

Air is a mixture of roughly 78% nitrogen, 21% oxygen and 1% argon and other inert gases.

Table 1
Composition of air

Name of component	Quantity by volume %	Boiling point °C
Nitrogen	78.0300	-195.80
Oxygen	20.9300	-182.96
Argon	00.9325	-185.70
Neon	00.0018	
Helium	00.0005	
Krypton	00.0001	
Xenon	00.000009	
Hydrogen	00.00005	
Carbon dioxide	00.030000	

The basis of the separation of the elements in air by this method depends on the difference in the boiling point of the major elements.

Between nitrogen and oxygen - 13°C

Between nitrogen and argon - 10°C

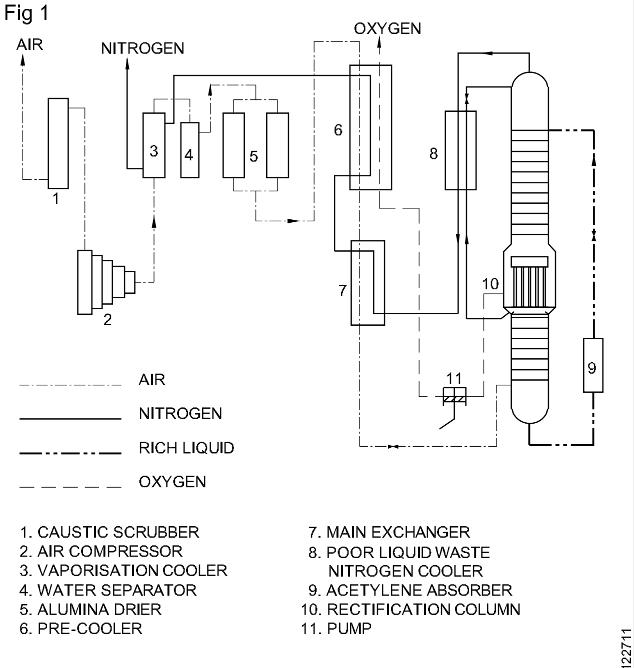
Between oxygen and argon - 3°C

Steps for separating oxygen (Fig 1)

Purification: Air is drawn from the atmosphere into large containers called washing towers, where it is washed and purified of carbon dioxide dust particles by means of caustic soda solution. The washed air from the washing towers is compressed by a compressor to 150 atmospheric pressure and passed through oil purging cylinders and then through aluminium driers, which remove the remaining carbon dioxide and water vapours.

Liquefaction: The dry, clean, compressed air then goes into liquefaction columns, where it is cooled and then expanded to change into liquid form.

Fig 1



PRODUCTION OF OXYGEN BY AIR LIQUEFACTION METHOD

Distillation: The liquid air is then rectified in the CONDENSER column by increasing the temperature on the basis of difference in the boiling points of its elements.

Nitrogen having a lower boiling point (-195.8°C) evaporates first.

Argon having a boiling point (-185.70°C) evaporates second leaving liquid oxygen in the bottom of the condenser.

Liquid oxygen can be stored in liquid form as shown in the liquid oxygen container. (Fig 2)

The liquid oxygen next passes through a heated coil which changes the liquid into a gaseous form.

The gaseous oxygen goes into a storage tank from where it is drawn and compressed into oxygen gas cylinders.

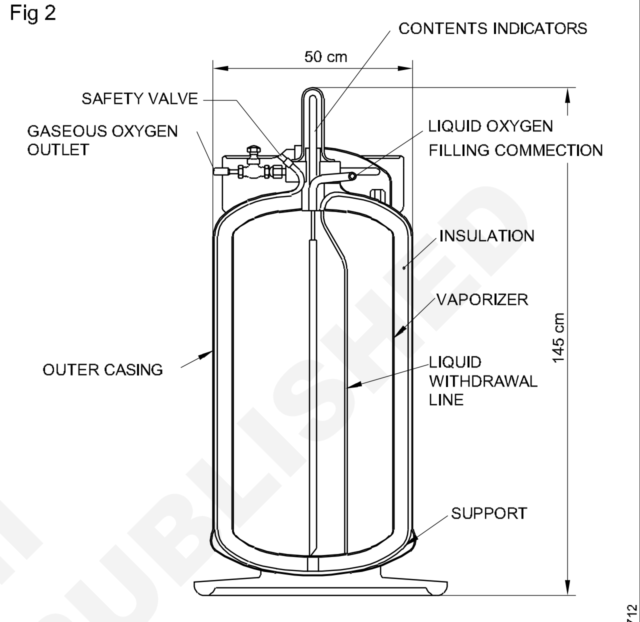
Electrolysis of water (Fig 3): In this method. DC electricity is passed through water causing the water to separate into its elements which are oxygen and hydrogen oxygen will collect at the positive terminal and hydrogen at the negative.

Caustic soda is added to the water to make it a good electrolyte since pure water will not allow the current to pass.

This method produces two volumes of hydrogen and one volume of oxygen.

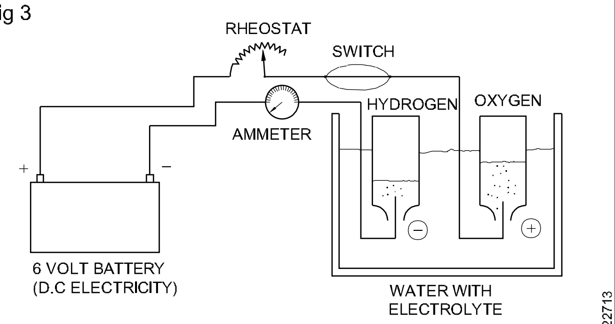
The cost of producing oxygen by this method is more the oxygen contains more moisture and it is difficult to obtain 99% purity and the process requires enormous quantity of water and electricity. So the air liquefaction method is more commonly used to produce commercial oxygen with a purity of 99.99%.

Fig 2



SECTIONAL VIEW OF THE LIQUID OXYGEN VESSEL OR CONTAINER (FLASK TYPE)

Fig 3



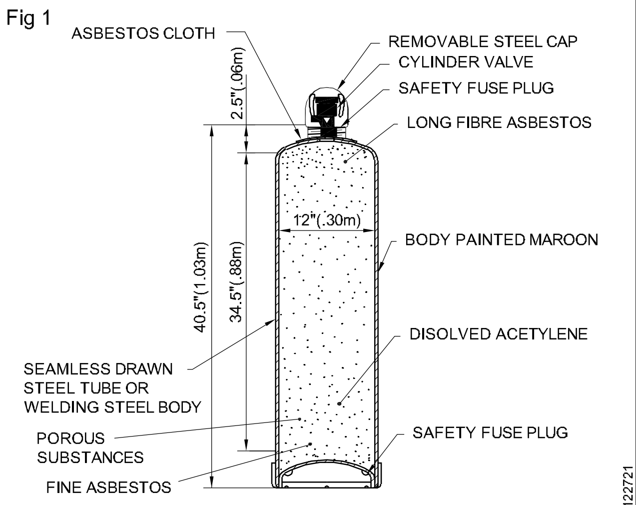
PRINCIPLE OF PRODUCING OXYGEN BY ELECTROLYSIS OF WATER METHOD

Charging process of oxygen and acetylene gases

Objectives: At the end of this lesson you shall be able to
- **describe the DA Co_2 gas cylinder and the method of charging.**

Charging of gas in oxygen cylinder: The oxygen cylinders are filled with oxygen gas under a pressure of 120-150 kg/cm^2. The cylinders are tested regularity and periodically. They are annealed to relieve stresses caused during 'on the job' handling. They are periodically cleaned using caustic solution.

Definition: It is a steel container used to store high pressure acetylene gas safely in dissolved state for gas welding or cutting purpose.



CONSTRUCTIONAL FEATURES OF A DISSOLVED ACETYLENE GAS CYLINDER

Method of charging D A gas cylinder: The storage of acetylene gas in its gaseous form under pressure above 1kg/cm^2 is not safe. A special method is used to store acetylene safely in cylinders as given below.

The cylinders are filled with porous substances such as:

- pith from corm stalk
- fullers earth
- lime silica
- specially prepared charcoal
- Fiber asbestos.

The hydrocarbon liquid named acetone is then charged in the cylinder, which fills the porous substances (1/3rd of total volume of the cylinder).

Acetylene gas is then charged in the cylinder, under a pressure of app. 15 kg//cm^2.

The liquid acetone dissolves the acetylene gas in large quantity as safe storage medium: hence, it is called dissolved acetylene. One volume of liquid acetone can dissolve 25 volumes of acetylene gas under normal atmospheric pressure and temperature. During the gas charging operation one volume of liquid acetone dissolves 25X15=375 volumes of acetylene gas under 15kg/cm^2 pressure at normal temperature. While charging cold water will be sprayed over the cylinder so that the temperature inside the cylinder does not cross certain limit.

Oxygen and dissolved acetylene gas cylinders and Color coding for different gas cylinders

Objectives : At the end of this lesson you shall be able to
- **identify different gas cylinders and colour coding**
- **explain the constructional features of oxygen gas cylinder.**

Definition of a gas cylinder: It is a steel container, used to store different gases at high pressure safely and in large quantity for welding or other industrial uses.

Types and identifications of gas cylinders: Gas cylinders are called by names of the gas they are holding. (Table 1)

Gas cylinders are identified by their body colour marks and valve threads. (Table 1)

Table 1

Identification of gas cylinders

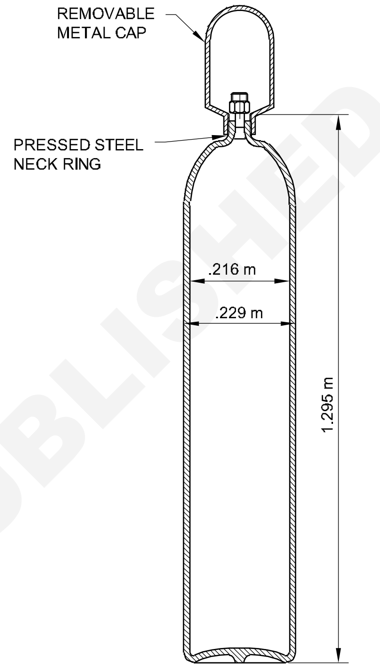
Name of gas Cylinder	Colour codling	Valve threads
Oxygen	Black	Right hand
Acetylene	Maroon	Left hand
Coal	Red (With name coal gas)	Left hand
Hydrogen	Red	Left hand
Nitrogen	Grey (With black neck)	Right hand
Air	Grey	Right hand
Propane	RED (with larger diameter and name propane)	Left hand
Argon	Blue	Right hand
Carbon-di-Oxide	Black (With white neck)	Right hand

Oxygen gas cylinder: It is a seamless steel container used to store oxygen gas safely and in large quantity under a maximum pressure of 150 kg /cm^2, for use in gas welding and cutting.

Constructional features of oxygen gas cylinder (Fig 1)

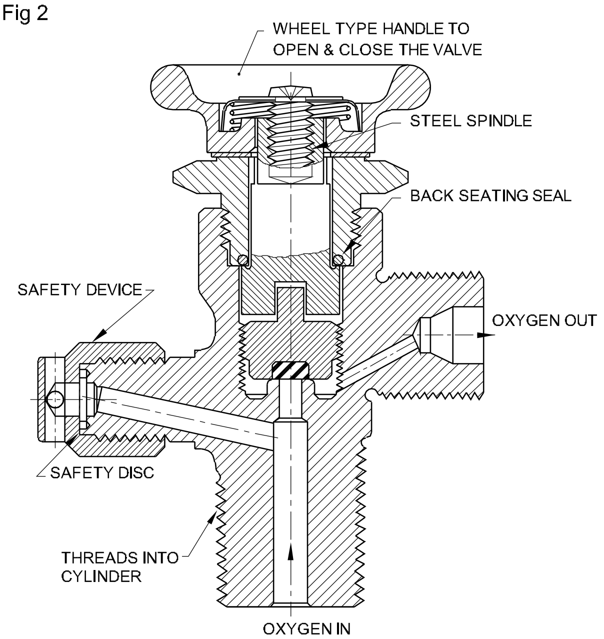
It is made from seamless solid drawn steel and tested with a water pressure of 225kg/cm^2. The cylinder top is fitted with a high pressure valve made from high quality forged bronze. (Fig 2)

Fig 1



CONSTRUCTIONAL FEATURE OF OXYGEN GAS CYLINDER

Fig 2



CONSTRUCTIONAL FEATURES OF A CYLINDER VALVE

The cylinder valve has a pressure safety device, which consists of a pressure disc, which will burst before the inside cylinder pressure becomes high enough to break the cylinder body. The cylinder valve outlet socket fitting has standard right hand threads, to which all pressure regulators may be attached. The cylinder valve is also fitted with a steel spindle to operate the valve for opening and closing. A steel cap is screwed over the valve to protect it from damage during transportation. (Fig 1)

The cylinder body is painted black.

The capacity of the cylinder may be 3.5m^3 - 8.5m^3.

Oxygen cylinders of 7m^3 capacity are commonly used.

Dissolved acetylene gas cylinder

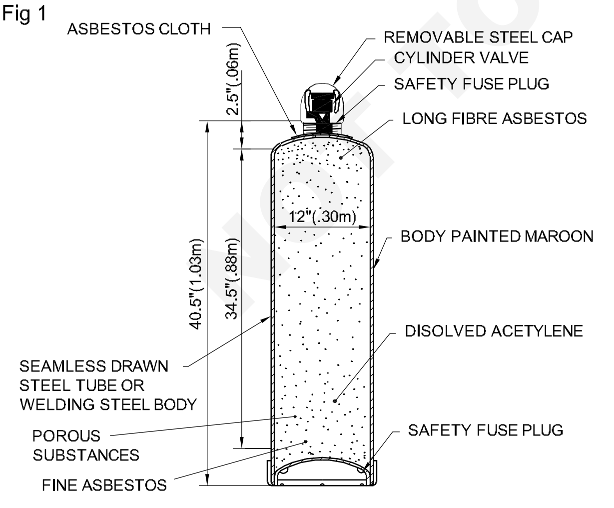
Objectives: At the end of this lesson you shall be able to
- **describe the constructional features of the DA gas cylinder and the method of charging**
- **state the safety rules for handling gas cylinders**
- **explain the safe procedure to be followed in handling an internally fired DA cylinder.**

Charging of gas in oxygen cylinder: The oxygen cylinders are filled with oxygen gas under a pressure of 120-150 kg/cm^2. The cylinders are tested regularity and periodically. They are annealed to relieve stresses caused during 'on the job' handling. They are periodically cleaned using caustic solution.

Definition: It is a steel container used to store high pressure acetylene gas safely in dissolved state for gas welding or cutting purpose.

Constructional features (Fig 1): The acetylene gas cylinder is made from seamless drawn steel tube or welded steel container and tested with a water pressure of 100kg/cm^2 The cylinder top is fitted with a pressure valve made from high quality forged bronze. The cylinder valve outlet socket has standard left hand threads to which acetylene regulators of all makes may be attached. The cylinder valve is also fitted with a steel spindle to operate the valve for opening and closing. A steel cap is screwed over the valve to protect it from damage during transportation. The body of the cylinder is painted maroon. The capacity of the DA cylinder may be 3.5m^3-8.5m^3.

Fig 1

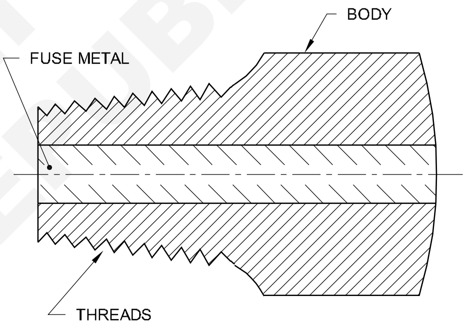


CONSTRUCTIONAL FEATURES OF A DISSOLVED ACETYLENE GAS CYLINDER

WS20N122821

The base of the D A cylinder (Curved inside) is fitted with fuse plugs which will melt at a temperature of app. 100°C. (Fig 2) In case the cylinder is subjected to high temperature, the fuse plugs will melt and allow the gas to escape, before the pressure increases enough to harm or rupture the cylinder. Fuse plugs are also fitted on the top of the cylinder.

Fig 2



CONSTRUCTIONAL FEATURE OF A FUSE PLUG FITTED WITH THE CYLINDER TOP AND BOTTOM

WS20N122822

Method of charging D A gas cylinder: The storage of acetylene gas in its gaseous form under pressure above 1kg/cm^2 is not safe. A special method is used to store acetylene safely in cylinders as given below.

The cylinders are filled with porous substances such as:

- pith from corm stalk
- fullers earth
- lime silica
- specially prepared charcoal
- Fiber asbestos.

The hydrocarbon liquid named acetone is then charged in the cylinder, which fills the porous substances (1/3rd of total volume of the cylinder).

Acetylene gas is then charged in the cylinder, under a pressure of app. 15 kg//cm^2.

The liquid acetone dissolves the acetylene gas in large quantity as safe storage medium: hence, it is called dissolved acetylene. One volume of liquid acetone can dissolve 25 volumes of acetylene gas under normal atmospheric pressure and temperature. During the gas charging operation one volume of liquid acetone dissolves 25X15=375 volumes of acetylene gas under 15kg/cm^2 pressure at normal temperature. While charging cold water will be sprayed over the cylinder so that the temperature inside the cylinder does not cross certain limit.

Welding gas regulator I & II stage and uses

Objectives: At the end of this lesson you shall be able to
- **state the different types of regulators**
- **describe the working principle of a single and double stage regulator and uses**

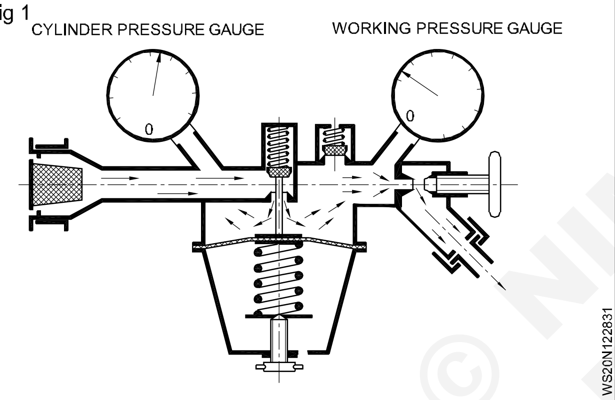
Types of regulators

- single stage regulator
- Double stage regulator

Welding regulator (Single stage)

Working principle: When the spindle of the cylinder is opened slowly, the high pressure gas from the cylinder enters into the regulator through the inlet valve. (Fig 1)

Fig 1



The gas then enters the body of the regulator which is controlled by the needle valve. The pressure inside the regulator rises which pushes the diaphragm and the valve to which it is attached, closes the valve and prevents any more gas from entering the regulator.

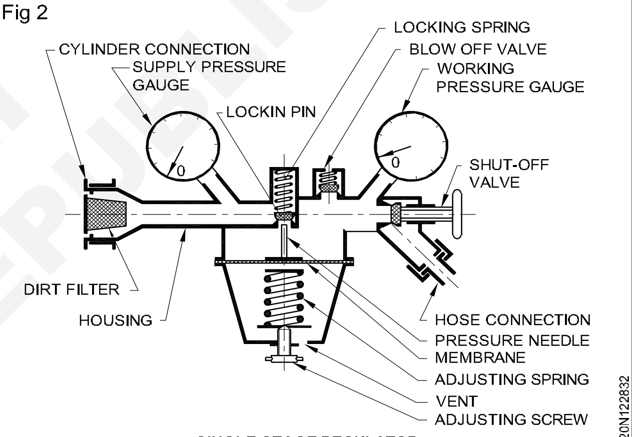
The outlet side is fitted with a pressure gauge which indicates the working pressure on the blowpipe. Upon the gas being drawn 'off from the outlet side, the pressure inside the regulator body falls, the diaphragm is pushed back by the spring and the valve opens, letting more gas 'in' from the cylinder. The pressure in the body, therefore, depends on the pressure of the springs and this can be adjusted by means of a regulator knob. (Fig 2)

Welding regulator (double stage)

Working principle: The two-stage regulator (Fig 3) is nothing but two regulators in one which operates to reduce the pressure progressively in two stages instead of one. The first stage, which is pre-set, reduces the pressure of the cylinder to an intermediate stage (i.e) 5 kg/mm^2 and gas at that pressure passes into the second stage, the gas now emerges at a pressure (Working pressure) set by the pressure adjusting control knob attached to the diaphragm. Two-stage regulators have two safety valves, so that if there is any excess pressure there will be no explosion. A major objection to the single stage regulator is the need for frequent torch adjustment, for as the cylinder pressure falls the regulator pressure likewise falls necessitating torch adjustment. In the two stage regulator, there is automatic compensation for any drop in the cylinder pressure.

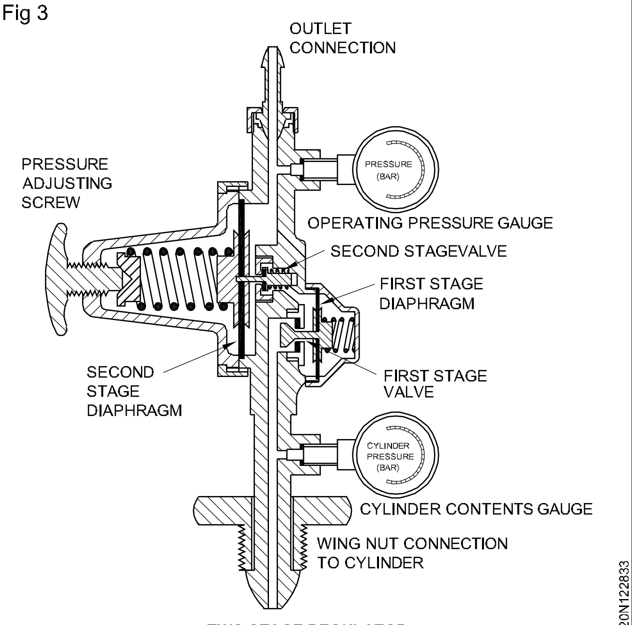
Single stage regulators may be used with pipelines and cylinders. Two stage regulators are used with cylinders and manifolds.

Fig 2



SINGLE STAGE REGULATOR

Fig 3



TWO STAGE REGULATOR

Oxy acetylene gas welding Systems (Low pressure and High pressure). Difference between gas welding blow pipe

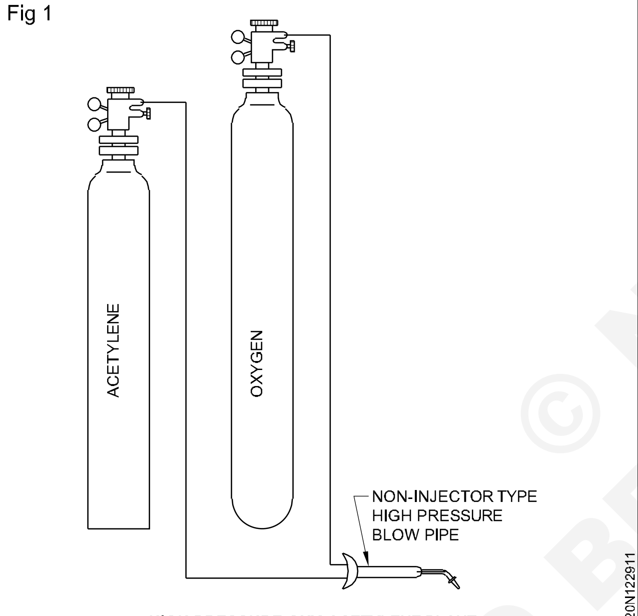
Objectives : At the end of this lesson you shall be able to
- **explain the low pressure and the high pressure systems of oxy-acetylene plants and systems**
- **distinguish between low pressure and high pressure blowpipes and cutting blow pipe.**

Oxy-acetylene plants: An oxy-acetylene plant can be classified into:

- high pressure plant
- low pressure plant.

A high pressure plant utilises acetylene under high pressure (15 kg/cm^2). (Fig 1)

Fig 1



HIGH PRESSURE OXY-ACETYLENE PLANT

Dissolved acetylene (acetylene in cylinder) is the commonly used source.

Acetylene generated from a high pressure generator is not commonly used.

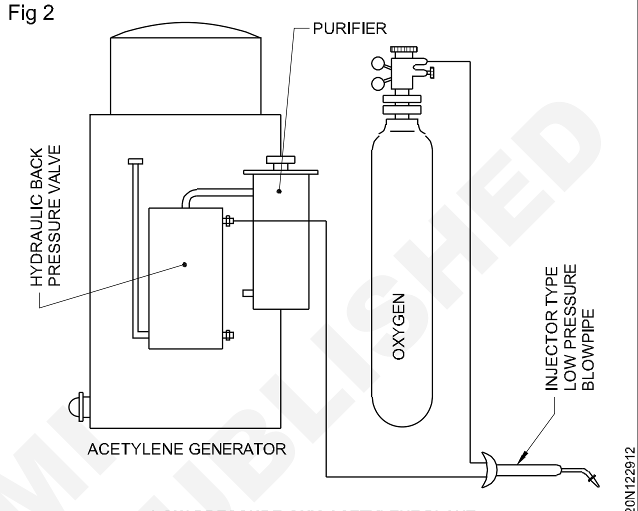
A low pressure plant utilizes acetylene under low pressure (0.017 kg/cm^2) produced by the acetylene generator only. (Fig 2)

High pressure and low pressure plants utilize oxygen gas kept in compressed high pressure cylinders only at 120 to 150 kg/cm^2 pressure.

Oxy acetylene systems: A high pressure oxy-acetylene plant is also called a high pressure system.

A low pressure acetylene plant with a low pressure acetylene generator and a high pressure oxygen cylinder is called a low pressure system.

Fig 2



LOW PRESSURE OXY-ACETYLENE PLANT

The terms low pressure and high pressure systems used in oxy-acetylene welding refer only to acetylene pressure, high or low.

Types of blowpipes: For the low pressure system, a specially designed injector types blowpipe is required, which may be used for high pressure system also.

In the high pressure system, a mixer type high pressure blowpipe is used which is not suitable for the low pressure system.

To avoid the danger of high pressure oxygen entering into the acetylene pipeline an injector is used in a low pressure blowpipe. In addition a non-return valve is also used in the blowpipe connection on the acetylene hose. As a further precaution to prevent the acetylene generator from exploding, a hydraulic back pressure valve is used between the acetylene generator and the blowpipe.

Types

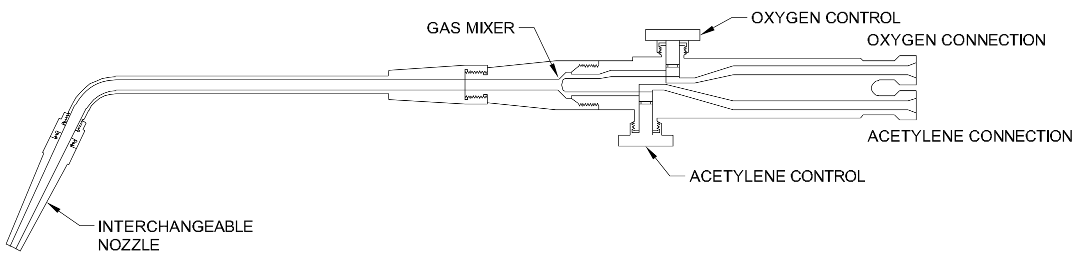
There are two types of blowpipes.

- High pressure blowpipe or non-injector types blowpipe
- Low pressure blowpipe or injector type blowpipe.

Uses of blow pipes: Each type consists of a variety of designs depending on the work for which the blowpipe is required, i,e., gas welding, brazing, very thin sheet welding, heating before and after welding, gas cutting.

Equal or high pressure blowpipe (Fig 1): The H.P. blowpipe is simply a mixing device to supply approximately equal volume of oxygen and acetylene to the tip, and is fitted with valves to control the flow of the gases as required i.e, the blow pipes/gas welding torches are used for welding of ferrous and non-ferrous metals, joining thin sheets by fusing the edges, preheating and post heating of jobs, brazing, for removing the dents formed by distortion and for gas cutting using a cutting blow pipe.

Fig 1

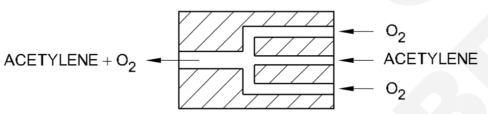


EQUAL OR HIGH PRESSURE BLOWPIPE

The equal pressure blow pipe (Fig.1) consists of two inlet connections for acetylene and oxygen gases kept in high pressure cylinders. Two control valves to control the quantity of flow of the gases and a body inside which the gases are mixed in the mixing chamber (Fig.2). The mixed gases flow through a neck pipe to the nozzle and then get ignited at the tip of the nozzle. Since the pressure of the oxygen and acetylene gases are set at the same pressure of 0.15 kg/cm^2 they mix together at the mixing chamber and flows through the blow pipe to the nozzle tip on its own. This equal pressure blow pipe/torch is also called as high pressure blow pipe/torch because this is used in the high pressure system of gas welding.

Fig 2

GAS PASSAGE IN THE GAS MIXING SECTION



EQUAL PRESSURE TYPE TORCH

A set of nozzles is supplied with each blowpipe, the nozzles having holes varying in diameters, and thus giving various sized flames. The nozzles are numbered with their consumption of gas in litres per hour.

Important caution: A high pressure blowpipe should not be used on a low pressure system.

Low pressure blowpipe (Fig 3)

This blowpipe has an injector (Fig 3) inside its body through which the high pressure oxygen passes. This oxygen draws the low pressure acetylene from an acetylene generator into a mixing chamber and gives it the necessary helps to prevent backfiring.

The low pressure blow pipe is similar to the equal pressure blow pipe except that inside its body an injector with a very small (narrow) hole in its center through which high pressure oxygen is passed. This high pressure oxygen while coming out of the injector creates a vacuum in the mixing chamber and sucks the low pressure acetylene from the gas generator (Fig 4)

It is usual for the whole head to be interchangeable in this type, the head containing both the nozzle and injector. This is necessary, since there is a corresponding injector size for each nozzle.

The L.P. blowpipe is more expensive than the H.P. blowpipe but it can be used on a high pressure system, if required.

Welding technique of oxy-acetylene welding

Objectives: At the end of this lesson you shall be able to
- **name the different gas welding techniques and explain the leftward and rightward welding techniques**
- **describe the edge preparation and application of leftward techniques.**

There are two welding techniques on oxy-acetylene welding process. They are:

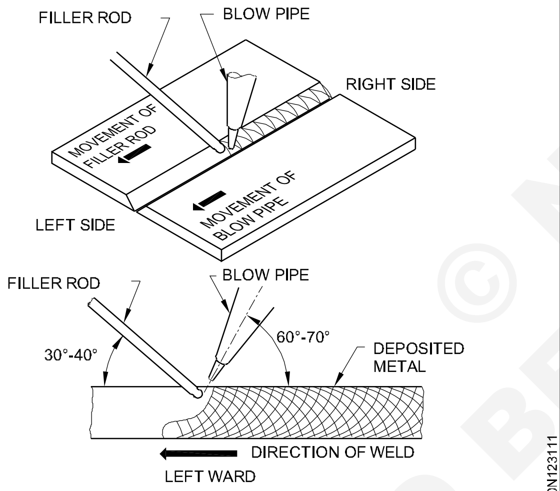
1 Leftward welding technique (Forehand technique)

2 Rightward welding technique (Backhand technique)

The leftward technique is explained below. For details of rightward technique refer Related Theory for exercise 2..6.

Leftward welding technique: It is the most widely used oxy-acetylene gas welding technique in which the welding commences at the right hand edge of the welding job and proceeds towards the left. It is also called forward or forehand technique. (Fig 1)

Fig 1



LEFT WARD WELDING TECHNIQUE

In this case welding is started at the right hand edge of the job and proceeds towards the left. The blowpipe is held at an angle of 60°-70° with the welding line. The filler rod is held at an angle of 30°-40° with the welding line. The welding blowpipe follows the welding rod. The welding flame is directed away from the deposited weld metal.

The blowpipe is given a circular or side-to-side motion to obtain even fusion on each side of the joint.

The filler rod is added in the (Weld) molten pool by a piston like motion and not melted off by the flame itself.

> **If the flame is used to melt the welding rod itself into the pool, the temperature of the molten pool will be reduced and consequently good fusion cannot be obtained.**

Table 1

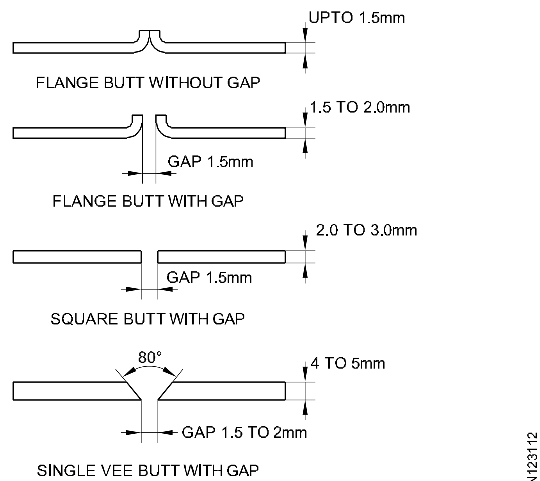
The table given below shows the details for welding mild steel by leftward technique (For Butt joints)

Metal thickness in mm	C.C.M.S filler rod diameter in mm	Blow pipe nozzle size	Edge preparation	Root gap in mm	Flux to be used
0.8	1.6	1	Flange	NIL	
1.6 to 2	1.6	3	Square	2	For gas welding of mild steel no flux is required to be used
2.5	2	5	Square	2	
3.15	2.5	7	Square	3	
4	3.15	7	80°Vee	3	
5	3.15	13	80°Vee	3	

Edge preparation for leftward technique: For fillet joints square edge preparation is done.

For butt joints the edges are prepared as shown in Fig 2. the table given below gives the details for welding mild steel by leftward technique for butt joints.

Fig 2



EDGE PREPARATION FOR LEFTWARD TECHNIQUE

> **For fillet joints one size larger nozzle is to be used.**

Above 5.0 mm thickness, the rightward technique should be used.

Application

This technique is used for the welding of:

- mild steel up to 5mm thick
- all metals both ferrous and non-ferrous.

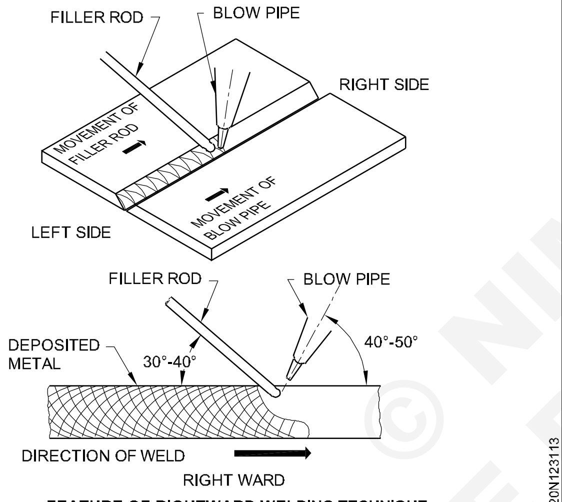
Rightward welding technique: It is an oxy-acetylene gas welding technique, in which the welding is begun at the left hand edge of the welding job and it proceeds towards the right.

This technique was developed to assist the production work on thick steel plates (Above 5mm) so as to produce economic welds of good quality.

It is also called backward or back hand technique.

the following are its features. (Fig 3)

Fig 3



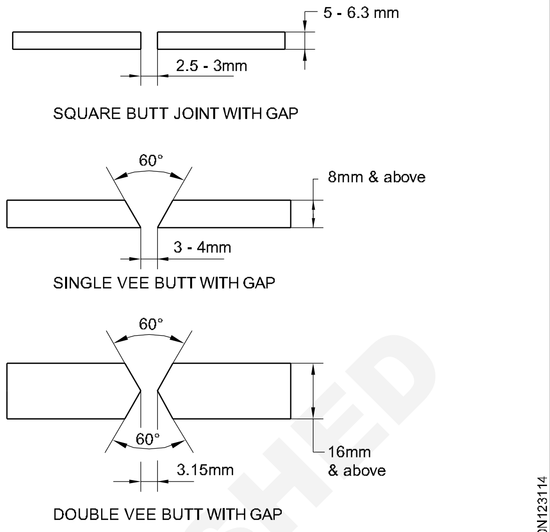
FEATURE OF RIGHTWARD WELDING TECHNIQUE

Welding is commenced at the left hand edge of the job and it proceeds to the right. The blowpipe is held at an angle of 40° - 50° with the welding line. The filler rod is held at an angle of 30° - 40° with the welding line. The filler rod follows the welding blowpipe. The welding flame is directed towards the deposited weld metal.

The filler rod is given a rotational or circular loop motion in the forward direction. The blowpipe moves back in a straight line steadily towards the right. This technique generates more heat for fusion, which makes it economical for thick steel plate welding.

Edge preparation for rightward technique (Fig 4)

Fig 4



EDGE PREPARATION FOR RIGHTWARD WELDING

For butt joints the edges are prepared as shown in Fig 2.

The table given below gives the details for welding mild steel by rightward welding technique for Butt joints.

Application: This technique is used for the welding of steel above 5mm thickness and 'LINDE' WELDING PROCESS of sheet pipes.

Advantage: Less cost per length run of the weld due to less bevel angle, less filler rod being used, and increased speed. Welds are made much faster.

It is easy to control the distortion due to less expansion and contraction of a smaller volume of molten metal. The flame being directed towards the deposited metal, is allowed to cool slowly and uniformly. Greater annealing action of the flame on the weld metal as it is always directed towards the deposited metal during welding.

We can have a better view of the molten pool giving a better control of the weld which results in more penetration. The oxidation effect on the motion metal is minimized as the reducing zone of the flame provides continuous coverage.

Table 1 (For Butt joints)

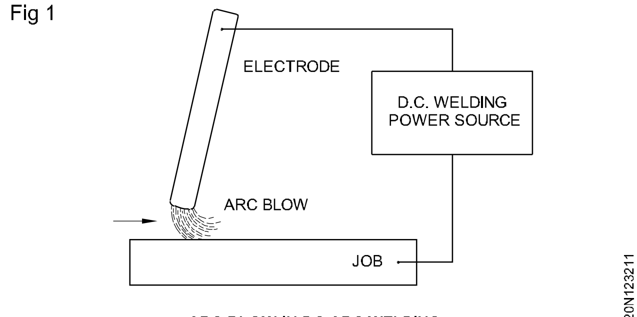
Metal thickness in mm	C.C.M.S filler rod diameter in mm	Blow pipe nozzle size	Edge preparation	Root gap in mm	Flux to be used
5	3.15	10	Square	2.5	For gas
6.3	4.0	13	Square	3.0	welding of mild
8	5.0	18	60° Vee	3.0	steel no flux
10 to 16	6.3	18	60° Vee	4.0	is required to
Above 16	6.3	25	60° double Vee	3.0	be used

Arc blow its causes and methods of controlling

Objectives : At the end of this lesson you shall be able to
- **explain the arc blow in DC welding**
- **explain the effects of arc blow on welds**
- **describe the various methods used to control the arc blow.**

Arc blow in dc welding: When the arc deviates from its regular path due to the magnetic disturbances it is called 'Arc blow'. (Fig 1)

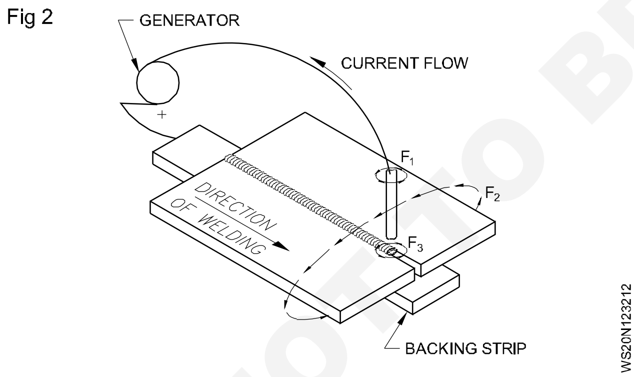
Fig 1



ARC BLOW IN DC ARC WELDING

Causes and effects of arc blow: Whenever a current flows in the electrode a magnetic field is formed around the electrode and the arc F_1 and F_3 (Fig 2). Likewise a similar magnetic field is also formed around the base metal F_2 (Fig 2). Due to the interaction of these two magnetic fields, the arc is blown to one side of the joint. At the starting of the weld there will be forward blow and at the end backward blow. (Fig 3)

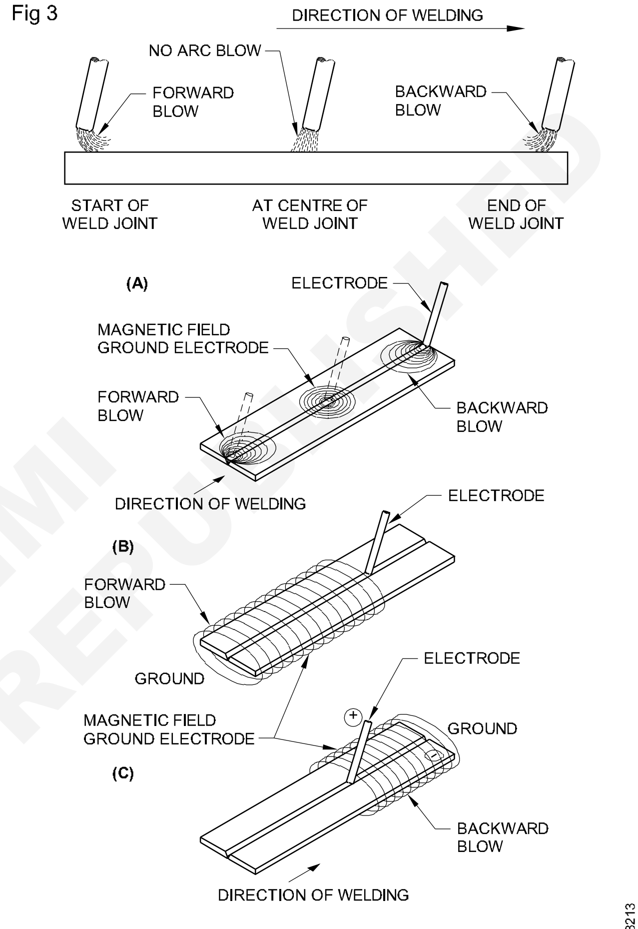
Fig 2



Due to this the following effects occur.

- more spatters with less deposition of weld metal.
- poor fusion/penetration.
- weak welds.
- Difficulty in depositing weld metal at the required place in the joint.
- The bead appearance will be poor and slag inclusion defect will also take place.

Fig 3



MAGNETIC FIELDS THAT RESULT IN FORWARD OR BACKWARD ARC BLOW (A) AROUND THE ELECTRODE/ARC (B) AND (C) AROUND THE WORK

Methods used to control the arc blow

The arc blow can be controlled by:

- Place the earth connection as far from the weld joint as possible. (Fig 4)
- changing the position of the earth connection on the work.
- Changing the position of the work on the welding table.
- wrapping the electrode cable around the work. (Fig 5)
- welding towards a heavy welding tack or a weld already made.

Fig 4

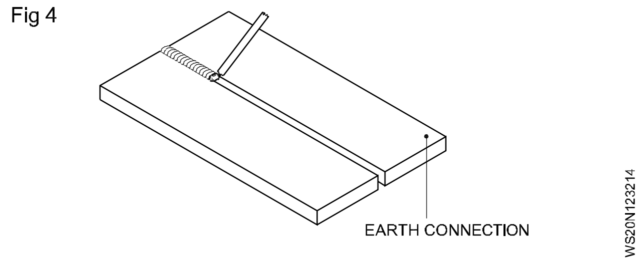
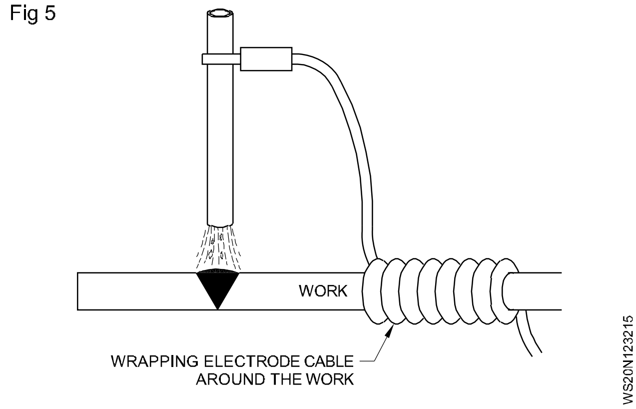


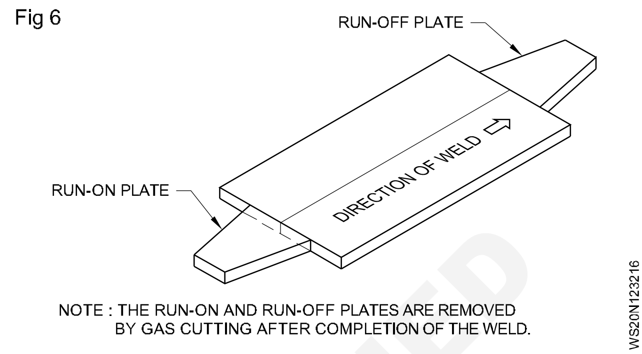
Fig 5



- keeping a magnetic bridge on the top of the groove joint.
- holding the correct electrode angle with a short arc. use 'run on' and 'run off plates. (Fig 6)

If all the above methods fail to control the 'arc blow', change to AC supply.

Fig 6

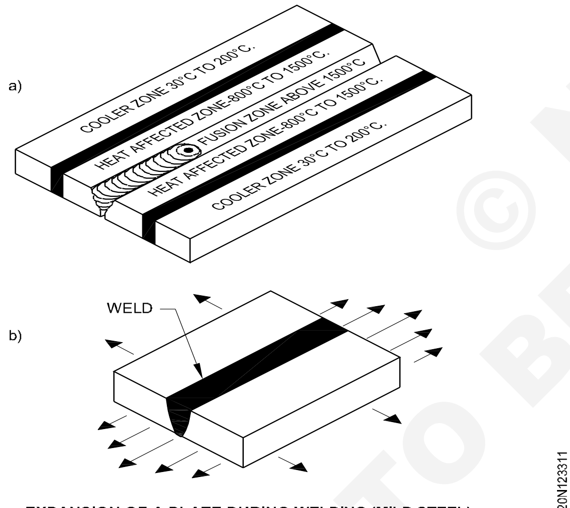


Distortion in arc & gas metal welding and methods employed to minimize distortion

Objectives : At the end of this lesson you shall be able to
- **explain the causes of distortion**
- **describe the types of distortion**
- **explain the methods of preventing distortion**
- **explain the methods of correcting distortion.**

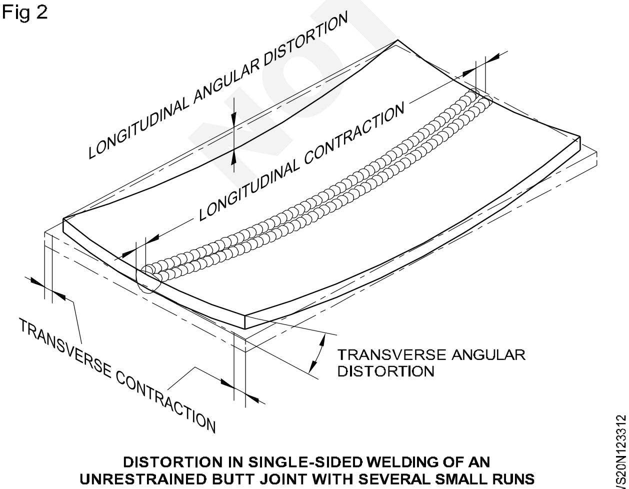
Causes of distortion: In arc welding, the temperature at different areas of the joint are different. (Fig 1a). The expansions in these areas are also different depending on the temperature (Fig 1b). In the same way after welding, different areas of the joint contract differently, But in a solid body (i.e., the parent metal) it cannot expand or contract differently at different areas. This uneven expansion and contraction of the welded joint due to uneven heating and cooling in welding creates stresses in the joint. These stresses make the welded job to change its size and shape permanently (i.e. deformation) and this is called distortion of the welded joint. (Fig 2)

Fig 1



EXPANSION OF A PLATE DURING WELDING (MILD STEEL)

Fig 2



DISTORTION IN SINGLE-SIDED WELDING OF AN UNRESTRAINED BUTT JOINT WITH SEVERAL SMALL RUNS

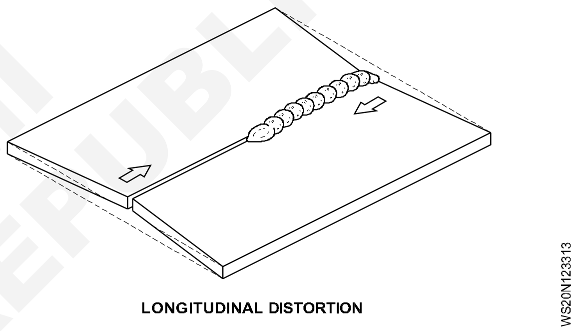
Types of distortion

The 3 types of distortion are:

- longitudinal distortion
- transverse distortion
- angular distortion.

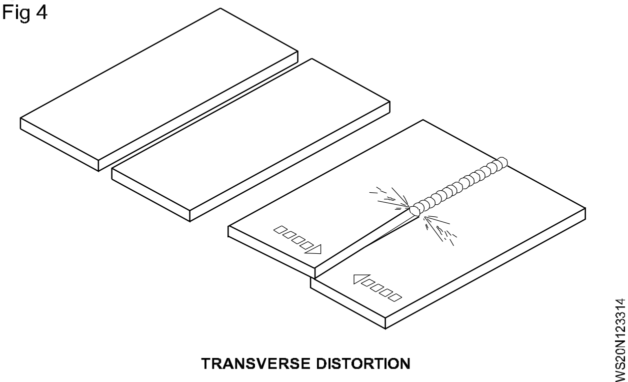
The figures (3,4,5) illustrate the different types of distortion.

Fig 3



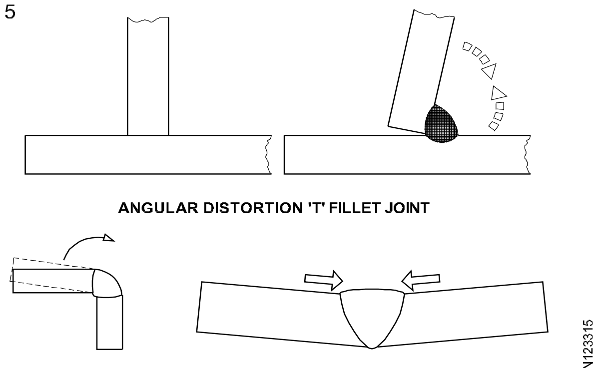
LONGITUDINAL DISTORTION

Fig 4



TRANSVERSE DISTORTION

Fig 5



OUTSIDE CORNER JOINT SINGLE 'V' BUTT JOINT

Factors affecting distortion

Design

Parent metal

Joint preparation and set up

Assembly procedure

Welding process

Deposition technique

Welding sequence

Unbalanced heating about the neutral axis

Restraint imposed

Either one or more of these above factors are responsible for distortion, in a welded job. To avoid or reduce the distortion in a welding job these factors are to be taken care of-before, during and after welding. The methods adopted to avoid or reduce distortion are as follows.

Prevention of distortion: The following methods are used to prevent and control distortion.

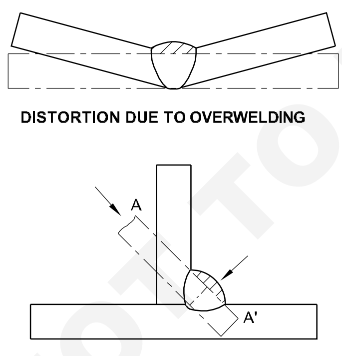
- Reducing the effective shrinkage force.
- Making the shrinkage forces to reduce distortion.
- Balancing the shrinkage force with another shrinkage force.

Methods of reducing the effective shrinkage forces

Avoiding over-welding/Excessive reinforcement: Excessive build up in the case of butt welds and fillet welds should be avoided. (Fig 6)

The permissible value of reinforcement in groove and fillet welds is T/10 where "T" is thickness of parent metal.

Fig 6

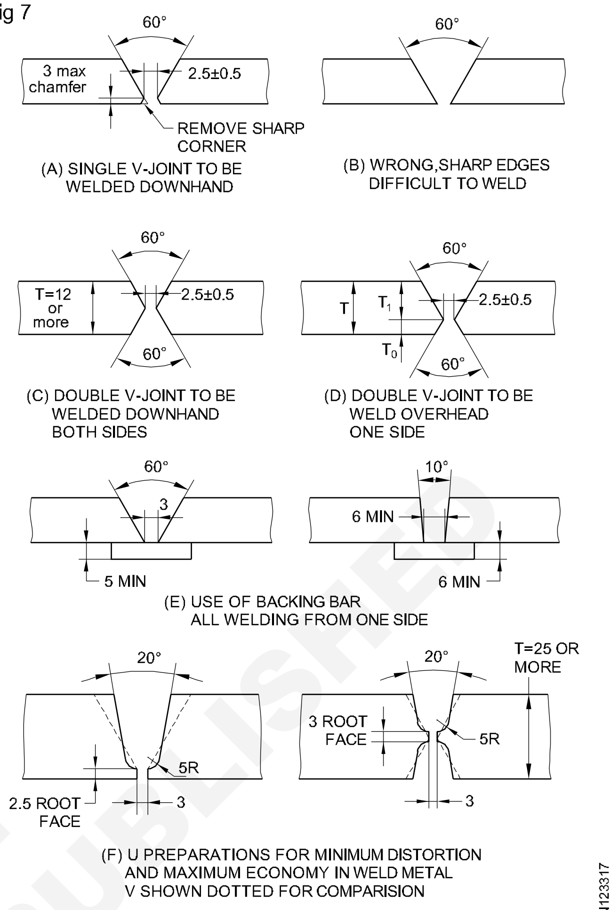


EXCESS WELD METAL ABOVE THE LINE A A' OF CONVENTIONAL FILLET WELD

Use of proper edge preparation and fit up: It is possible to reduce the effective shrinkage force by correct edge preparation. This will ensure proper fusion at the root of the weld with a minimum of weld metal. (Fig 7)

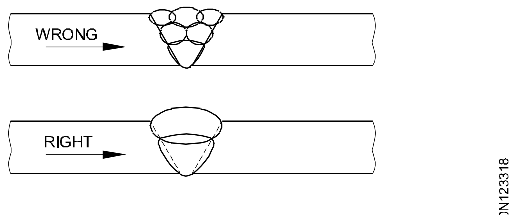
Use of few passes: Use of fewer passes with large dia. electrodes reduces distortion in the lateral direction. (Fig8)

Fig 7



PREPARATION OF PLATES FOR BUTT WELDING

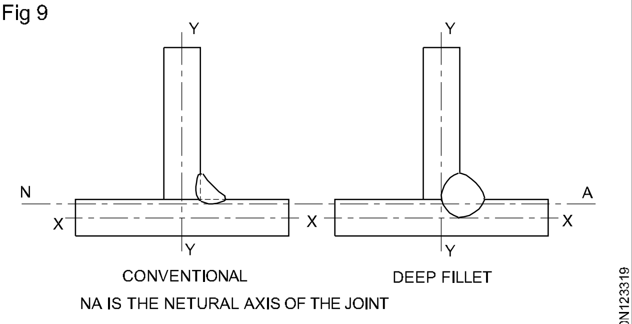
Fig 8



COMPARISION OF PASSES OF WELD

use of deep fillet weld: Place the weld as possible to the neutral axis by using the deep fillet method. This will reduce the leverage of pulling the plates out of alignment. (Fig 9)

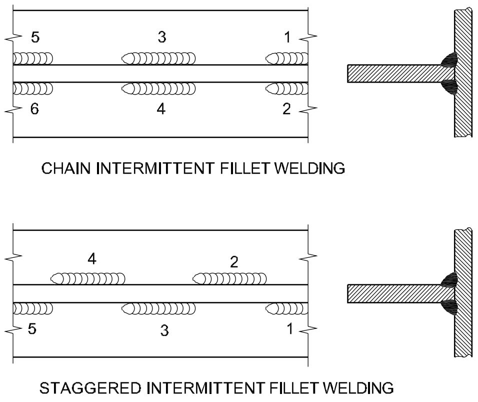
Fig 9



DEEP PENETRATION FILLET WELD

Use of intermittent welds: Minimize the amount of weld metal with the help of intermittent welds instead of continuous welds. This can be used with fillet welds only. (Fig 10)

Fig 10

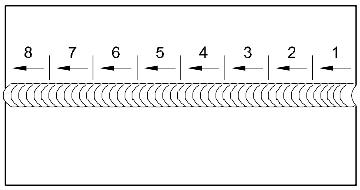


INTERMITTENT WELDING

WS20N12331A

Use of 'back step' welding method: The general direction of welding progression is from left to right. But in this method each short bead is deposited from right to left. In this method. the plates expand to a lesser degree with each bead because of the locking effect of each weld. (Fig 11)

Fig 11



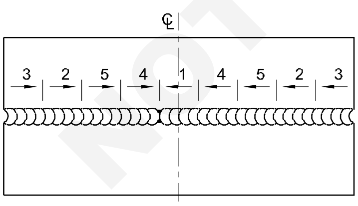
BACK STEP WELDING METHOD

WS20N12331B

Welding from center: Welding of long joints from center outwards breaks up the progressive effect of high stresses on continuous weld.

Use of planned wandering method: In this method welding starts at the center, and thereafter portions are completed on each side of the center in turn. (Fig 12)

Fig 12

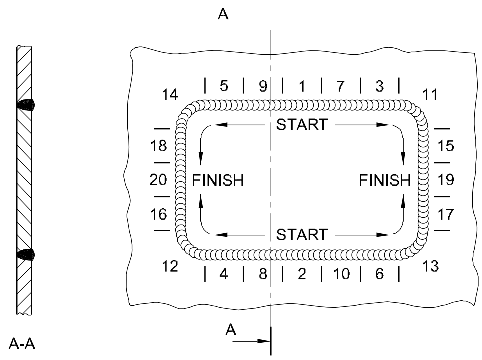


PLANNED WANDERING METHOD

WS20N12331C

Use of skip welding: In this method, the weld is made not longer than 75 mm at one time. Skip welding reduces locked up stresses and warping due to more uniform distribution of heat. (Fig 13)

Fig 13



AS USED TO MINIMIZE LOCKED UP STRESSES IN TIED JOINT

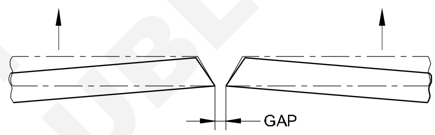
SKIP WELDING

WS20N12331D

Methods used for making the shrinkage forces work to reduce distortion

Locating parts out of position: Distortion may be allowed for by pre-setting the plates in the opposite way so that the weld pulls them to the desired shape. When the weld shrinks it will pull the plate to its correct position (Fig 14 & 15)

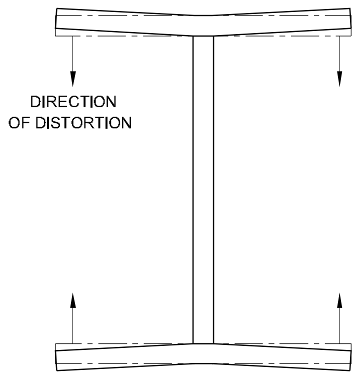
Fig 14



PRE-SETTING TO COMPENSATE FOR ANGULAR DISTORTION

WS20N12331E

Fig 15

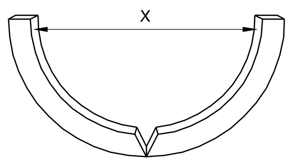


PRE-CAMBERING TO COMPENSATE FOR ANGULAR DISTORTION

WS20N12331F

Spacing of parts to allow for shrinkage: Correct spacing of the parts prior to welding is necessary. This will allow the parts to be pulled in correct position by the shrinkage force of the welding. (Fig 16)

Fig 16



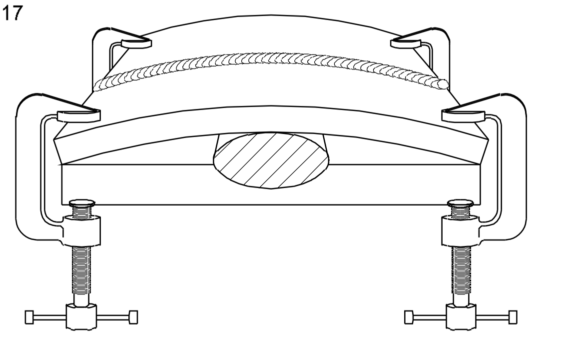
X = DIAMETER + SHRINKAGE ALLOWANCE

SPACING OF PARTS TO ALLOW FOR SHRINKAGE

WS20N12331G

Pre-bending: Shrinkage forces may be put to work in many cases by pre-bending. (Fig 17)

Fig 17

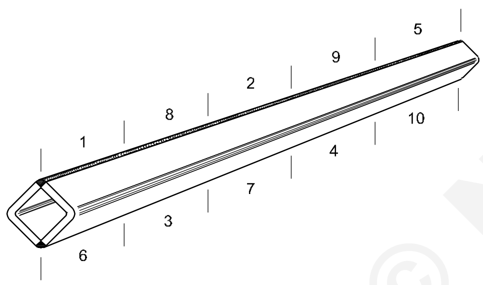


PRE-BENDING

Methods of balancing of one shrinkage force with another shrinkage force

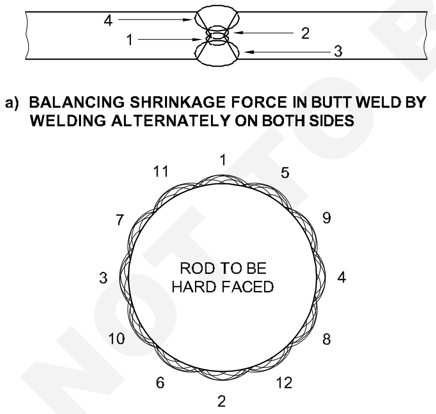
Use of proper welding sequence: This places the weld metal at different points about the structure. In this method, welds are made from each side alternately so that when a second run of weld metal shrinks it will counteract the shrinkage forces of the first weld. (Figs 18, 19 a and 19b)

Fig 18



AS USED WHEN FABRICATING SQUARE SECTIONS FROM ANGLES OR CHANNELS

Fig 19

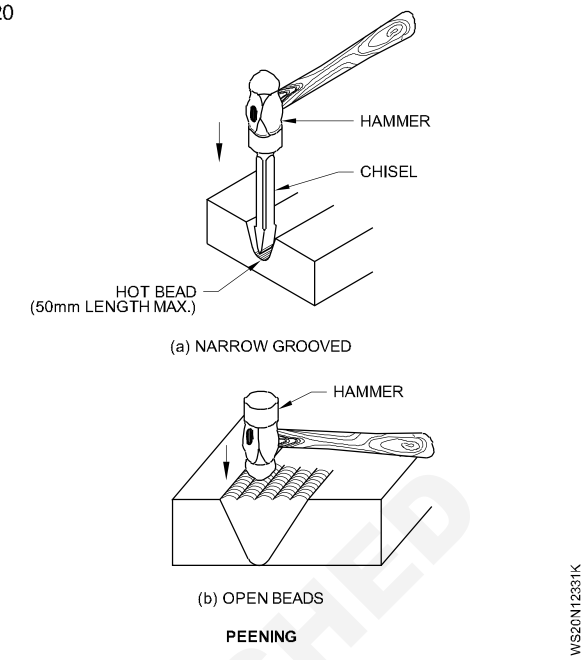


a) BALANCING SHRINKAGE FORCE IN BUTT WELD BY WELDING ALTERNATELY ON BOTH SIDES

b) SEQUENCE WELDING USED TO CONTROL DISTORTION IN HARD FACING OPERATION

Peening: This is light hammering of the weld metal immediately after it is deposited. By peening the bead, it is actually stretched counteracting its tendency to contract as it cools. Fig 20.

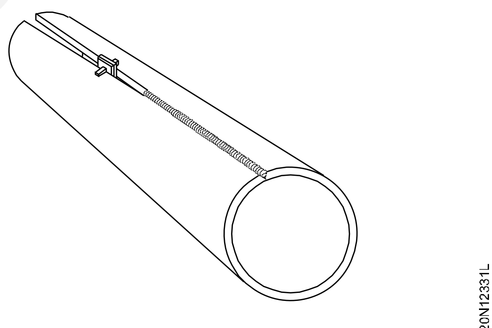
Fig 20



PEENING

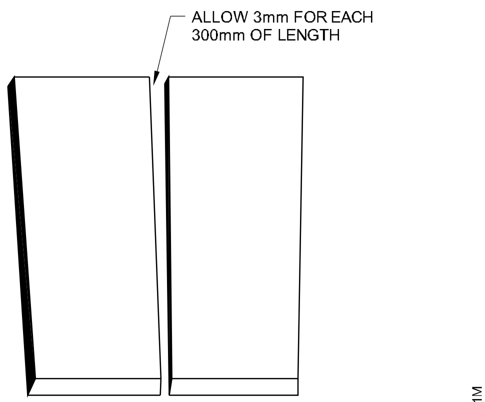
Divergence allowance: As there is a tendency of the plates to extend & converge along the seam during welding, this technique is used to diverge the plates from the point where welding commences by placing a wedge or an alignment clamp between the plates ahead of the weld. (Fig 21& 22)

Fig 21



DIVERGENCE ALLOWANCE

Fig 22



PROVIDE SPACE BETWEEN THE EDGES TO BE WELDED

DIVERGING ALLOWANCE

The spacing allowances are as follows.

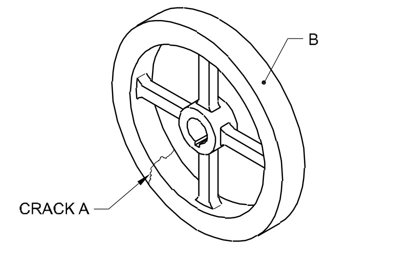
3mm/m for (mild steel) Ferrous metals

10 mm/m for non ferrous metals

While cooling, the shrinkage stresses will pull the plate in correct alignment.

Preheating: Some metals would normally fracture if welded in the cold state. They may be welded successfully by preheating and subsequent controlled cooling. (Fig 23)

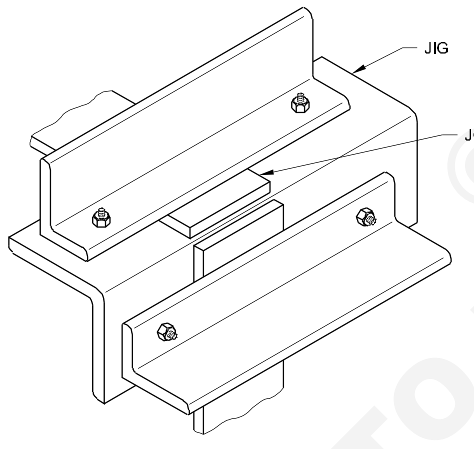
Fig 23



TECHNIQUE OF LOCAL PREHEATING

Jigs and fixtures: Jigs and fixtures are used to hold the work in a right position during welding. By using them the shrinkage forces of the weld are balanced with sufficient counter force of the jigs and fixtures. (Fig 24)

Fig 24



USE OF JIGS AND FIXTURES TO AVOID DISTORTION

Tack-welding: A tack weld is a short weld made prior to welding to hold the plates in perfect alignment and with uniform root gap. Tack welds are made at regular intervals along the joint with high current to obtain proper penetration. (Fig 25) They are necessary where the plates cannot be held by a fixture. (Fig 26)

Methods of correcting distortion: Distortion may take place even after following a planned procedure as it is difficult to control distortion to the full extent. So some mechanical means and application of heat are used to remove distortion after it occurs.

Mechanical methods: Small parts, deformed by angular distortion can be straightened by using a press. If the parts of the assembly are not restrained, they can be brought into alignment by hammering, drifting or jacking without giving excessive force (stress}.

Fig 25

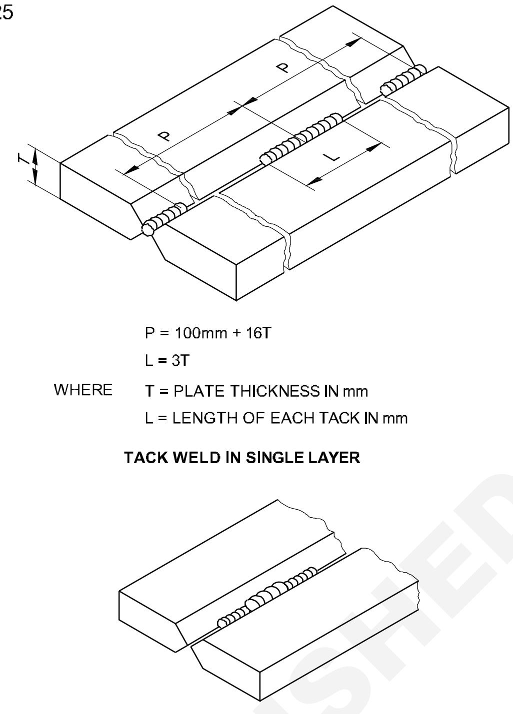
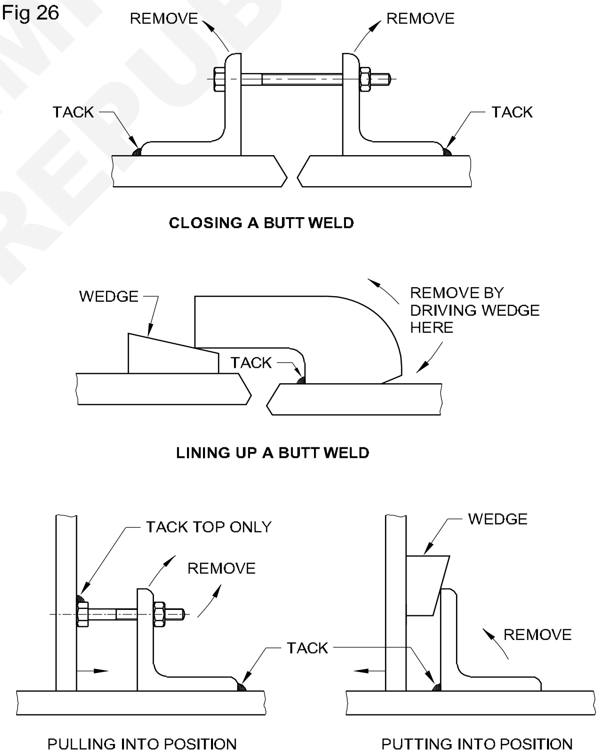


Fig 26



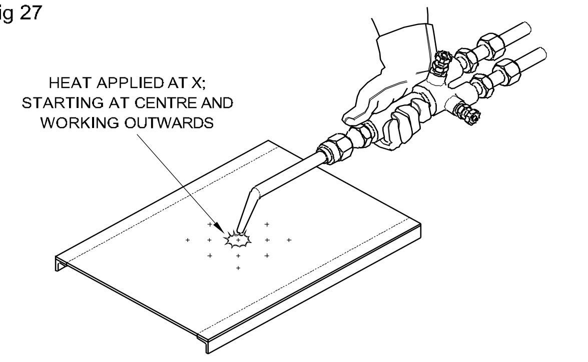
TACK WELDING ERECTION CLEATS AND AIDS TO ASSEMBLY

Heating methods: The distorted part is heated locally and rapidly keeping the surrounding metal reasonably cool.

Heat small areas at a time. It should not exceed bright red hot condition.

If thin plates are buckled they can be corrected by local spot heating on the convex side. Starting at the center of the buckled area heat symmetrically outwards as shown in Fig 27.

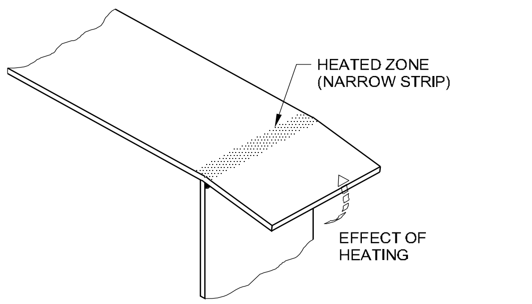
Fig 27



SPOT HEATING TO CORRECT BUCKING OF THIN SHEET

Correction of distortion caused by fillet welds is done by local heating on the underside of the plate in a narrow strip following the line of the joint. (Fig 28)

Fig 28



CORRECTION OF DISTORTION CAUSED BY FILLET WELD

Straightening by flame heating: The most common distortion-removal technique is to use a flame and heat the part at selected spots or along certain lines and then to aircool it. The area to be straightened is heated to between 600 and 650°C for plain carbon and low alloy steels and suddenly cooled in air, or if necessary with a spray of water in low carbon steels.

The methods of flame straightening are shown in Fig 29.

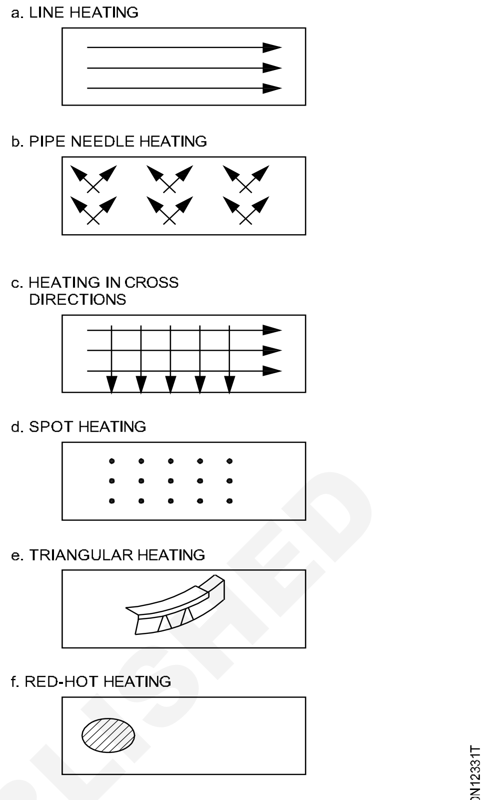
In Line heating (Fig 29a) heat from the torch is applied along a line or a set of parallel lines. This method is frequently used for removing the angular distortion produced by the fillet welds attaching a plate to its stiffener.

In pipe-needle (Fig 29b) heating, heat is applied along two short lines crossing each other. This method is half way between line heating and spot heating. Since the shrinkage and angular distortion occur in two directions, this method produces a uniform distortion-removal effect.

In checker board (cross-directions) heating, (Fig 29c) heat is applied along a pair of two lines crossing each other. This method is used to remove severe distortion.

In spot heating. (Fig 29e) heat is applied on a wedge shaped area, and this method is useful for the removal of bending distortion in frames.

Fig 29



METHODS OF FLAME-STRAIGHTENING

In triangular heating (Fig 29e) heat is applied on a wedge shaped area, and this method is useful for the removal of bending distortion in frames.

Red hot heating (Fig 29f) is used when severe distortion has occurred in a localised area, and it may be necessary to heat the area to a high temperature and beat it with a hammer. This method can cause metallurgical changes.

Thermal treatments: To reduce distortion, various thermal treatments are done. They include preheat and post weld thermal treatments.

Preheating: Weld shrinkage is generally reduced by preheating. Actual measurements across welds during cooling have shown that less than 30% total contraction occurred in joints preheated to 200°C, compared to non-preheating joints.

Stress relief: In many cases thermal stress relief is necessary to prevent further distortion being developed before the weldment is brought to its finished state. Residual tensile stress in welds are always balanced by compressive residual stresses. If a considerable portion of the stressed material is machined out, a new balance of residual stress will result, causing new distortion. Weld stress-relieving prior to machining is thus very important for prolonged dimensional accuracy of sliding and rotating parts.

ARC Welding defects causes and remedies

Objectives: At the end of this lesson you shall be able to
- **name different weld defects in arc welded joints**
- **define weld defect**
- **state the effect of defects on the welded joints**
- **differentiate between external and internal defects.**

Introduction: The strength of a welded joint should be more than or equal to the strength of the base metal. If any weld defect is in a welded joint, then the joint becomes weaker than the base metal. This is not acceptable.

So a strong or good weld should have uniformly rippled surface, even contour, bead width, good penetration and should not have defect.

Definition of a weld defect/fault: A defect or fault is one which does not allow the finished joint to withstand or carry the required load.

Effects of weld defect/fault: Always a defective welded joint will have the following bad effects.

– The effective thickness of the base metal is reduced.
– The strength of the weld is reduced
– The effective throat thickness is reduced
– The joint will break, when loaded, causing accident.
– The properties of base metal will change.
– More electrodes are required which will also increase the cost of welding.
– Waste of labour and materials.
– The weld appearance will be poor.

Since the weld defects will give bad effects on the joint, always proper care and action has to be taken before and during welding to avoid/prevent the defects. If the defects have already taken place then proper action has to be taken to correct/rectify the defect after welding.

The action/measure taken to avoid/prevent and correct/rectify a weld defect is also called as a remedy.

So some remedies may help to avoid/prevent a weld defect and some remedies may help to correct/rectify a weld defect which has already taken place.

Weld defect may be considered under two heads.

– External defects
– Internal defects

The defects which can be seen with bare eyes or with a lens on the top of the weld bed, or on the base metal surface or on the root side of the joint are called external defects.

Those defects, which are hidden inside the weld bead or inside the base metal surface and which cannot be seen with bare eyes or lens are called internal defects.

Some of the weld defects are external defects, some are internal defects and some defects like crack, blow hole and porosity, slag inclusion, lack of root penetration in fillet joints, etc. will occur both as external and internal defects.

External defects

1 Undercut
2 Cracks
3 Blow hole and porosity
4 Slag inclusions
5 Edge plate melted off
6 Excessive convexity/Oversized weld/Excessive reinforcement
7 Excessive concavity/insufficient throat thickness/insufficient fill
8 Incomplete root penetration/lack of penetration
9 Excessive root penetration
10 Overlap
11 Mismatch
12 Uneven/irregular bead appearance
13 Spatters

Internal defects

1 Cracks
2 Blow hole and porosity
3 Slag inclusions
4 Lack of fusion
5 Lack of root penetration
6 Internal stresses or locked-up stresses or restrained joint.

Defects in arc Welding - Definition, Causes and Remedies

Objectives: At the end of this lesson you shall be able to
- **define common weld defects in arc welded joints**
- **describe the causes, remedies and corrections of weld defects.**

A sound or good weld will have uniformly rippled surface, even contour, bead width, good penetration and no defects.

Definition of a defect: A defect is one which does not allow the finished joint to withstand the required strength (load).

Causes for weld defects means wrong actions taken which creates the defect.

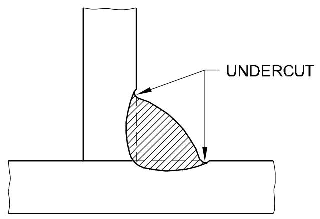
A remedy can be

a Preventing the defect by taking proper actions before and during welding.

b Taking some corrective actions after welding to rectify a defect which has already taken place.

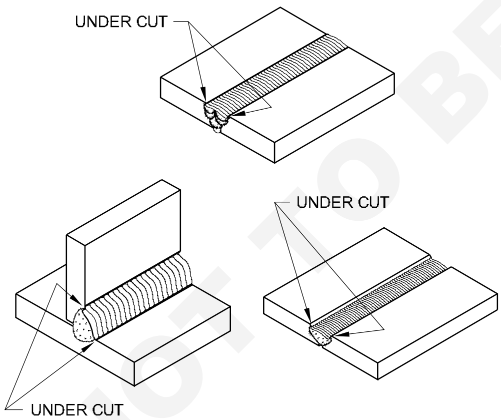
Undercut: A grooved or channel formed in the parent metal at the toe of the weld. (Figs 1, 2 & 3)

Fig 1



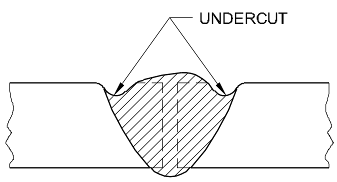
TEE-JOINT FILLET WELD

Fig 2



A SCHEMATIC DIAGRAM OF UNDERCUTS IN FILLET AND BUTT WELDS.

Fig 3



SQUARE-BUTT WELD

Causes

- Current too high
- Use of a very short arc length
- Welding speed too fast
- Overheating of job due continuous welding
- Faulty electrode manipulation
- Wrong electrode angle

Remedies

a Preventive action

Ensure

- proper current is set
- correct welding speed is used
- correct arc length is used
- correct manipulation of electrode is followed

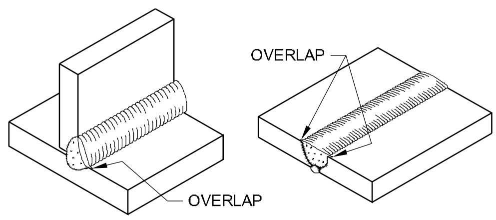
b Corrective action

- deposit a thin stringer bead at the top of the weld using a 2mm ø electrode to fill up the undercut.

Overlap

An overlap occurs when the molten metal from the electrode flows over the parent metal surface without fusing into it. (Fig 4)

Fig 4



SCHEMATIC DIAGRAM OF OVERLAP IN FILLET AND BUTT WELDS

Causes

- Low current.
- Slow arc travel speed.
- Long arc.
- Too large a diameter electrode.
- Use of wrist movement for electrode weaving instead of arm movement.

Remedies

a Preventive actions

- Correct current setting.
- Correct arc travel speed.

– Correct arc length.

– Correct diameter electrode as per metal thickness.

– Proper manipulation of electrode.

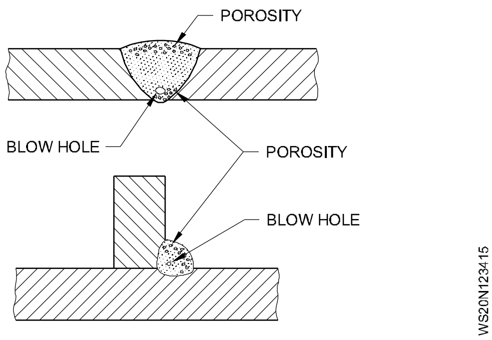
b Corrective actions

– Remove the overlap by grinding without an undercut.

Blowhole and porosity

Blow hole or gas pocket is a large diameter hole inside a bead or on the surface of the weld caused by gas entrapment. Porosity is a group of fine holes on the surface of the weld caused by gas entrapment. (Fig 5)

Fig 5



Causes

Presence of contaminants/impurities on the job surface or on electrode flux, presence of high sulphur in the job or electrode materials. Trapped moisture between joining surfaces. Fast freezing of weld metal. Improper cleaning of the edges.

Remedies

a Preventive actions

– Remove oil, grease, rust, paint, moisture, etc. from the surface. Use fresh and dried electrodes. Use good flux-coated electrodes. Avoid long arcs.

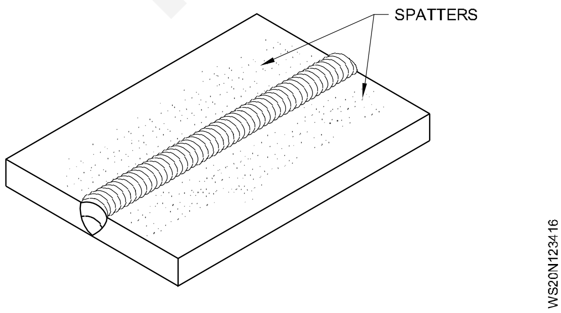
b Corrective action

– If the blowhole or porosity is inside the weld then gouge the area and re-weld. If it is on the surface then grind it and re-weld.

Spatter

Small metal particles which are thrown out of the arc during welding along the weld and adhering to the base metal surface. (Fig 6)

Fig 6



Causes

Welding current too high. Wrong polarity (in DC). Use of long arc. Arc blow. Uneven flux coated electrode.

Remedies

a Preventive actions

– Use correct current.

– Use correct polarity (DC).

– Use correct arc length.

– Use good flux-coated electrode.

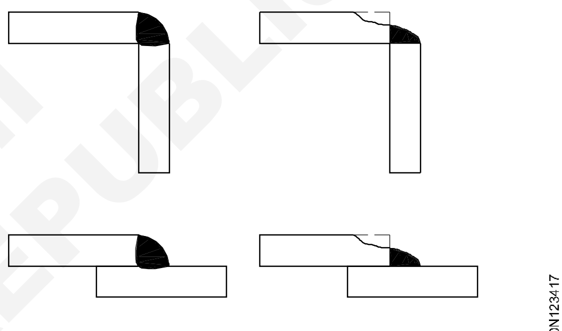
b Corrective actions

– Remove the spatters using a chipping hammer and wire brush.

Edge of plate melted off

Edge of plate melted off defect takes place in lap and corner joints only. If there is excess melting of one of the plate edges resulting in insufficient throat thickness then it is called edge of plate melted off defect. (Fig 7)

Fig 7



EDGE OF PLATE MELTED OFF

Causes

– Use of oversize electrode.

– Use of excessive current.

– Wrong manipulation of the electrode i.e. excessive weaving of electrode.

Remedies

a Preventive action

– Select correct size electrode.

– Set correct current.

– Ensure correct manipulation of electrode.

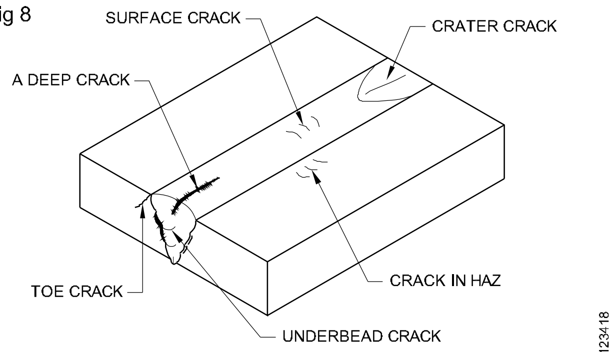
b Corrective action

– Deposit additional weld metal to increase throat thickness.

Crack

A hairline separation exhibits in the root or middle or surface and inside of the weld metal or parent metal. (Fig 8)

Fig 8



DIFFERENT TYPES OF CRACKS

Causes

- Wrong selection of electrode.
- Presence of localized stress.
- A restrained joint.
- Fast cooling.
- Improper welding techniques/sequence.
- Poor ductility.
- Absence of preheating and post-heating of the joint.
- Excessive sulphur in base metal.

Remedies

a Preventive actions

- Preheating and post-heating to be done on copper, cast iron, medium and high carbon steels.
- Select low hydrogen electrode.
- Cool slowly.
- Use fewer passes.
- Use proper welding technique/sequence.

Cracks

b Corrective actions

- For all external cracks to a smaller depth, take a V groove using a diamond point chisel upto the depth of the crack and re-weld (with preheating if necessary) using low hydrogen electrode. Cool the job slowly.
- For internal/hidden cracks gouge upto the depth of the cracks and re-weld (with preheating if necessary) using low hydrogen electrode. Cool the job slowly.

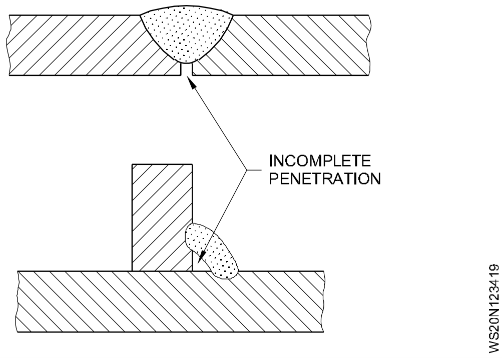
Incomplete penetration

Failure of weld metal to reach and fuse the root of the joint. (Fig 9)

Causes

- Edge preparation too narrow - less bevel angle.
- Welding speed too much.

Fig 9



- Key-hole not maintained during welding the root run of a grooved joint.
- Less current.
- Use of larger dia. electrode.
- Inadequate cleaning or gouging before depositing sealing run.
- Wrong angle of electrode.
- Insufficient root gap.

Remedies

a Preventive actions

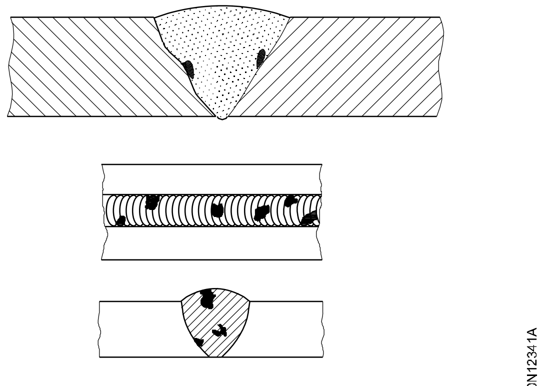
- Correct edge preparation is required.
- Ensure correct angle of bevel and required root gap.
- Use correct size of electrode.
- Correct welding speed is required.
- Maintain a keyhole throughout the root run.
- Correct current setting is required.

b Corrective actions

- For butt welds and open corner welds gouge the root of the joint and deposit the root run from the bottom side of the joint. For a Tee & lap fillet welds blow off the full weld deposit and reweld the joint.

Slag inclusion: Slag or other non-metallic foreign materials entrapped in a weld. (Fig 10)

Fig 10



SLAG INCLUSION IN BUTT WELD

Causes

- Incorrect edge preparation.
- Use of damaged flux coated electrode due to long storage.
- Excessive current.
- Long arc length.
- Improper welding technique.
- Inadequate cleaning of each run in multi-run welding.

Remedies

a Preventive actions

- Use correct joint preparation.
- Use correct type of flux coated electrode.
- Use correct arc length.
- Use correct welding technique.
- Ensure thorough cleaning of each run in multi-run welding.

b Corrective actions

- For external/surface slag inclusion remove them using a diamond point chisel or by grinding and re-weld that area. For internal slag inclusions use gouging upto the depth of the defect and re-weld.

Excessive convexity (Fig 11)

This defect is also called as oversize weld or excessive reinforcement. It is the extra weld metal deposited in the final layer/covering run.

Excessive concavity/insufficient throat thickness

If the weld metal deposited into a butt or fillet weld is below the line joining the toes of the weld then this defect is called excessive concavity or insufficient throat thickness. (Fig 12)

Causes

- Incorrect bead profile due to improper weaving of electrode.

Fig 11

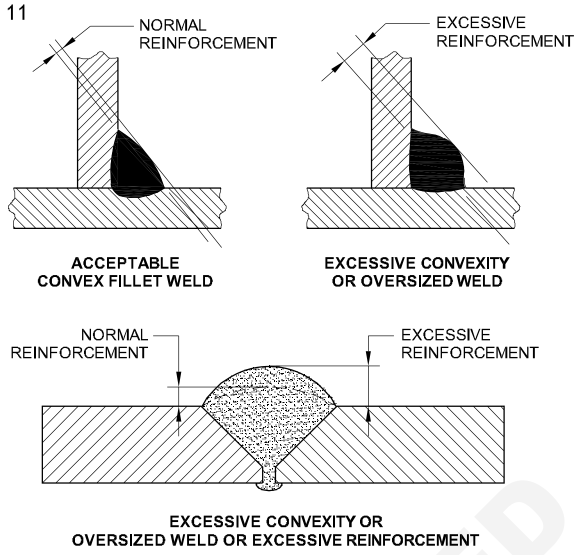
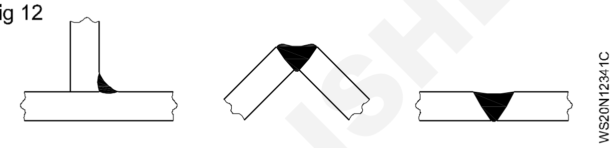


Fig 12



- Use of small dia. electrode.
- Excessive speed of welding.
- Wrong welding sequence when using stringer beads to fill the groove.
- Sagging of weld metal is not controlled in horizontal position.
- Electrode movement is not uniform.
- Improper electrode angle between the plate surfaces.

Remedies

- Lack of fusion.
- Mismatch.
- Uneven/irregular bead appearance.
- Excessive root penetration.

Specification of pipes,various types of pipe joints, pipe welding positions, and procedure

Objectives: At the end of this lesson you shall be able to
- **specification of pipes**
- **different methods of pipes joints**
- **describe the methods of welding pipes in '1G' position.**

Specification of Pipes

- In a pipe its size is measured by nominal diameter (or) nominal outside diameter (OD).
- It is also mentioned as nominal pipe size (NPS).
- Pipe is normally used to transport gases or liquids in a process.

Tube is normally used for standard purpose and it is mentioned as outside diameter and its wall thickness as tube.

As per Indian standard 1161-1998, it is specified as steel tubes of nominal force, and thickness having outside diameter in mm under light, medium and heavy class.

Welded pipe joints

Pipes of all types and sizes are used in great deal today in transporting oil, gas, water etc. They are also used extensively for piping systems in building, refineries and industrial plants.

Advantages of welded pipe

Pipes are mostly made of ferrous and non-ferrous metals and their alloys. They possess the following advantages.

– Improved overall strength.

– Ultimate saving in cost including maintenance.

– Improved flow characteristics.

– Reduction in weight due to its compactness.

– Good appearance.

Method of pipes welding

The following are the methods of pipe welding by arc.

– Metallic arc welding

– Gas metal arc welding

– Tungsten inert gas welding

– Submerged arc welding

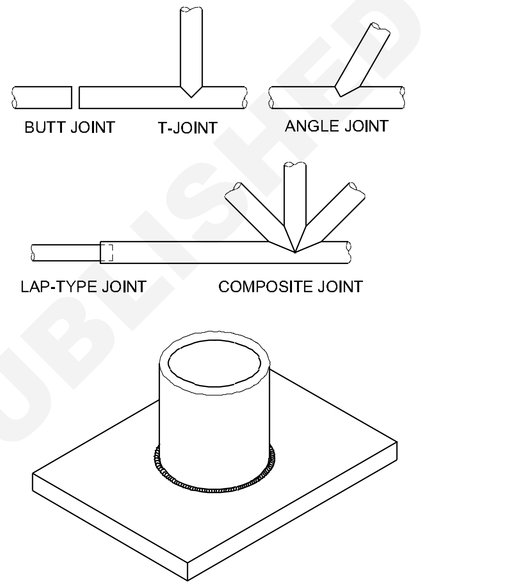
– Carbon arc welding

All these methods, except carbon arc welding are commonly used and the choice of welding depends upon the size of the pipe and its application.

Types of pipe joints

1 Butt joint
2 'T' joint
3 Lap joint (Fig 1)
4 Angle joint
5 composite joint
6 Pipe flange joint

Fig 1



7 Y joint (Fig 2)
8 Elbow joint (Fig 3)

Fig 2

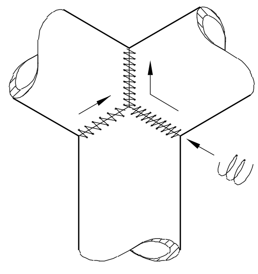


Fig 3

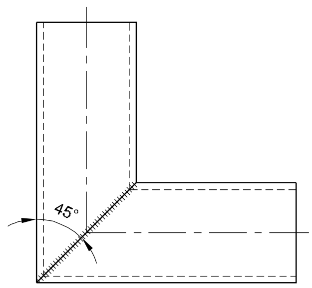


Table 1

Sizes and Properties of Steel Tubes for Structural Purposes

(*Clauses* 3.1, 6.1, 6.1.1 *and* 6.1.2)

Nominal Bore	Outside Diameter	Class	Thickness	Mass	Area of Cross Section	Internal Volume	Surface		Moment of Inertia	Modulus of Section	Radius of Gyration	Square of Radius of Gyration
							External	Internal				
mm (1)	mm (2)	(3)	mm (4)	kg/m (5)	cm^2 (6)	cm^3/m (7)	cm^3/m (8)	cm^3/m (9)	cm^4 (10)	cm^3 (11)	cm (12)	cm^2 (13)
15	21.3	Light	2.0	0.947	1.21	235		543	0.57	0.54	0.69	0.47
		Medium	2.6	1.21	1.53	203	669	506	0.69	0.64	0.66	0.44
		Heavy	3.2	1.44	1.82	174		468	0.75	0.70	0.55	0.42
20	26.9	Light	2.3	1.38	1.78	390		700	1.36	1.01	0.87	0.76
		Medium	2.6	1.56	1.98	370	845	681	1.48	1.10	0.86	0.74
		Heavy	3.2	1.87	2.38	330		644	1.70	1.26	0.84	0.71
25	33.7	Light	2.6	1.98	2.54	638		895	3.09	1.83	1.10	1.21
		Medium	3.2	2.41	3.06	585	1 059	857	3.61	2.14	1.08	1.17
		Heavy	4.0	2.93	3.73	518		807	4.19	2.48	1.05	1.11
32	42.4	Light	2.6	2.54	3.25	1 086		1 168	6.47	3.05	1.41	1.98
		Medium	3.2	3.10	3.94	1 017	1 332	1 130	7.62	3.59	1.39	1.93
		Heavy	4.0	3.79	4.82	929		1 080	8.99	4.24	1.36	1.86
40	48.3	Light	2.9	3.23	4.13	1 418		1 335	10.70	4.43	1.61	2.59
		Medium	3.2	3.56	4.53	1 378	1 517	1 316	11.59	4.80	1.59	2.54
		Heavy	4.0	4.37	5.56	1 275		1 265	13.77	5.70	1.57	2.47
50	60.3	Light	2.9	4.08	5.23	2 332		1 711	21.59	7.16	2.03	4.13
		Medium	3.6	5.03	6.41	2 213		1 667	25.88	8.58	2.00	4.02
		Heavy	4.5	6.19	7.88	2 066		1 611	30.90	10.2	1.98	3.92
65	76.1	Light	3.2	5.17	7.32	3 814		2 189	48.79	12.82	2.58	6.66
		Medium	3.6	6.42	8.20	3 727	2 391	2 163	54.02	14.20	2.57	6.60
		Heavy	4.5	7.93	10.1	3 534		2 107	65.12	17.1	2.54	6.43
80	88.9	Light	3.2	6.72	8.61	5 343		2 591	79.23	17.82	3.03	9.19
		Medium	4.0	8.36	10.7	5 138	2 793	2 540	96.36	21.68	3.00	9.00
		Heavy	4.8	9.90	12.7	4 936		2 490	112.52	25.31	2.98	8.88
90	101.6	Light	3.6	8.70	11.1	6 995		2 964	133.27	26.23	3.47	12.03
		Medium	4.0	9.63	12.3	6 877	3 192	2 939	146.32	28.80	3.45	11.91
		Heavy	4.8	11.5	14.6	6 644		2 889	171.44	33.75	3.43	11.76

Welding of pipe butt joints: Normally joints in pipes and tubes cannot be welded from the inside of the bore. Hence before starting to learn pipe welding, a person should be proficient in welding in all positions i.e. flat, horizontal, vertical and overhead.

All these positions are used to weld pipes.

Pipes welding positions (Fig 4, 5)

Fig 4

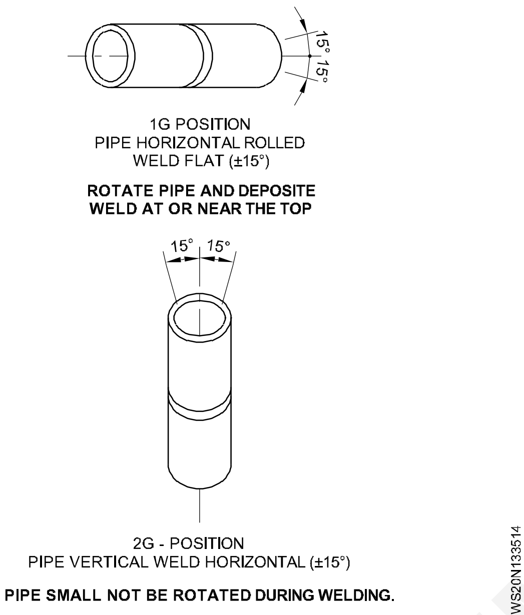
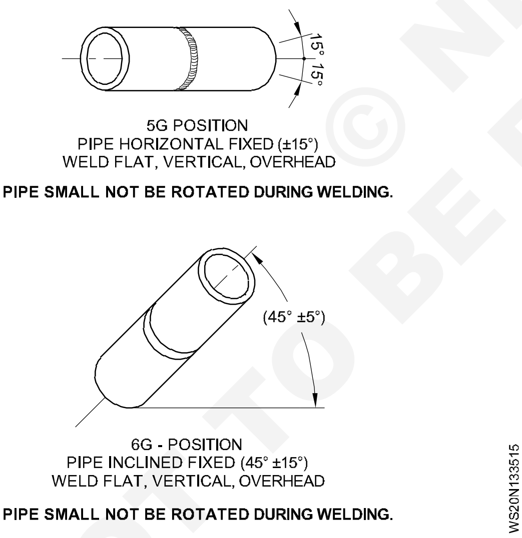


Fig 5



1 G - Pipe weld in flat (roll) position i.e. pipe axis is parallel to the ground.

2 G - Pipe weld in horizontal position i.e. pipe axis is perpendicular to the ground.

5 G - Pipe weld in flat (fixed) position i.e. pipe axis is parallel to the ground.

6 G - Pipe weld in including (fixed) position i.e. pipe axis is including to both horizontal and vertical planes.

During the welding of butt joints the pipe may be

1 rolled or rotated (1G position)

2 fixed (2G, 5G and 6G position).

Welding of pipe butt joints by arc can be done in 1G position by

a Continuous rotation method and

b Segmental method.

1a Pipe welding by arc (in 1G position) by continuous rotation method: Satisfactory welding of butt joints in pipes depends upon the correct preparation of pipe ends and careful assembly of the joint to be welded. Ensure that the bores and root faces are in correct alignment and that the gap is correct.

Clean the edges. Prepare an angle of bevel 35° by gas cutting and filing. A root face 1.5 to 2.5 mm is to be provided.

Setting the pipes for welding: Tack weld together with 4 small equally spaced tacks. The gap should be equal to the root face dimension plus 0.75 mm. Support the tacked assembly on V blocks or rollers so that the assembly can be rolled or rotated with the free hand.

Select a 2.5 mm rutile electrode for 1st run and a 3.15 mm rutile electrode for 2nd run.

Set a current of 70-80A for 1st run and 100-110 for the 2nd run.

Rotate the assembly as welding proceeds. (Fig 6) keeping the welding arc within an area between vertical and 10° from the vertical in the direction of welding Fig 7. (Use a helmet type screen).

Fig 6

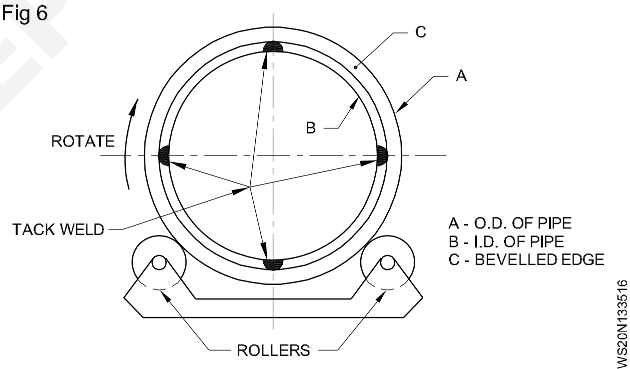
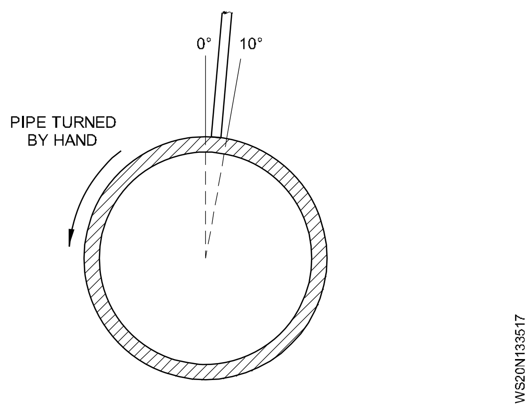


Fig 7



– Direct the electrode centrally at the root of the joint and in line with the radius of the pipe at the point of welding.

– Strike the arc near the top dead center and hold the arc length as short as possible. Continue to weld as the pipe is rotated manually at steady speed.

– Deposit first run by weaving the electrode very slightly from root face to root face.

– Adjust the speed of rotation to obtain full fusion of the root faces without excessive penetration.

– Chip out tack weld as they are approached. Do not weld over tacks otherwise loss of penetration at the tacking points may occur.

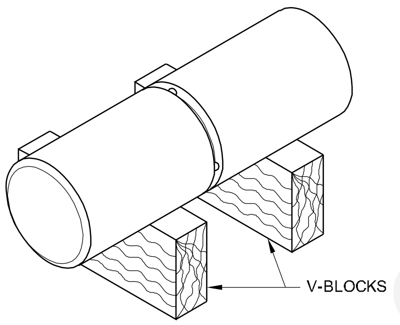
– Complete the weld with the second run. Adjust the speed of rotation to secure fusion to the outer edge of each fusion face. The amount of reinforcement should be even around the edge of the joint.

1b Welding of a pipe butt (IG position i.e. by rotation) by segmental welding.

– The edges of the pipe are beveled to 35 to 40° angle with a root gap of 2.5 mm.

– Tack the pipe as before and support the assembly on two 'V' blocks. (Fig 8)

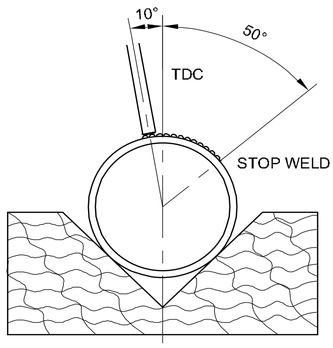
Fig 8



– Strike the arc at 10° from Top Dead Centre (TDC) and deposit the root run. Use a small weaving motion to achieve fusion of the root faces. Adjust travel speed to control root penetration. (Fig 9)

– When a segment equivalent to 60° has been welded, terminate/stop the weld run. Avoid the formation of a crater.

Fig 9



WELDING FIRST SEGMENT

– Move the pipe until the end of the segment is at 10° before TDC.

– Strike the arc on the end of the previous weld run and establish a weld pool.

– Weld a further 60° segment. (Fig10)

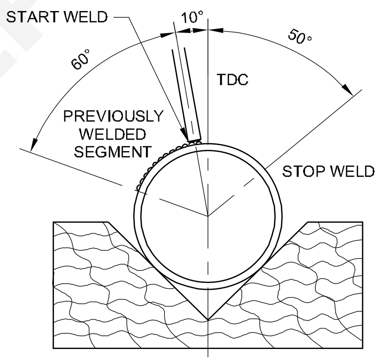
– Continue welding in segments until the root run has been completed.

– Move the pipe until the mid point of the segments is at TDC.

– Strike the arc and deposit the second (filling) run, use a side-to-side weaving position to fill the preparation and to achieve fusion of the pipe edges.

– Complete the filling run in 60° segments.

Fig 10



WELDING SECOND SEGMENT

Pipe welding by arc in fixed positions

Objectives: At the end of this lesson you shall be able to
- **state different fixed pipe welding positions**
- **explain different methods of pipe welding in 5G position**
- **explain the welding producer of M.S. pipe butt joint by arc in fixed (5G) position.**

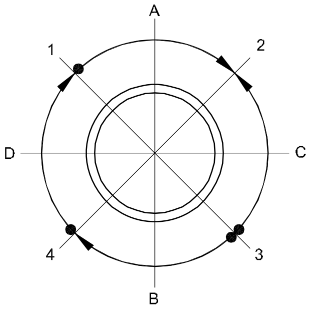
Whenever the pipes to be welded cannot be rotated or whenever the pipes are to be welded in the field i.e. at work site, then they are welded in fixed position. If the fixed pipe axis is horizontal, then the welding position is called 5G position.

The other pipe welding positions in which the pipes are fixed during welding are 2G and 6G positions. If the axis of the fixed pipes to be welded are vertical then this position is called 2G position. If the axis of the fixed pipes in inclined at 45° to both horizontal and vertical planes, then the welding position is called 6G position.

In 5G position, a pipe butt joint can be welded by the following method.

Method 1: The pipe joint circumference is divided into four positions as A, B, C and D. First portion 'A' is welded from 1 to 2 in more or less in flat position. Then portion B is welded from 3 to 4 in overhead position. Next portion C from 3 to 2 and then portion D from 4 to 1 are welded in vertical up position. (Fig 1)

Fig 1

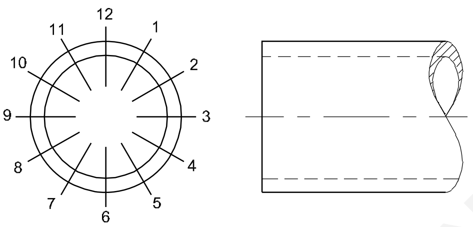


It is important that a key hole is maintained throughout the welding operation to ensure proper root penetration. Also the electrode position is continuously changed as the joint surface is curved. In addition, the starting and ending of each weld portion i.e. A, B, C and D properly done so that they merge with the previous portion.

Method 2: The pipe outer circumference is divided into 12 equal divisions as in a clock.

The top of the pipe is 12 O'clock position and the bottom is in 6 O'clock position. (Fig 2)

Fig 2



THE IDENTIFICATION OF THE WELDING POSITION AROUND THE THE PIPE JOINT BYTHE NUMBERS ON THE FACE OF A CLOCK.

The weld is started from 12 O'clock position to 6 O'clock position on the right side vertically downwards. Then welding is done again from 12 O'clock to 6 O'clock position on the left side (Fig 3). This method is called down hill method and is normally used for thin walled pipes with wall thickness of 3 to 4 mm.

Fig 3

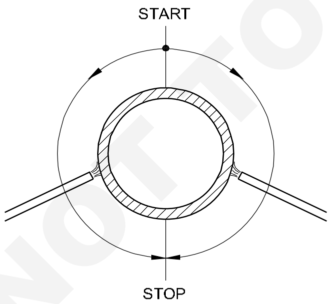
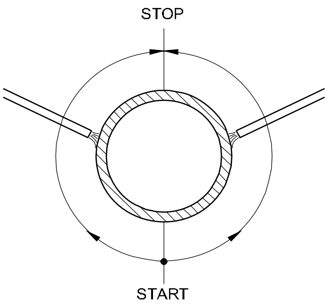


Fig 4

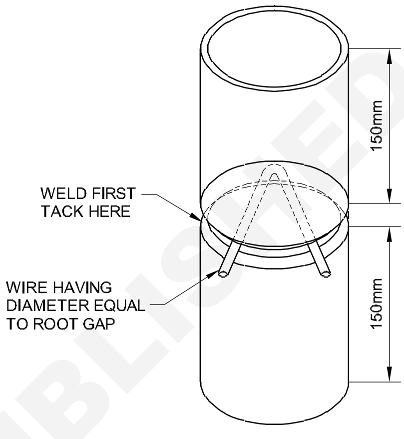


Method 3: The weld is started from 6 O'clock to 12 O'clock position on the right side first and then again from the 6 O'clock to 12 O'clock position on the left side (Fig 4). This method is called uphill method or vertical up method. This uphill method is used to weld pipes of 5 mm and above wall thickness.

Welding in 2G and 6G positions are done based on the position of the pipe axis.

In the 2G position, the horizontal pipe welding with its axis being vertical, the weld joint connecting the two pipes is in the horizontal position. The weld must be made around the pipe. (Fig 5)

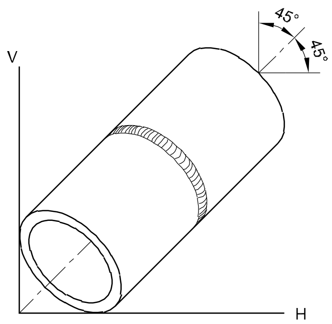
Fig 5



USE OF BEND WIRE OF SPACER TO SET ROOT GAP

In the 6G position welding is usually done by using one of the methods i.e. uphill or downhill welding. (Fig 6)

Fig 6



POSITION 6 G

Use electrodes specially manufactured for pipe welding to get good penetration, appearance and strength, (low hydrogen electrodes, deep penetration electrodes etc.)

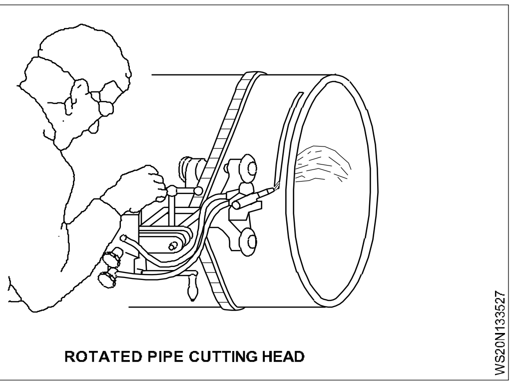
Welding procedure of M.S. pipe butt joint by arc in fixed (5G) position.

Edge preparation and cleaning: If the wall thickness is 3 mm and below the edges of the pipe end is filed square i.e. perpendicular to the pipe axis. The welding of the joint is complete in one pass using the down hill method or by segmental method i.e. welding the top quarter in flat, bottom quarter in overhead and the two side quarter portion in vertical up position. The electrode has to be held at angles as shown in Fig 14 for welding the root pass of a thicker pipe explained later in this lesson.

For welding pipes with higher wall thickness the following procedure is to be followed.

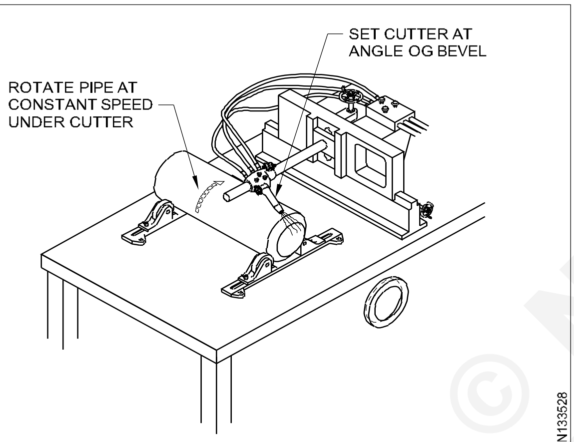
Edge preparation: The pipe ends are beveled by flame cutting or machining in the shop (Figs 7, 8) The including angle is 75° the root face and root gap are 2.5 mm to 3 mm. All traces of oxide from and other contaminations must be removed before starting the weld. (Fig 9)

Fig 7



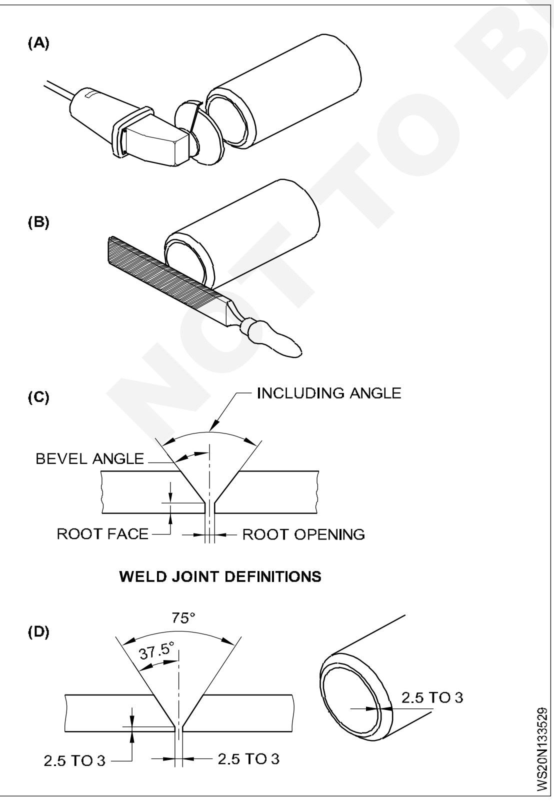
ROTATED PIPE CUTTING HEAD

Fig 8



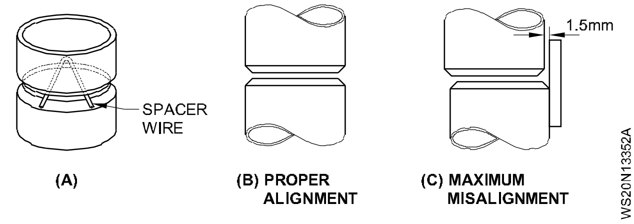
CUTTING BEVEL ON PIPE

Fig 9



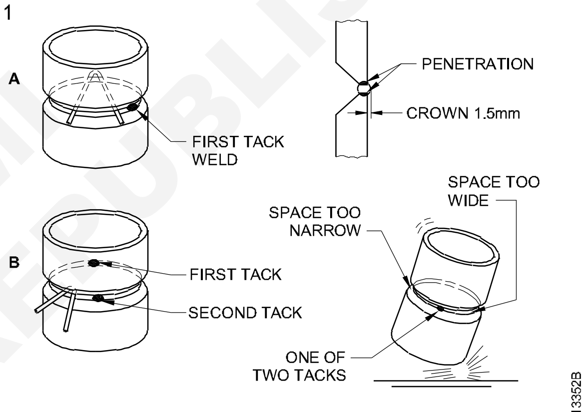
Setting of pipe: Pipe to be joined together must be accurately aligned prior to welding. The inside surface of the pipe must be blended together smoothly as in the outer surface. Maintain the root opening 2.5 mm, use a M.S. angle and strength bar for checking the alignment of the pipe. (Fig 10)

Fig 10



Tacking: Place a 2.5 mm bend wire between the edges. The tack length should be 3 times the metal thickness. Put the first tack at the root side and the second tack at the opposite side of the first tack. Arrange the third and fourth tacks at 90° from the first and second tacks. (Fig 11)

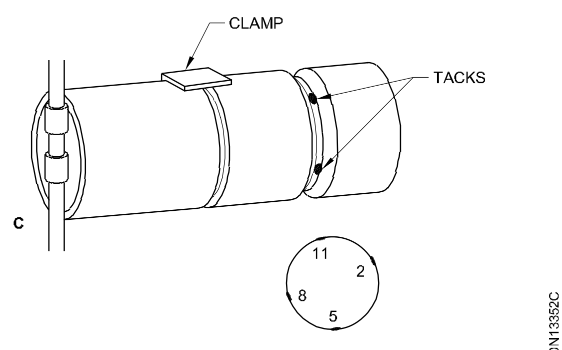
Fig 11



A. FIRST TACK WELD WITH WIRE SPACERS IN PLACE.
B. SECOND TACK WELD OPPOSITE TO FIRST TACK.

Root pass: Fix the job in the clamp and adjust the height to a position convenient to you. The position of tack weld should be fixed as in Fig 12. The keyhole is an essential part in the welding of the root pass. (Fig 13) It should be about $\sqrt{1\frac{1}{3}}$ of the diameter of the electrode. Maintain the electrode angle as shown in Fig 14 Weld the root pass on side 2 of the pipe joint. (Fig 14)

Fig 12



PIPE CLAMPED IN PLACE AFTER TACK WELD.

Fig 13

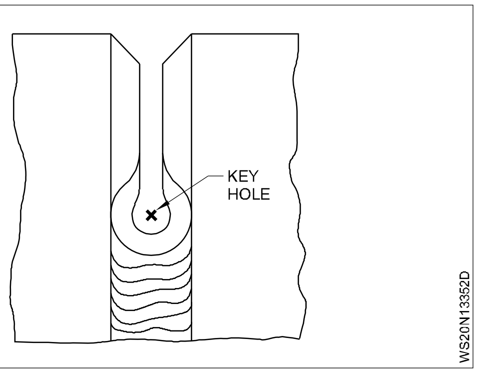
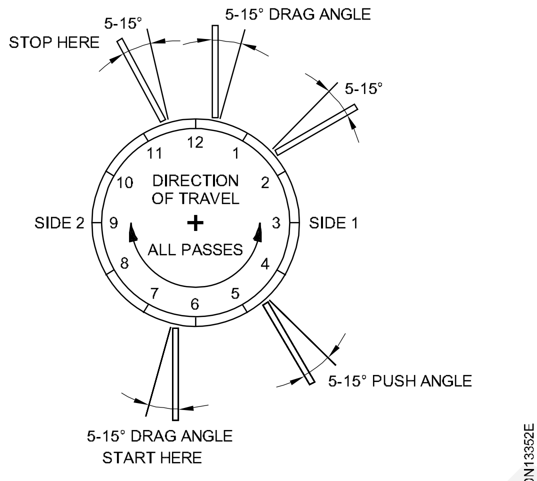


Fig 14



EECTRODE DRAG AND PUSH ANGLES.

The side 1 of the root pass is started at 6½ hrs position and stopped at 11½ hrs position. The side 2 is started at 5½ hrs position and stopped at 12½ hrs position.

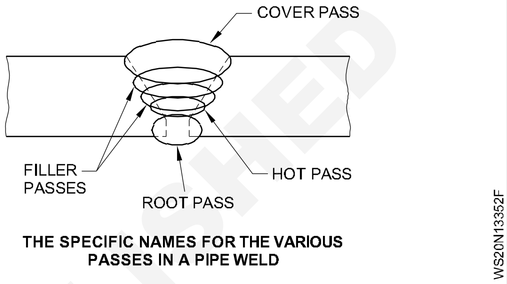
The weld beads on side 1 and side 2 will overlap for a short distance at the start and at the stop positions.

After completing the root pass, depending on the wall thickness of the pipe there will be further weld deposits either 2 or 3 or more passes. These passes can be a mixture of stringer beads and weaved beads by vertical up/uphill method.

The names of each pass is given in Fig 15. Usually the second weld bead after the root pass is deposited keeping the joint hot. So it is called hot pass.

For hot pass and cover pass maintain the electrode angle as shown in the Fig 14. Each pass should start at a different place of the joint. The second pass should fill the groove by using side-to-side movement. The final cover pass should be made wider than the second pass. The third pass should be smooth and of uniform appearance, and must have minimum reinforcement. (Fig 15)

Fig 15



THE SPECIFIC NAMES FOR THE VARIOUS PASSES IN A PIPE WELD

Advantages of H/P pipe welding

- The joint is permanent.
- Saving of material.
- Reduction of joint weight.
- Less expensive.
- Multiple lines grouped together more closely.
- Repair and maintenance cost is less.

Welding of M.S. pipe

Objectives: At the end of this lesson you shall be able to

- **classify and specify mild steel pipes**
- **state and explain different methods of welding M.S. pipes**
- **state the method of edge preparation, tacking and necessary of key hole maintenance**
- **explain the pipe welding procedure by gas welding.**

Welding of M.S. pipe: Mild steel pipes are classified into two groups.

1 Seamless pipes manufactured by piercing a hot solid round billets/rods. (Fig 1)

2 Resistance welded pipes manufactured by continuously feeding a strip of metal through a machine which rolls the strip into cylindrical shape and the seam is electrically resistance welded. (Fig 2)

Based on the wall thickness, these pipes are further categorised as "Standard pipes", "Extra Strong pipes" and "Double extra strong pipes". Also the pipes are specified by first the material then by the diameter followed by the wall thickness. (Fig 3) For example a M.S. pipe 100 mm long with 50 mm inside diameter and 3 mm wall thickness is specified as M.S. ø 50 WT3 × 100 mm.

In the actual usage of pipes in various applications like transmitting water, oil, chemical, air, gases, etc. it is necessary to weld them as a butt, elbow and Tee joints as well as branch pipe joints at various angles.

The welding of smaller diameter pipes and bigger diameter pipes inside a welding shop can be done by rotating the pipes on roller or manually by a helper using an angle iron and tongs. (Fig 4 and Fig 5)

Fig 1

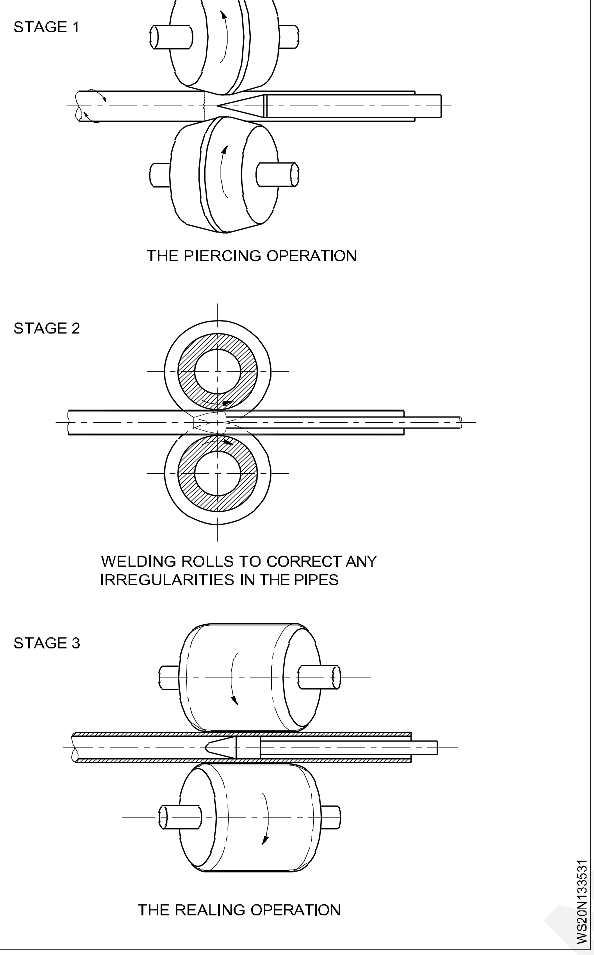


Fig 2

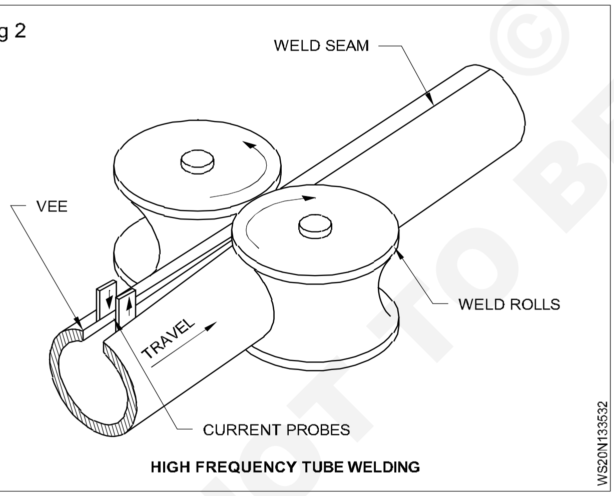


Fig 3

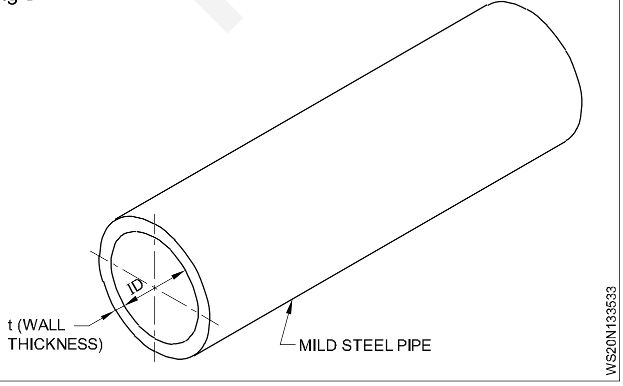


Fig 4

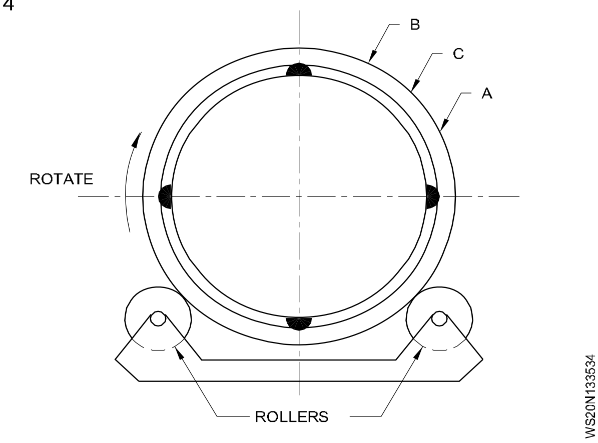
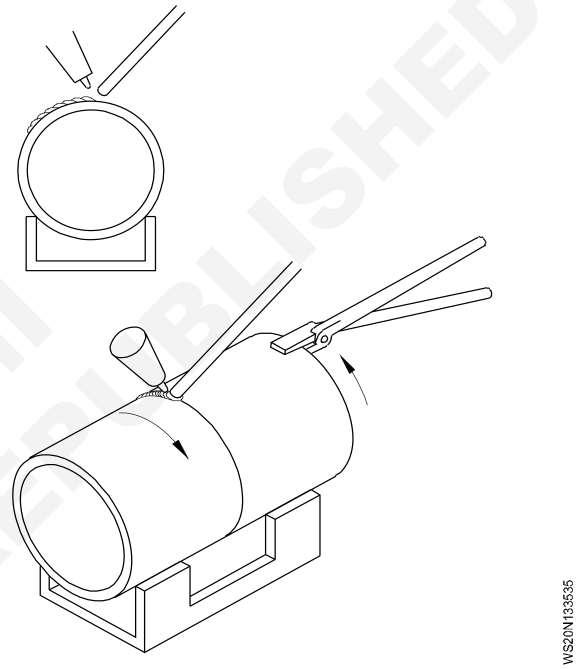


Fig 5



If the pipes are larger and are to be welded in the field/ work site or if the pipes cannot be rotated, then in such cases, the pipes are welded in fixed position i.e. the pipe will not be rotated, but the welder has to move the blowpipe and filler rod along the curved line of the joint around the pipe to complete the weld.

The edges of the pipe joints are prepared depending on the type of joint and the wall thickness of the pipe. For a pipe flange joint and for pipe butt joint with 1.5 to 3 mm wall thickness, the pipe edges are filed or ground square (Fig 6) for pipe butt joints above 3 mm wall thickness, the pipe edges are beveled as shown in Fig 7 with 1.5 mm root face.

Fig 6

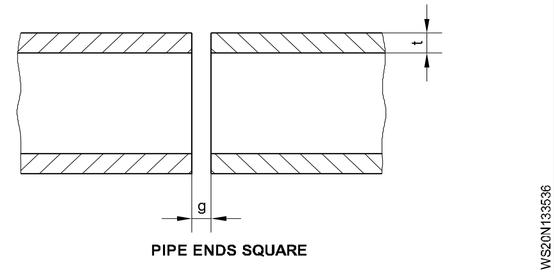
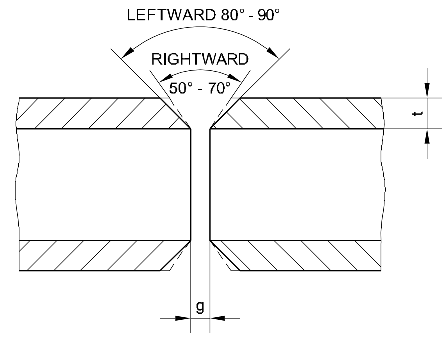


Fig 7

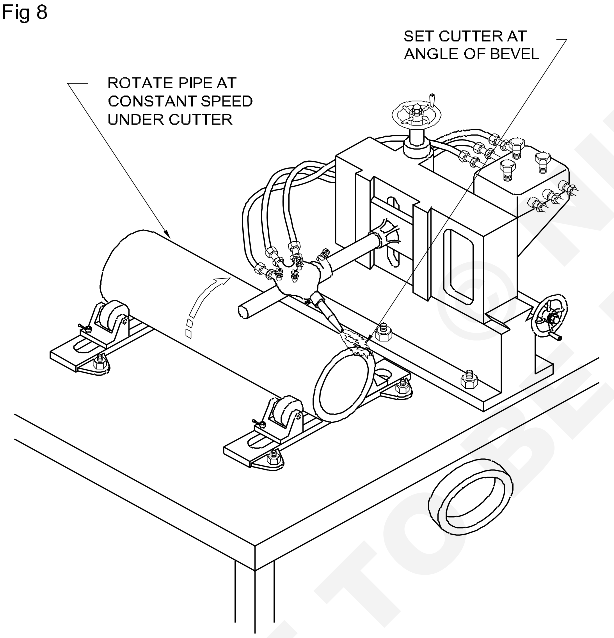


PIPE ENDS BEVELLED

Weld defects like incomplete or lack of root penetration cannot be rectified from inside small diameter pipes. Hence slightly larger root gaps are given while welding pipe butt joints to ensure proper root penetration. (Table 1) Fig 6 and Fig 7 gives the details of edge preparation.

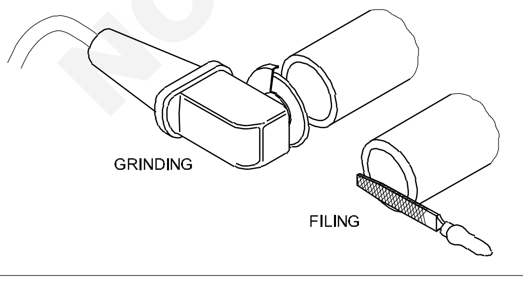
For pipes with wall thickness 3 mm and below, the edges are prepared by a file. If the wall thickness is more than 3 mm then the beveling is done by gas cutting (Fig 8) and the root face is prepared by filing/grinding. (Fig 9)

Fig 8



CUTTING BEVEL ON PIPE

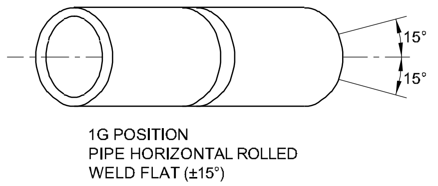
Fig 9



As welding of pipes is done either by rotating the pipe or by the fixed method, the pipe welding procedure also differs accordingly.

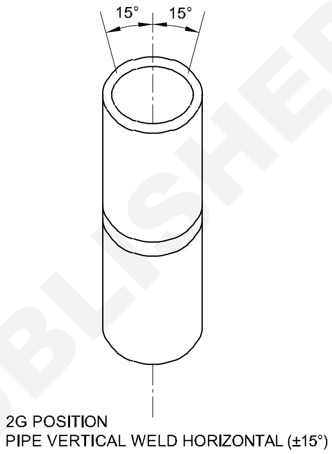
The different positions used to weld pipe butt joints are named as 1G, 2G, 5G and 6G as shown in Fig 10 to Fig 13. These positions are decided based on the position of the pipe axis and whether the welding is done by rotating the pipe or by keeping the pipe fixed.

Fig 10



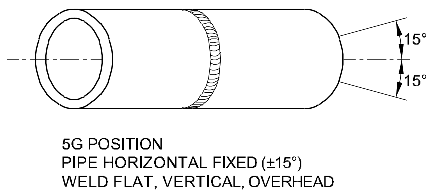
ROTATE PIPE AND DEPOSITE WELD AT OR NEAR THE TOP

Fig 11



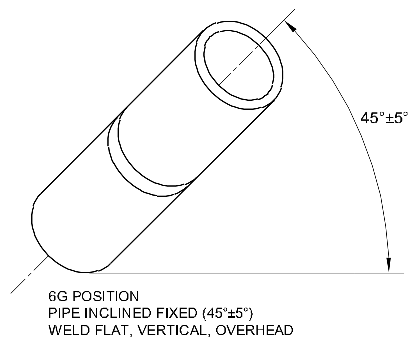
PIPE SHALL NOT BE ROTATED DURING WELDING

Fig 12



PIPE SHALL NOT BE ROTATED DURING WELDING

Fig 13



PIPE SHALL NOT BE ROTATED DURING WELDING

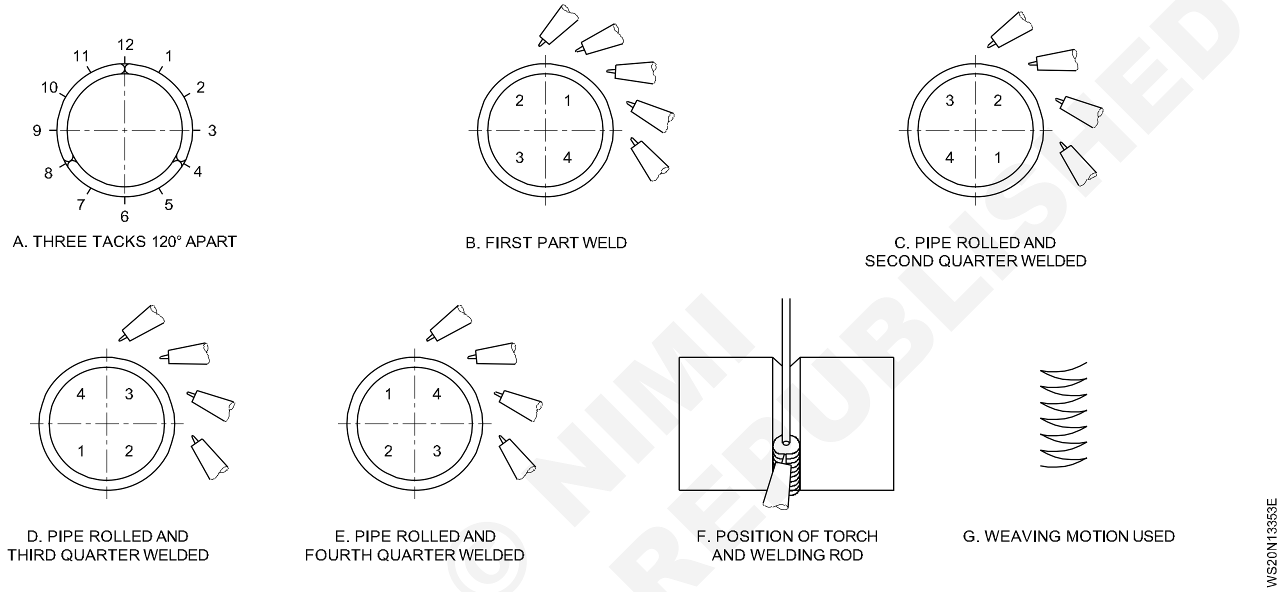
But in gas welding only 1G, 2G and 5G position are used. The 6G position welding is done by arc welding and it is usually used to test the skill/ability of a welder in pipe welding.

Pipe welding by rotation method (Position 1G): The method of welding pipes using pipe rotation is shown in the Fig 14. The two pipes after cleaning and preparing the edges, are set with proper root gap on an angle iron or channel so that the axes of the pipes are properly aligned. Then tack weld them at 3 places at 120° intervals. (Fig 14A)

Table 1

Wall thickness (t)	Pipe and preparation	Welding technique	Root gap (g)
3 mm or less	Square	Leftward	2.5 - 3 mm
5 mm or less	Square	Rightward or all-positional rightward	2.5 - 3 mm
3 - 5 mm	Beveled	Leftward	1.5 - 2.5 mm
5 - 7 mm	Beveled	Rightward or all-positional rightward	3 - 4 mm

Fig 14

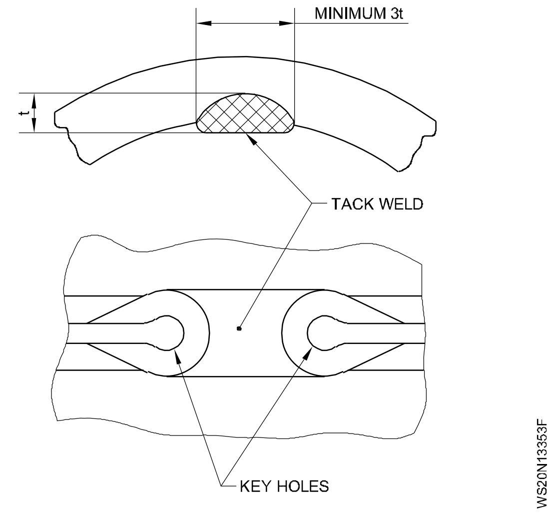


Start the weld at 3 O'clock position and finish at 12 O'clock position. Now the first ¼ portion of the pipe joint, marked as 1 in Fig 14B is welded. Rotate the pipe joint by 90° in clockwise direction so that the 12 O'clock position on the pipe comes to 3 O'clock position. Weld the portion marked as 2 in Fig 14C as done in welding portion 1 already. Now rotate the pipe by 90° and weld portion 3 (Fig 14D). On completing welding of portion 3 rotate the pipe again by 90° so that the portion 4 can be welded (Fig 14E). The position of blowpipe/torch and filler rods is shown in Fig 14F and the blowpipe weaving motion is shown in Fig 14G. It is very important to continuously maintain a key hole both while tacking Fig 15 and during welding (Fig 16).

In this method leftward technique is used and the metal deposition starts in vertical at 3 O'clock position and ends with flat position at 12 O'clock position. Care should be taken to properly overlap the previous weld deposit while starting the 2nd, 3rd and 4th segments.

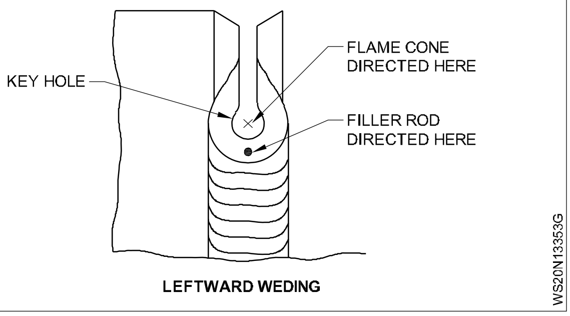
Pipe welding in fixed position (position 5G): The welding of the pipeline without rotating the pipe during welding is called fixed position welding. (5G) In this position the welder has to move according to the condition of the pipeline in different positions, such as vertical, down hand and overhead positions.

Fig 15



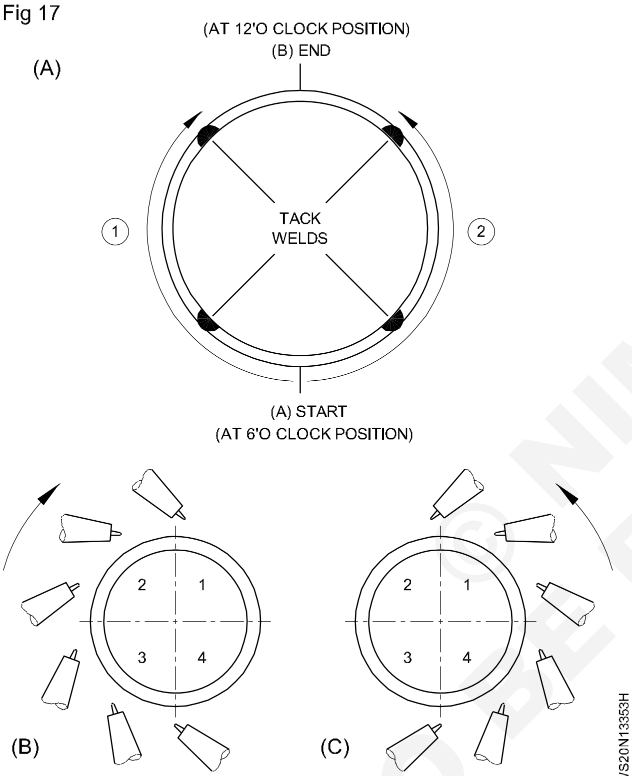
In fixed position pipe welding, the welder has to weld according to the conditions of the pipeline.

Fig 16



In this system, the welding should be started from 6 O'clock position and move to 12 O'clock position on either side by moving the blowpipe and the filler rod from bottom in the upward direction as shown in Fig 17a, 17b, 17c.

Fig 17



This also can be welded by the four quarter method, first by welding two quarter distance (opposite to each other) by moving the blowpipe in the upward vertical direction. (Fig 18a and Fig 18b) Then weld the top quarter distance in the down hand position. Finally weld the bottom quarter distance in the overhead position. The clock face and its relationship to pipe welding and various blowpipe and filler rod positions are illustrated in Fig 19.

Fig 18

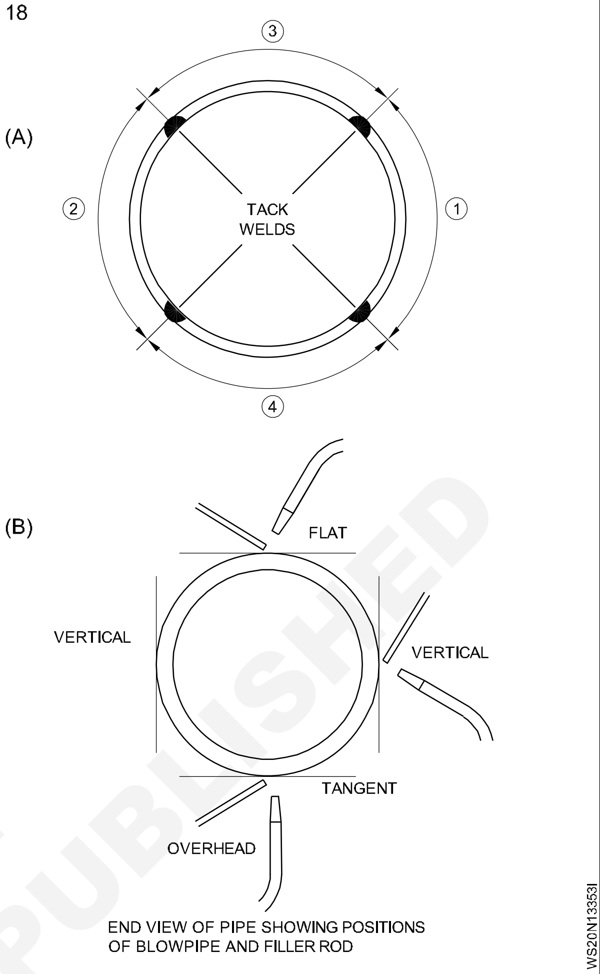
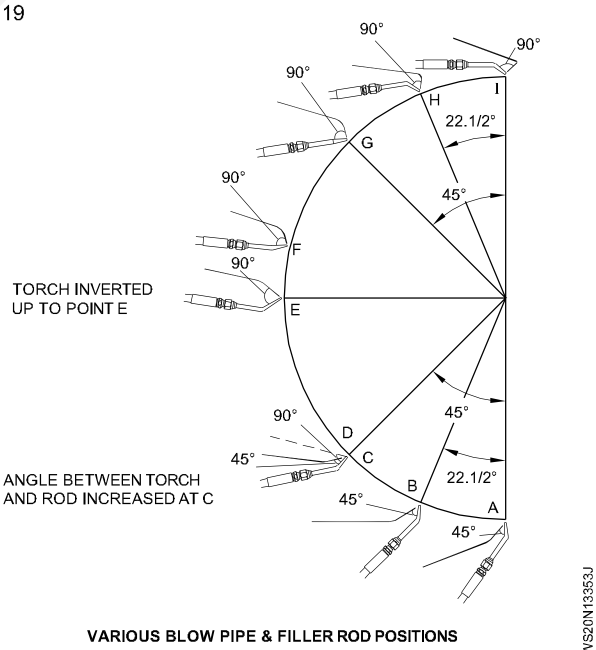
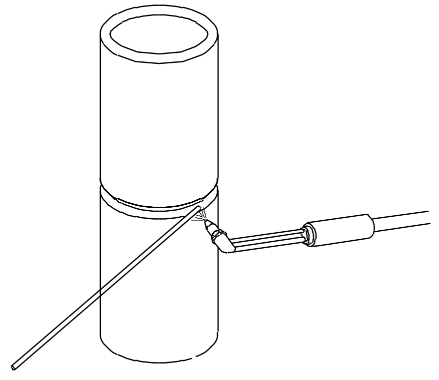


Fig 19



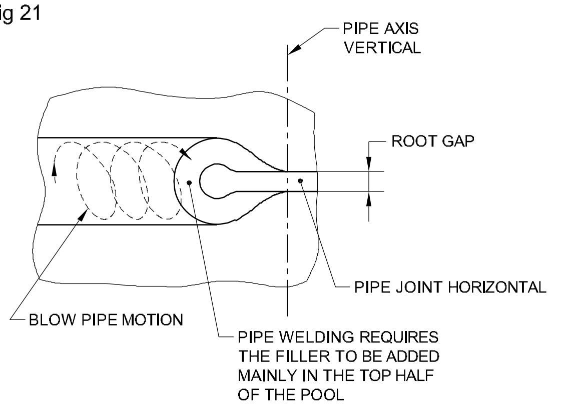
Pipe welding in 2G position (Pipe axis is vertical): In a pipe butt joint if the axis of the pipes is vertical and the weld joint is in the horizontal plane then it is called pipe welding in 2G position. (Fig 20) It is a fixed position welding and the blowpipe and filler rod are to be moved around the pipe surface. The position of blowpipe and the filler rod are given in Fig 20. To avoid sagging of weld metal the blowpipe is given a motion as shown in Fig 21 and the filler rod is fed at the top half of the molten pool.

Fig 20



2G POSITION
SINGLE "V" GROOVE PIPE JOINT
(PIPE AXIS VERTICAL)

Fig 21



Difference between pipe welding and plate welding

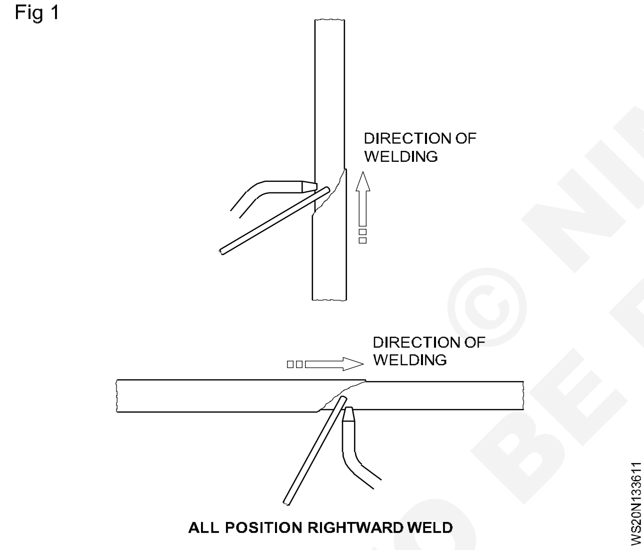
Objectives: At the end of this lesson you shall be able to
- **describe plate welding**
- **explain pipe welding**
- **explain the differences between plate welding and pipe welding.**

Plate welding: Plate welding is a fusion welding process. It joins plate metals using the combustion of oxygen and fuel gas. The intense heat that is produced melts and fuses together the edges of the parts to be welded generally with the help of a filler metal.

Plate welding by gas can be done in two ways. One is leftward welding and the other rightward welding.

All the-position rightward welding is used for all position of welding. (Fig 1) The path travelled by the flame and the filler rod varies with the welding position. The angles at which the flame and the filler rod are held also vary.

Fig 1



Pipe welding: When welding the circumference of a mild steel pipe, the angles of the rod and the blowpipe are given in relation to the tangent to the pipe at the point of welding.

The welding position can be seen in relation to the plane of the joint.

The techniques used will depend upon:

– the pipe wall thickness

– the welding positions

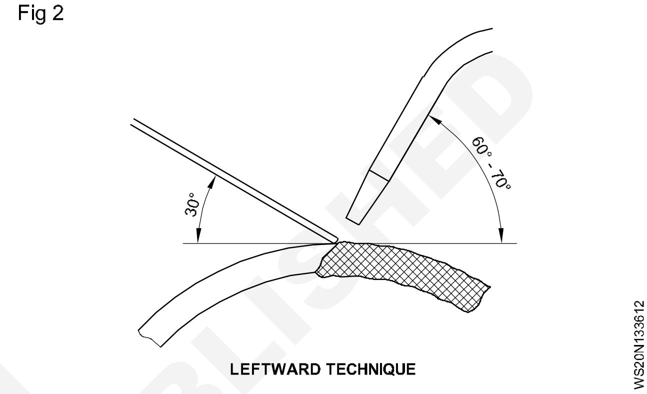
– whether the pipe is fixed or can be rotated.

When the pipe remains stationary, the following techniques are used.

The techniques used for the positional welding of plates are also applied when welding pipes.

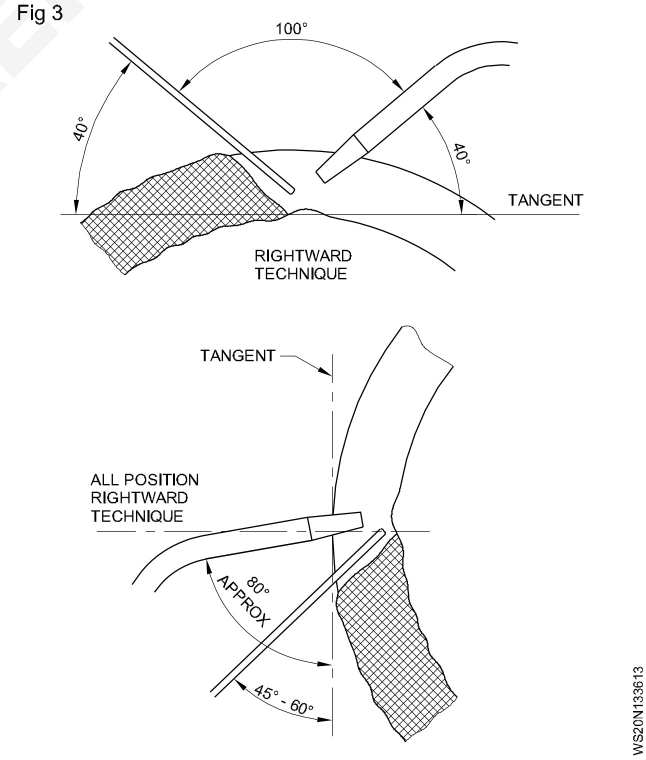
For thin walled pipes up to 5 mm, the leftward technique is used in any position. (Fig 2)

Fig 2



The leftward, rightward or all-position rightward techniques are used as appropriate on sections of 5 mm and above. (Fig 3)

Fig 3

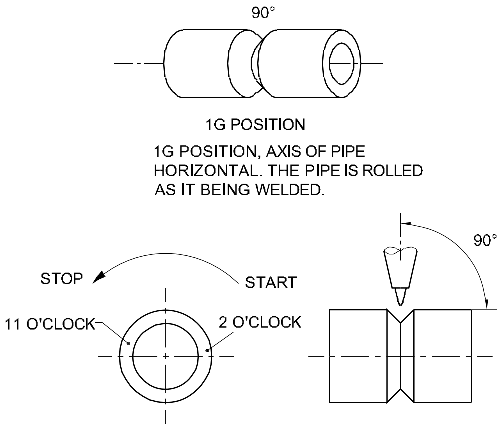


Differences between plate welding and pipe welding

In the plate welding the total welding line can be seen at any time. In pipe welding only a portion of the welding line can be seen at any time.

In plate welding, the line of weld is in only one position. In pipe welding, welding can be done in one position when it can be rotated. (Fig 4) Otherwise all-position welding can be done in the pipe when the pipe is in fixed position. (Fig 6) Sometimes the pipe may be in a fixed position and only one position of welding will be done. E.g. 2G Position.

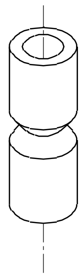
Fig 4



WELDING PIPE IN THE 1G POSITION

WS20N133614

Fig 5



2G POSITION

2G POSITION, AXIS OF PIPE VERTICAL

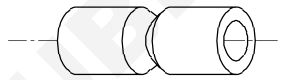
WS20N133615

In plate welding the sealing run can easily be deposited when needed. In pipe welding the sealing run cannot be deposited in small pipes. Sealing run can be deposited only when the pipe has so large a diameter as to allow the welder to enter into the pipe.

Possibility of distortion is higher in plate welding. Possibility of distortion is less in pipe welding.

Tip travel and hand travel will be equal in plate welding. Tip travel will be less and hand travel will be more in pipe welding.

Fig 6



5G POSITION

5G POSITION, AXIS OF PIPE HORIZONTAL. THE PIPE IS ROLLED AS IT BEING WELDED.

WS20N133616

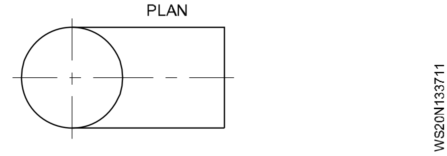
Pipe development for elbow joints,'T" joint, Y joint and branch joint

Objectives: At the end of this lesson you shall be able to
- **develop and layout the pattern for 90° elbow 'T' joining two equal diameter pipe by parallel line method.**

Develop the pattern for a 90° elbow of equal diameter pipes by parallel line method:

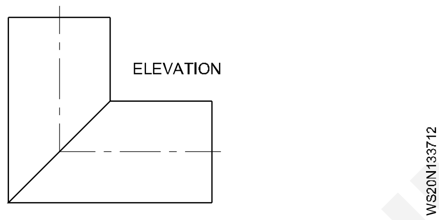
Draw plan as shown in Fig 1.

Fig 1



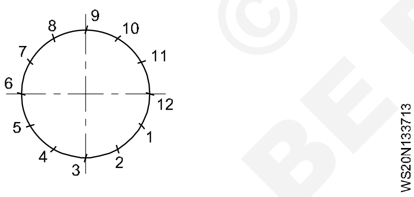
Below this, draw the front elevation as shown in Fig 2.

Fig 2



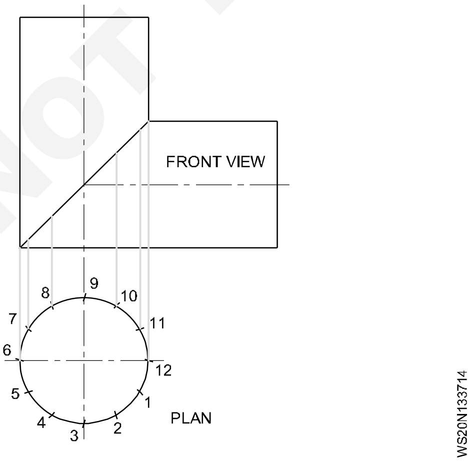
Divide the circle in the plan into twelve equal parts and number the points 0 to 12 as shown in Fig 3.

Fig 3



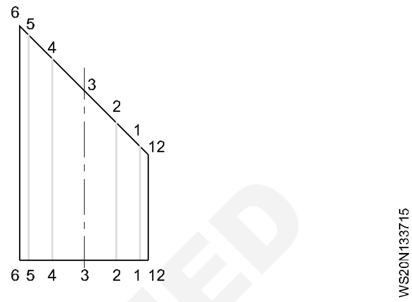
Draw the perpendicular line from these points towards the front view and number 1 to 12 as shown in Fig 4.

Fig 4



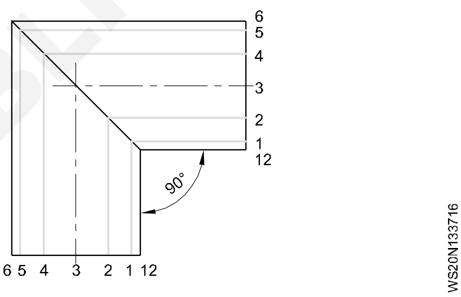
Now you find that the vertical lines are cutting at six different points top and bottom in the elevation line. Number them as shown in Fig 5.

Fig 5



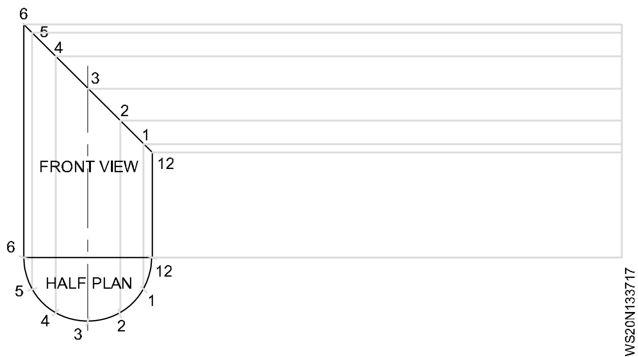
Draw horizontal parallel lines from each point and number them as shown in Fig 6.

Fig 6



Extend the front elevation base line as shown in Fig 7.

Fig 7



Take the distance equal to one division of plan and mark twelve times on base line by a compass and draw perpendicular lines from each point as shown in Fig 8.

Now you find that each horizontal line and corresponding vertical line meet at a point. Number the points as 1 to 12 as shown in Fig 9.

Fig 8

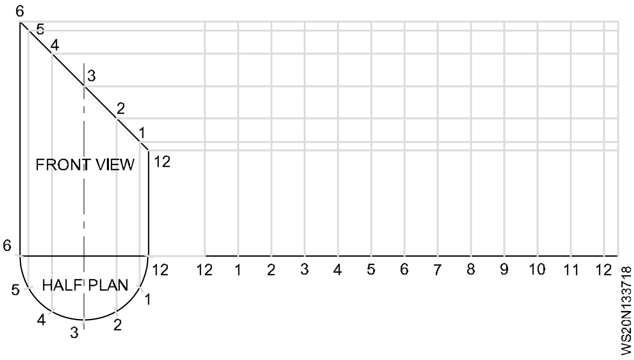
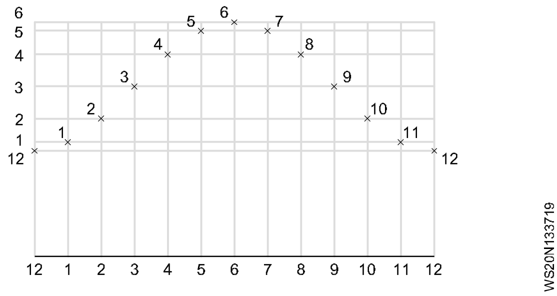
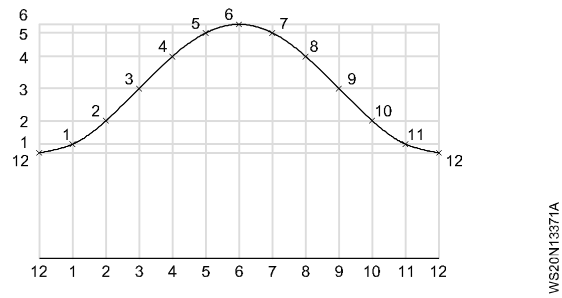


Fig 9



Join these points by free hand curve as shown in Fig 10.

Fig 10



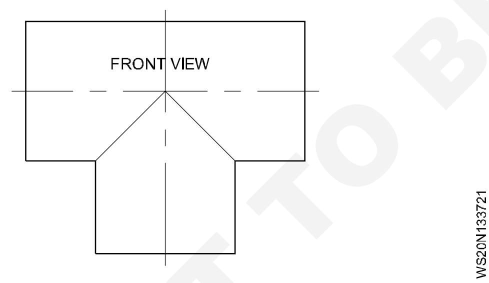
Development of a pipe "T" joint

Objective: At the end of this lesson you shall be able to
- **develop and layout the pattern for 90° "T" pipe of equal diameter by parallel line method.**

Develop the pattern for a 90° "T" pipe of equal diameter by parallel line method:

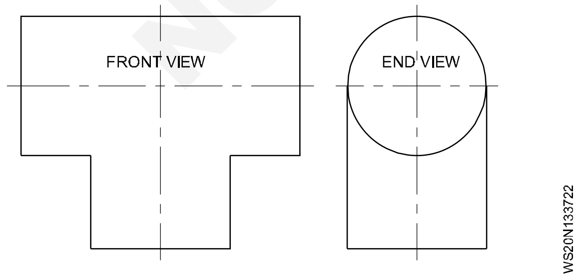
Draw the front view as shown in Fig 1.

Fig 1



Draw the side view as shown in Fig 2.

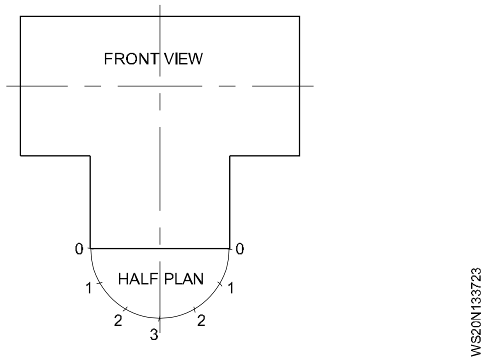
Fig 2



Draw a semi-circle on the base line of the front elevation. (Fig 3)

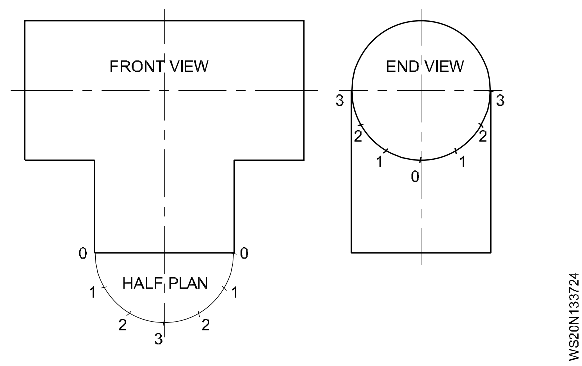
Divide the semi-circle into six equal parts and number them as 0, 1, 2, 3, 2, 1, 0. (Fig 3)

Fig 3

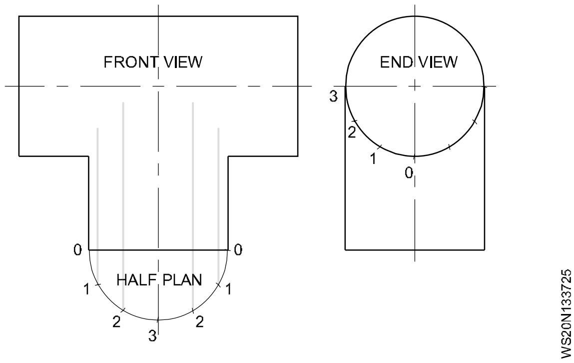


Divide a semi-circle in side view into six equal parts and number as 3, 2, 1, 0, 1, 2, 3 as shown in Fig 4.

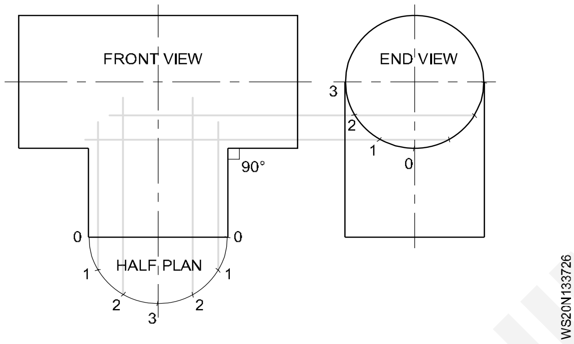
Fig 4



Draw the perpendicular lines from each point of the semi-circle of the view as shown in Fig 5.

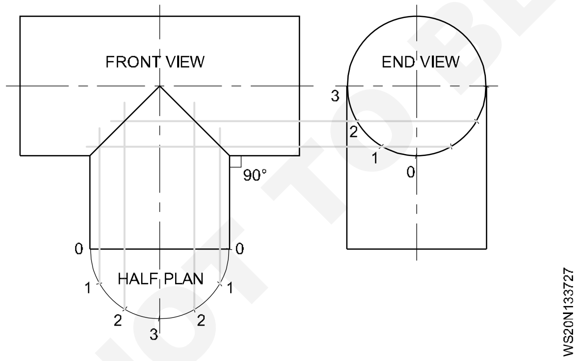
Fig 5


Draw horizontal lines from the side view towards the front view as shown in Fig 6.

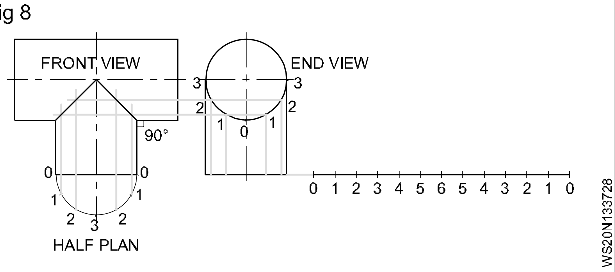
Fig 6


Now the vertical lines of the front view and the horizontal lines of side meet at their respective points.

Join these points to get the line of intersection of "T" pipe as shown in Fig 7.

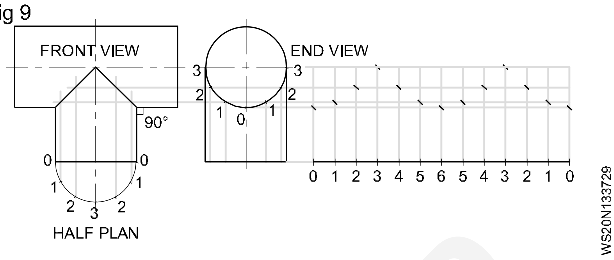
Fig 7


Extend the base line of the side view and mark the end point as 0. (Fig 8)

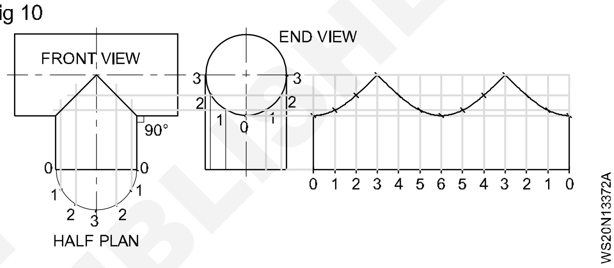
Fig 8


Take one division of the semi-circle in side view and transfer it 12 times on the base line starting from: 0: and number as 0, 1, 2, 3, 2, 1, 0, 1, 2, 3, 2, 1, 0 as shown in Fig 9.

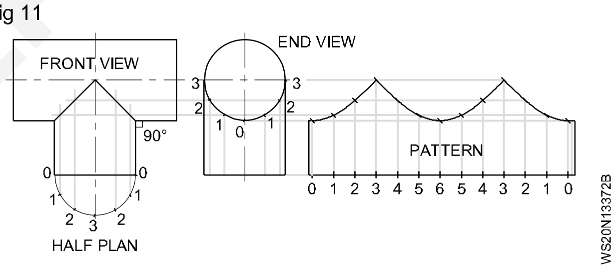
Draw perpendicular lines from these points and draw horizontal lines from the points on the line of intersection of "T". These line meet at their respective points. (Fig 9)

Fig 9


Join these points by free hand curve. (Fig 10)

Fig 10


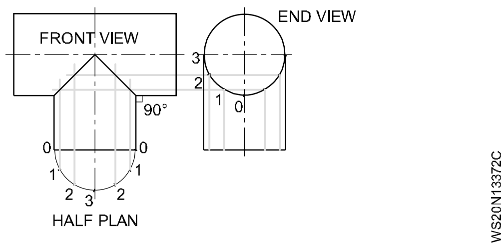
Provide locked grooved joint allowance as shown in Fig 11.

Fig 11


Check the pattern once again and cut. Thus you get the pattern for branch pipe.

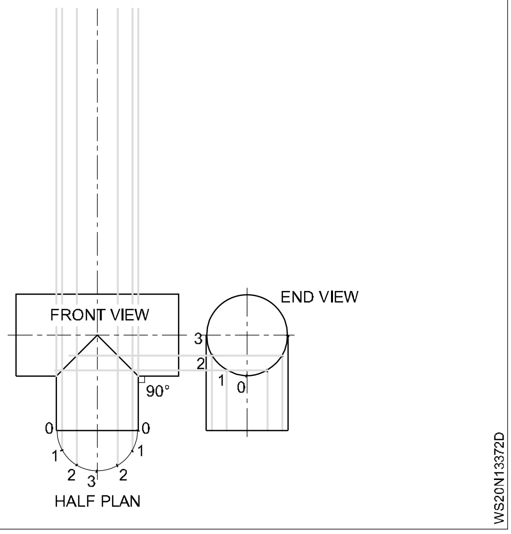
For main pipe, develop and layout the pattern as follows:

Draw the front view and end view. (Fig 12)

Fig 12


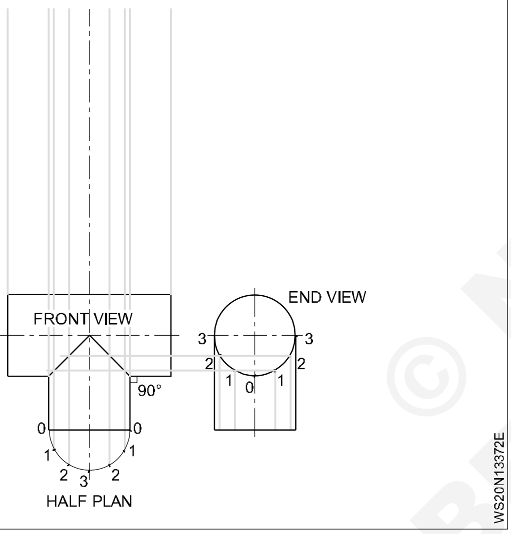
Extend the vertical lines 0, 1, 2, 3, 1, 0 of branch pipe from the front view as shown in Fig 13.

Fig 13



Extend the two extreme end vertical lines of the main pipe from the front view as shown in Fig 14.

Fig 14



On one of these lines, take point "0" as starting point and mark points 0, 1, 2, 3, 2, 1, 0, 1, 2, 3, 2, 1, 0 at equal distances equal to one division of the semi-circle and draw horizontal lines from these points. (Fig 15)

Now these horizontal lines meet the vertical lines at their respective points as shown in Fig 16.

Join these points by free hand curve and get the pattern for the main pipe. (Fig 17)

Provide the locked grooved joint allowances as shown in Fig 17.

Fig 15

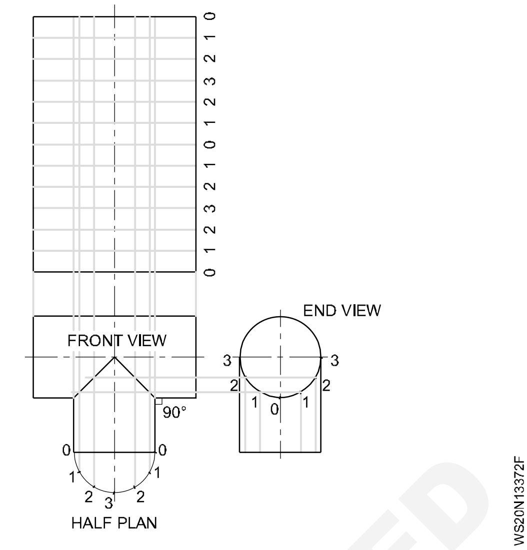


Fig 16

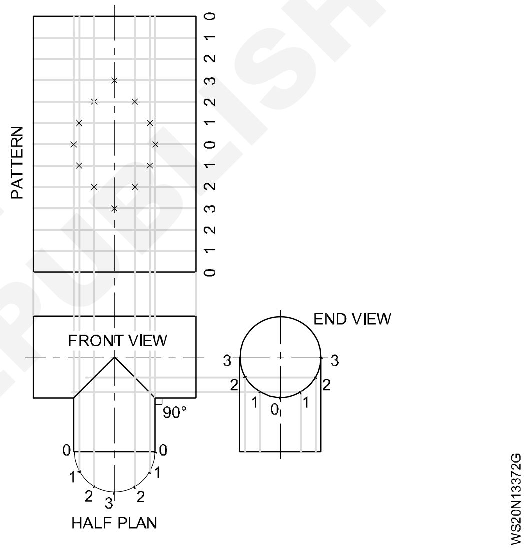
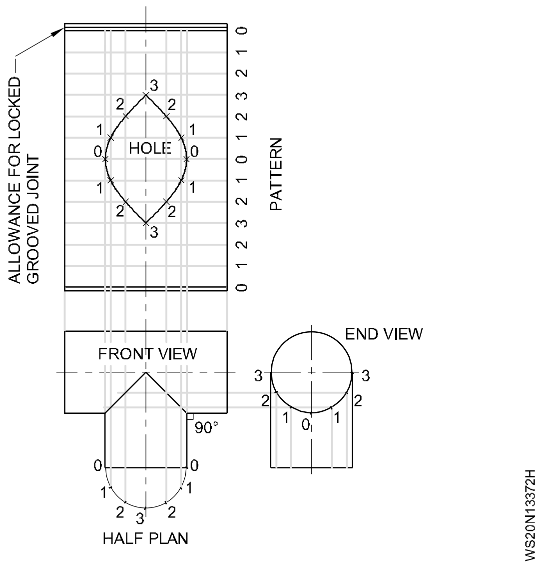


Fig 17



Pipe development for "Y" joint

Objectives: At the end of this lesson you shall be able to
- **develop and able to layout the pattern for "Y" joint pipes intersecting at 120°**
- **develop and layout the pattern for "Y" joint pipes branching at 90°.**

Development of "Y" joint pipes intersecting at 120°: Draw the development of intersecting cylinders of dia. 30 mm at 120°. (Fig 1)

All the cylindrical pipes are of same diameter and intersecting each at equal angles. Hence in this case the development of all the pipes are same and so the development of one pipe will represent other pipes.

- Draw the plan and elevation of the pipe 'A' and mark the division on the plan. (Fig 1b)
- Draw the vertical projectors from the plan to front view to meet the line of intersection.
- Draw horizontal projectors from these points on to the development.
- Mark the intersecting points and join with a smooth curve to complete the required development.

Development of 'Y' joint branching at 90°: Three cylindrical pipes of X, Y, Z form a 'Y' piece. (Fig 2) Draw the lateral surface development of each pipe.

In the three pipes XYZ, Y & Z are similar in size and shape, hence their developments are also similar.

- Draw the development of pipe 'X' as in the previous exercise.
- Draw the elevation and plan of pipe 'Y' as shown.
- Divide the plan circle into 16 equal parts.
- Project the points to the elevation.
- Draw the rectangle ABCD in which AB is equal to D.
- Draw the development of pipe Y as shown in Fig 2.

Fig 1

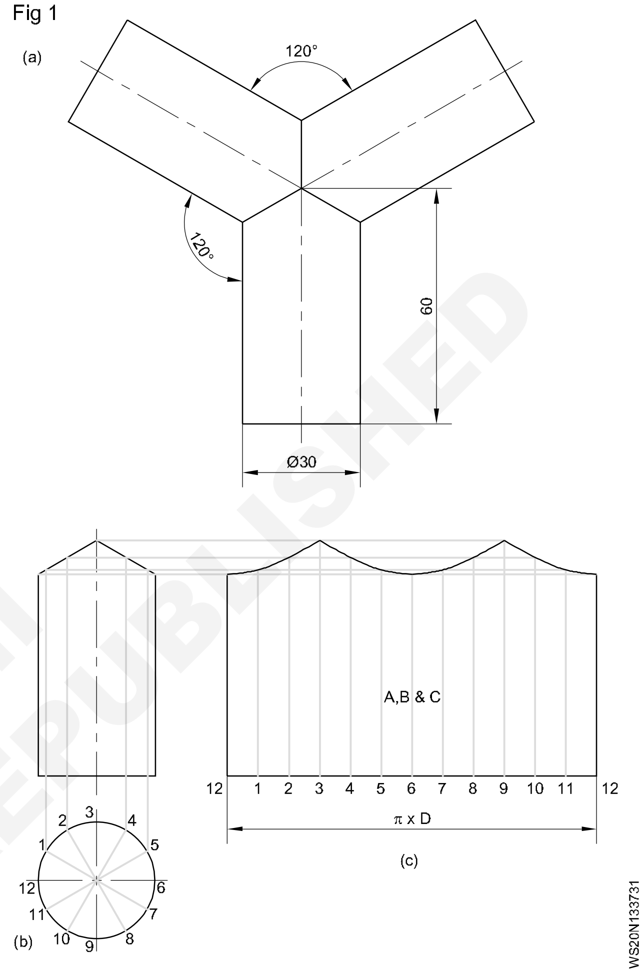
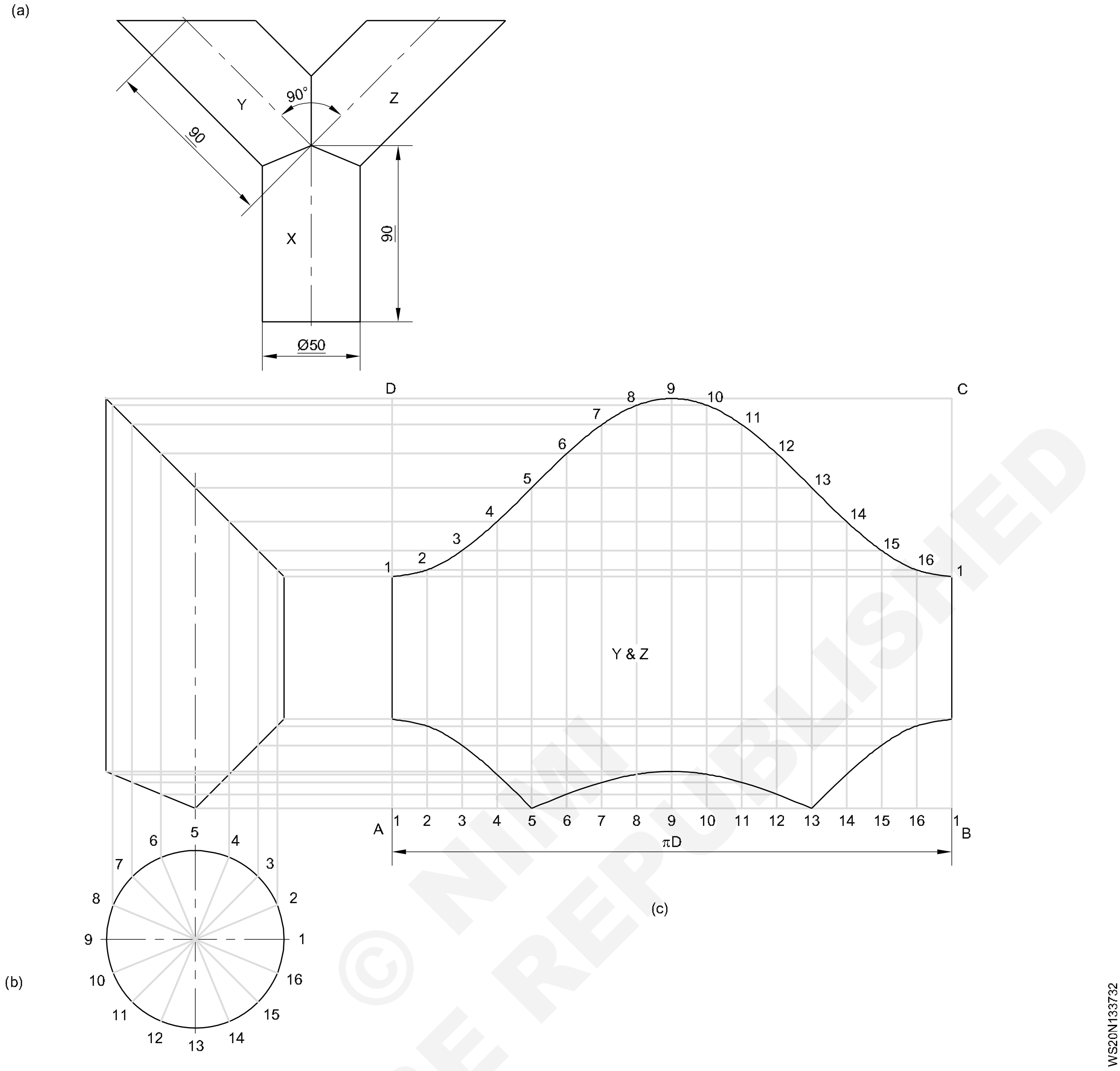


Fig 2



Development of 45° and 90° branch pipe

Objective: At the end of this lesson you shall be able to
- **prepare the development of pipe for 45° and 90° branch pipe.**

Procedure for development of 45° branch pipe: Refer Fig 1. Draw a center line AB.

Mark the points C, D, E and F taking the radius and the length of the given pipe with the center line AB as reference line.

On the line "CD" locate the position of the 45° branch pipe. This will be "G".

Draw a 45° angle at the point "G".

Choose a suitable height and mark the height of the branch pipe (GI) in 45° line from point G.

From I, draw a horizontal line on both sides (XX'). This XX' will be the base line for drawing development.

From I, plot the outside diameter of the branch pipe IJ on the line XX'.

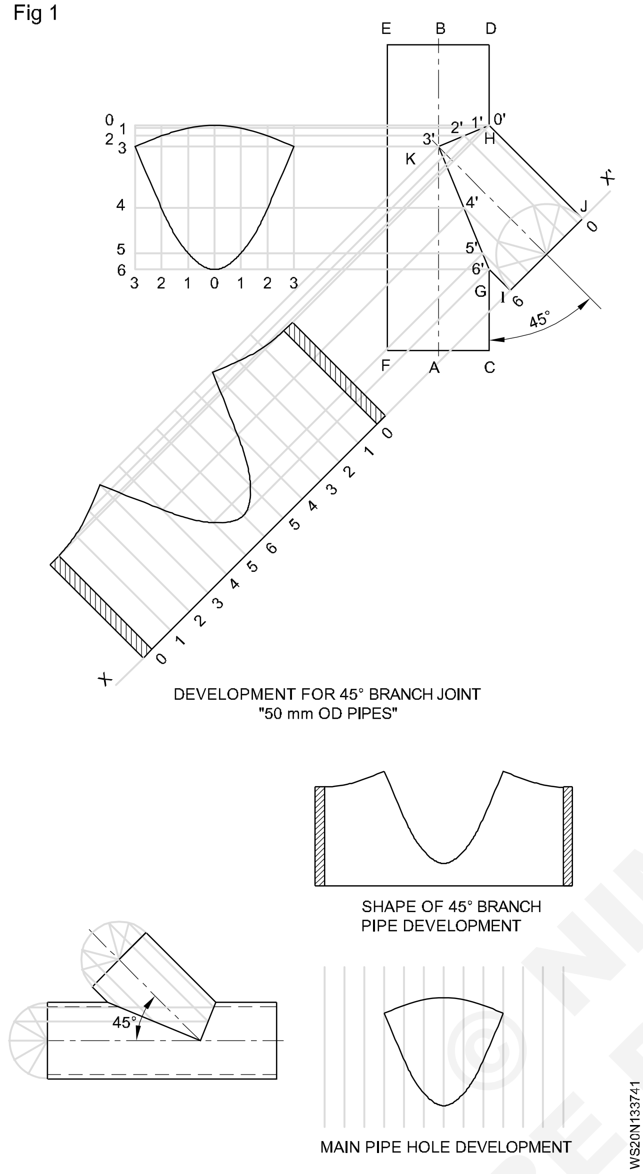
Draw a center line for the branch pipe. This line will cut the main pipe's center line AB at K.

Join GK. Draw a perpendicular line to GK at K which meets CD at H. Join KH. Now IHKHJ will be the shape (outline) of the branch pipe.

Draw a semi-circle equal to the branch pipe outside diameter.

Divide the semi-circle into 6 equal parts as 0-1; 1-2; 2-3; 3-4; 4-5 & 5-6.

Fig 1



Draw vertical lines from these points 1, 2, 3, 4, 5. Already there will be two vertical lines IG from the points 6 and JH from point 0. These vertical lines will cut the branch pipe lines 'GK' and 'KH' at points 6', 5', 4', 3', 2', 1', & 0'. Note that points 6' and G as points 0' and H are the same points. In the base line XX' plot 12 points equal to the distance of '0-1' as 0, 1, 2, 3, 4, 5, 6, 5, 4, 3, 2, 1, 0.

Draw vertical lines to XX' from these 13 points.

Draw horizontal lines parallel to XX' from points 6', 5', 4', 3', 2', 1', 0'. These 7 horizontal lines will cut the 13 vertical lines from the base line at 13 points.

Join the 13 cutting points with a regular smooth curve. Now the required development for the 45° branch pipe will be ready. Give allowance of 3 to 5 mm at the edges of the development. (Fig 1)

For developing a hole in the base pipe: Above the main pipe, draw 7 lines parallel to AB namely 3, 2, 1, 0, 1, 2, 3 equal to the distance of 0-1 on the semi circle.

Draw vertical lines from 0', 1', 2', 3', 4', 5', 6'. These vertical lines will intercept the 7 horizontal lines. Join the intercepting points with a smooth curve. The required development for hole is now ready.

Uses of Manifold system

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of the manifold system and its types**
- **describe the construction of the manifold system**

When large volumes of oxygen and acetylene gas are required on a temporary or permanent basis for many welding and cutting operations in a workshop, a manifold system is most suitable one.

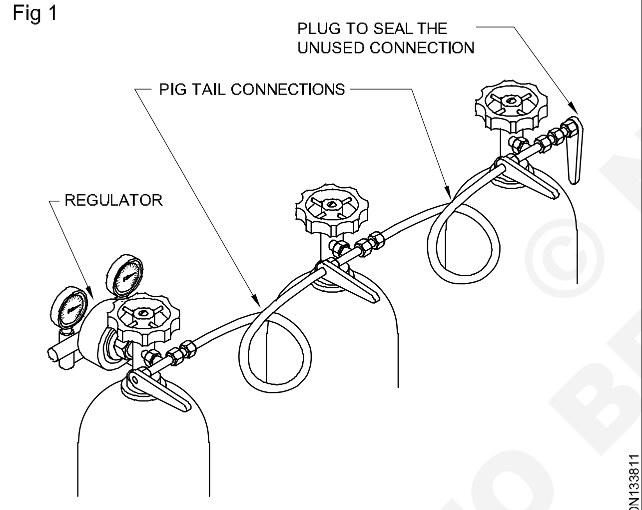
Types

– Portable manifold system

– Stationary manifold system

Portable manifold system means two or three cylinders are coupled with a suitable apparatus - namely 'PIG TAIL' and connected to a main distribution pipe. (Fig 1) Separate arrangements are made for oxygen and acetylene gases.

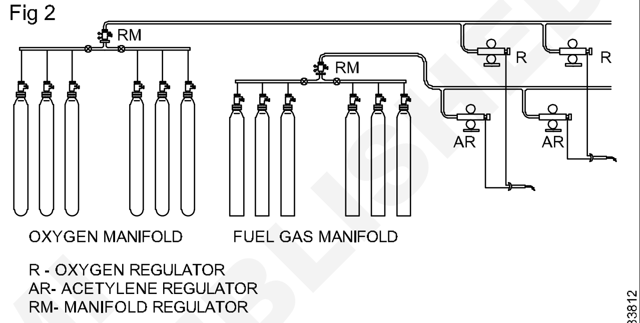
Fig 1



PORTABLE MANIFOLD SYSTEM (EXTENDABLE)

When the demand is even more, many cylinder are coupled together, and this is called stationary 'MANIFOLD' system. (Fig 2) Separate manifold systems are installed for oxygen and acetylene. These manifolds usually have two banks of cylinders. One bank is kept in reserve while the other one is in use.

Fig 2



STATIONARY MANIFOLD SYSTEM

The use of such manifolds reduces substantially the cost of handling the cylinders inside the workshop.

These manifolds are fitted with master regulators which reduce the cylinder pressure to about 15 kg/cm^2 for feeding into the distribution pipe to the various consuming points. The consuming points are fitted with an outlet value, stop-valves and regulators for individual pressure control at the site for gas welding or cutting operations.

Gas welding filler rods, specifications and sizes

Objectives: At the end of this lesson you shall be able to
- **state the filler rods and name the different types of filler rods and their sizes**

Sizes as per IS: 1278 - 1972)

The size of the filler rod is determined from the diameter as: 1.00, 1.20. 1.60, 2.00, 2.50, 3.15, 4.00, 5.00 and 6.30mm. For leftward technique filler rods up to 4mm dia. are used. For rightward technique upto 6.3 mm dia. is used. For C.I welding filler rods of 6mm dia. and above are used. Length of filler rod:-500mm or 1000mm.

Filler rods above 4mm diameter are not used often for welding of mild steel.

The usual size of mild steel filler rods used are 1.6mm and 3.15mm diameter. All mild steel filler rods are given a thin layer of copper coating to protect them from oxidation (rusting) during storage. So these filler rods are called copper coated mild steel (C.C.M.S) filler rods.

All types of filler rods are to be stored in sealed plastic covers until they are used.

Definition of filler rod: A filler rod is a metallic wire made out of ferrous or non-ferrous metal to deposit the required metal in a joint or on the base metal.

Types of filler rods: The following types of filler rods are classified in gas welding.

- Ferrous filler rod
- Non-Ferrous filler rod
- Alloy type filler rod for ferrous metals
- Alloy type filler rod for non-ferrous metals

A ferrous type filler rod has a major % of iron.

The ferrous type filler rod contains iron, carbon, silicon, sulphur and phosphorous.

The alloy type filler contains iron, carbon, silicon and any one or many of the following elements such as manganese, nickel, chromium, molybdenum, etc.

The non-ferrous type filler rod which contains elements of non-ferrous metals. The composition of non-ferrous type filler rods is similar to any non-ferrous metal such as copper, aluminium. A non-ferrous alloy type filler rod contains metals like copper, aluminium, tin, etc. along with zinc, lead, nickel, manganese, silicon, etc.

Selection of the correct filler rod for a particular job is a very important step for successful welding. Cutting out a strip from the material to be welded is not always possible and even when it is possible, such a strip cannot replace a recommended welding filler materials. Composition of a filler metal is chosen with special consideration to the metallurgical requirement of a weldment. A wrong choice due to either ignorance or a false consideration of economy may lead to costly failures. IS: 1278-1972* specifies requirements that should be met by filler rods for gas welding. There is another specification IS: 2927-1975* which covers brazing alloys. It is strongly recommended that filler material confirming to these specifications is used. In certain rare cases, it may be necessary to use filler rods of composition not covered by these specifications; in such cases filler rods with well established performances should be used.

To select a filler rod in respect to the metal to be welded, the filler rod must have the same composition with respect to the base metal to be welded.

Factors to be considered for selection of filler rod are:

a the type and composition of base metal

b the base metal thickness

c the type of edge preparation

d the weld is deposited as root run, intermediate runs or final covering run

e welding position

f whether there is any corrosion effect or loss of material from the base metal due to welding.

Table 1
Filler metals and fluxes for gas welding

Filler metal type	Application	Flux
Mild steel - Type S-FS1	A general purpose rod for welding mild steel where a minimum butt-weld tensile strength of 35.0 kg/mm^2 is required. (Full fusion technique with neutral flame.)	Not required.
Mild steel - Type S-FS2	Intended for application in which minimum butt-weld tensile strength of 44.0 kg/mm^2 is required. (Full fusion technique with neutral flame.)	Not required.
Wear-resisting alloy steel	Building up worn out crossings and other application where the steel surfaces are subject to extreme wear by shock and abrasion. (Surface fusion technique with excess acetylene flame.)	Not required.
3 percent nickel steel Type S-FS4	These rods are intended to be used in repair and reconditioning parts which have to be subsequently hardened and tempered. (Full fusion technique with neutral flame.)	Special flux (if necessary).
Stainless steel decay-resistant (niobium bearing)	These rods are intended for use in the welding of corrosion-resisting steels such as those containing 18 percent chromium and 8 percent nickel. (Full fusion technique with neutral flame.)	Necessary
High silicon cast iron-Type S-C11	Intended for use in the welding of cast iron where an easily machinable deposit is required. (Full fusion technique with neutral flame.)	Flux necessary.
Copper filler rod - Type S-C1	For welding of de-oxidized copper. (Full fusion technique with neutral flame.)	Flux necessary.
Brass filler rod - Type S-C6	For use in the braze welding of copper and mild steel and for the fusion welding of material of the same or closely similar composition. (Oxidising flame.)	Flux necessary.
Manganese bronze (high tensile brass) - Type S-C8	For use in braze welding of copper, cast iron and malleable iron and for the fusion welding of materials of the same or closely similar composition. (Oxidising flame.)	Flux necessary.
Medium nickel bronze - Type S-C9	For use in the braze welding of mild steel, cast iron and malleable iron. (Oxidising flame.)	Flux required.
Aluminium (Pure) - Type S-C13	For use in the welding of aluminium grade 1B. (Full fusion technique with neutral flame.)	Flux necessary.
Aluminium alloy-5 percent silicon - Type S-NG21	For welding of aluminium casting alloys, except those containing magnesium, or zinc as the main addition. They may also be used to weld wrought aluminium-magnesium-silicon alloys. (Full fusion technique with neutral flame.)	Flux necessary.
Aluminium alloy-10-13 percent silicon - Type 5-NG2	For welding high silicon aluminium alloys. Also recommended for brazing aluminium. (Neutral flame.)	Flux necessary.
Aluminium alloy-5 percent copper	For welding aluminium casting particularly those containing about 5 percent copper. (Full fusion technique with neutral flame.)	Flux necessary.

Filler metal type	Application	Flux
Stellite: Grade 1	Hard facing of components subjected mainly to abrasion. (Surface fusion technique with excess acetylene flame.)	None is usually required. A cast iron flux may be used, if necessary
Stellite: Grade 6	Hard facing of components subjected to shock and abrasion, (Surface fusion technique with excess acetylene flame.)	-do-
Stellite: Grade 12	Hard facing of components subjected to abrasion and moderate shock. (Surface fusion technique with excess acetylene flame.)	-do-
Copper-phosphorus brazing alloy - Type BA-CuP2	Brazing copper, brass and bronze components. Brazing with slightly oxidising flame on copper; neutral flame on copper alloys.	Necessary
Copper-phosphorus brazing alloy - Type BA-CuP5	For making ductile joint in copper without flux. Also widely used on copper based alloys of the brass and bronze type in conjunction with a suitable silver brazing flux. (Flame slightly oxidising on copper; neutral on copper alloys.)	None for copper. A flux is nece-ssary for brazing copper alloys.
Silver-copper-zinc (61 per-cent silver) type brazing alloys - Type BA-CuP3	Similar to type BA-CuP5 but with a slightly lower tensile strength and electrical conductivity (flame slightly oxidising on copper; neutral on copper alloys). NOTE: Phosphorus bearing silver brazing alloys should not be used with ferrous metal or alloys of high nickel content.	None for copper. A flux is necess-ary for brazing copper alloys.
Silver-copper-zinc (61 percent silver) - Type BA-Cu-AG6	This brazing alloy is particularly suitable for joining electrical components requiring high electrical conductivity. (Flame neutral)	Flux necessary.

Gas Welding Fluxes and types & Functions

Objectives: At the end of this lesson you shall be able to
- **explain flux and its function in gas welding**
- **describe the types of welding fluxes and their storage.**

Flux is a fusible (easily melted) chemical compound to be applied before and during welding to prevent unwanted chemical action during welding and thus making the welding operation easier.

The function of flux in gas welding: To dissolve oxides and to prevent impurities and other inclusion that could affect the weld quality.

Fluxes help the flow of their metal into very small gap between the metals being joined.

Fluxes act as cleaning agents to dissolve and remove oxides and clean the metal for welding from dirt and other impurities.

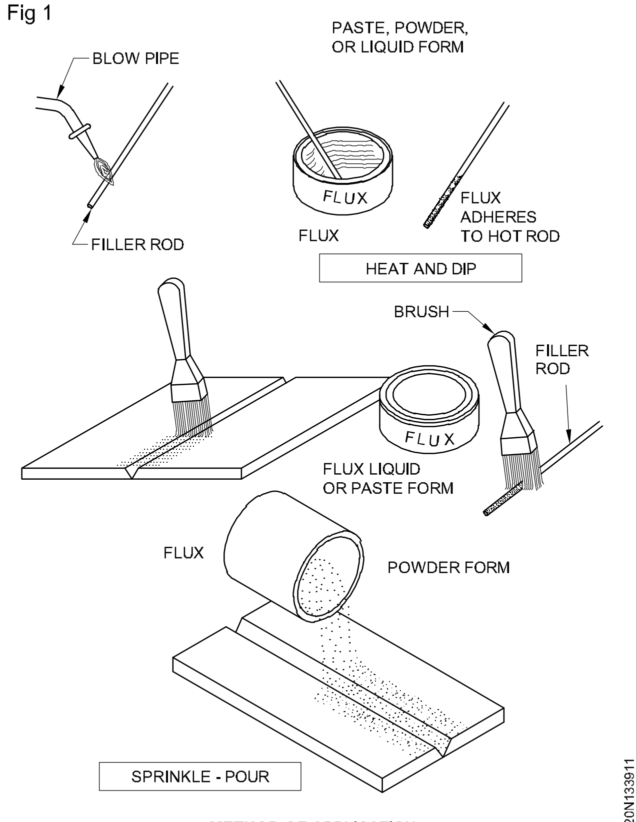
Fluxes are available in the form of paste, powder and liquid. The method of application of flux is shown in Fig 1.

Storing of fluxes: Where the flux is in the form of a coating on the filler rod, protect carefully at all times against damage and dampness. (Fig 2)

Seal flux tin lids when storing especially for long periods. (Fig 2)

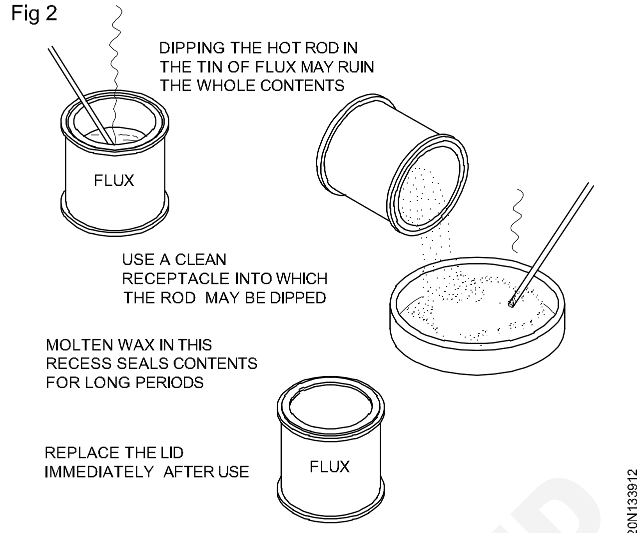
Though the inner envelope of an oxy-acetylene flame offers protection to the weld metal, it is necessary to use a flux in most cases. Flux used during welding not only protects the weldment from oxidation but also from a slag which floats up and allows clean weld metal, to be deposited. After the completion of welding, flux residues should be cleaned.

Fig 1



METHOD OF APPLICATION

Fig 2



METHOD OF STORING FLUX

Gas Welding defects, causes and remedies

Objectives: At the end of this lesson you shall be able to
- **name and define various weld defects**
- **identify the common faults in gas welding.**

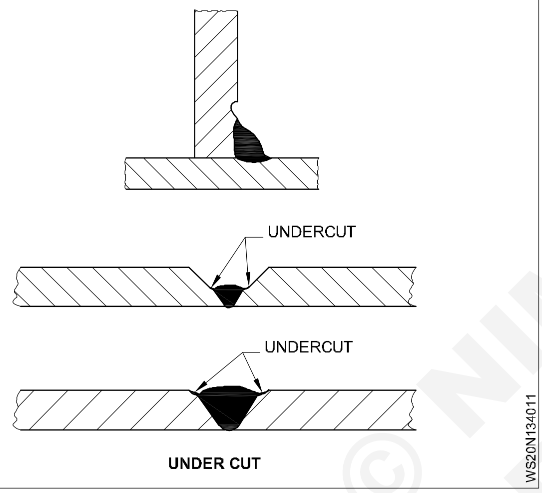
Definition

A fault is an imperfection in the weld which may result in failure of the welded joint while in service.

The following faults occur commonly in gas welding.

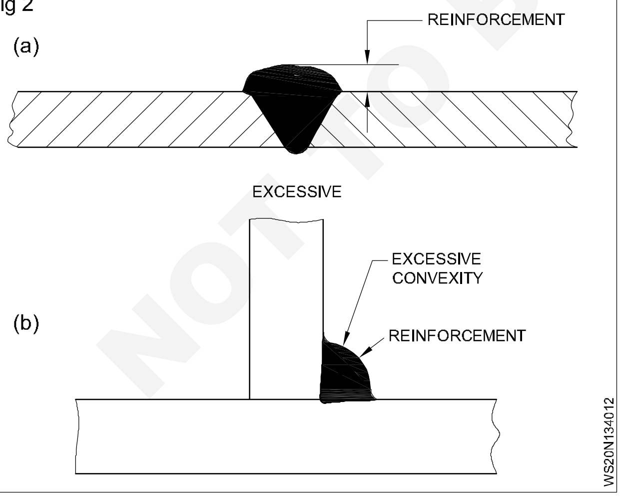
Undercut: A groove or channel formed along the toe of the weld on one side or on both sides. (Fig 1)

Fig 1



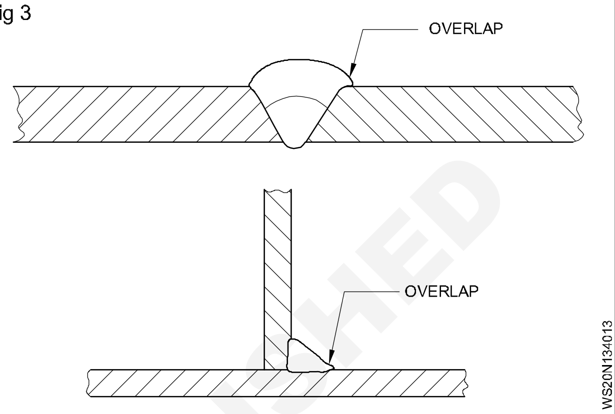
Excessive convexity: Too much weld metal added to the joint so that there is excessive weld reinforcement. (Fig 2)

Fig 2



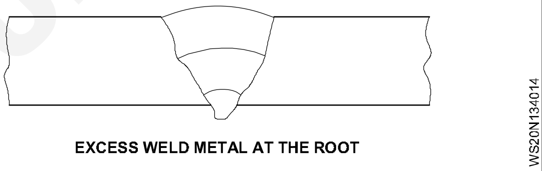
Overlap: Metal flowing into the surface of the base metal without fusing it. (Fig 3)

Fig 3



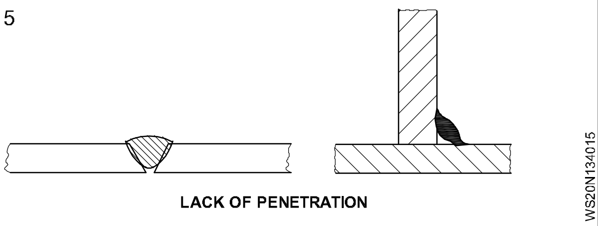
Excessive penetration: Depth of fusion at the root of the grooved joint is more than the required amount. (Fig 4)

Fig 4



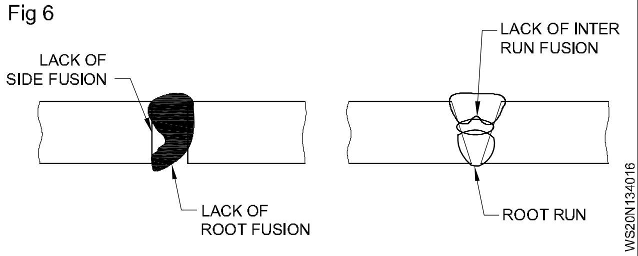
Lack of penetration: Required amount of penetration is not achieved, i.e. fusion does not take place up to the root of the weld. (Fig 5)

Fig 5



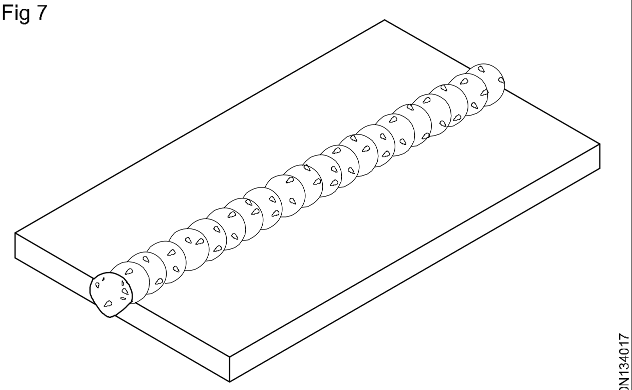
Lack of fusion: If there is no melting of the edges of the base metal at the root face or on the side face or between the weld runs, then it is called lack of fusion. (Fig 6)

Fig 6



Porosity: Number of pinholes formed on the surface of the deposited metal. (Fig 7)

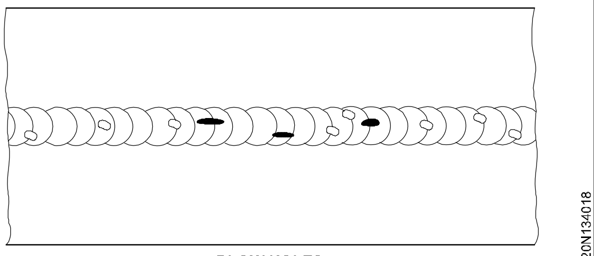
Fig 7



POROSITY

Blow-holes: These are similar to pinholes but have a greater diameter. (Fig 8)

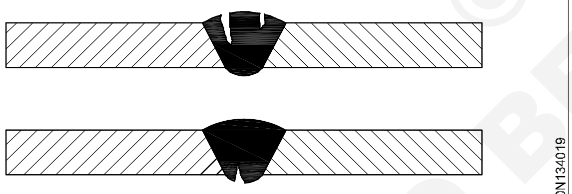
Fig 8



BLOW HOLES

Cracks: A discontinuity in the base metal or weld metal or both. (Fig 9)

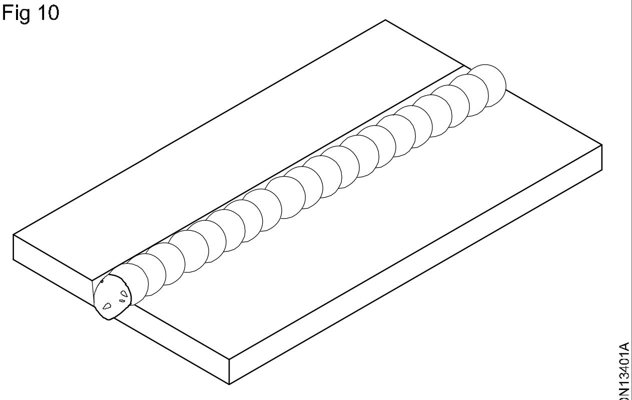
Fig 9



CRACKS

Unfilled crater: A depression formed at the end of the weld. (Fig 10)

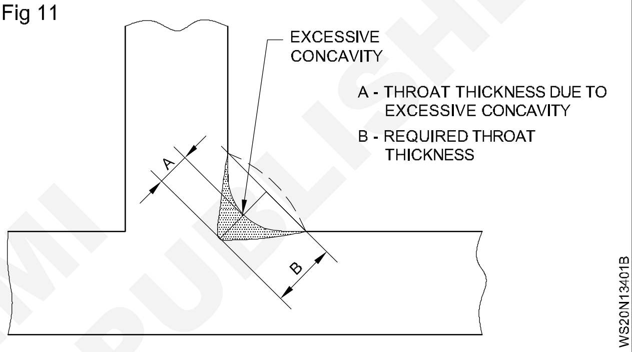
Fig 10



UNFILLED CRATER

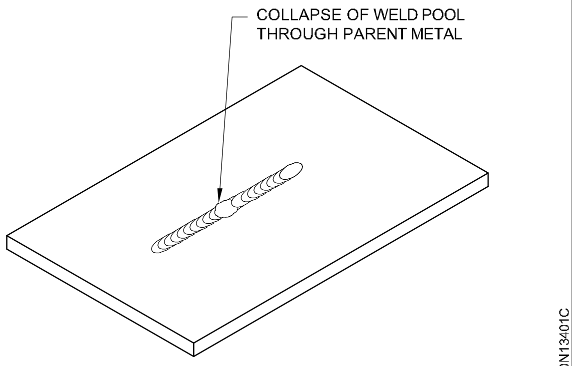
Excessive concavity/insufficient throat thickness: Enough weld metal is not added to the joint so that there is insufficient throat thickness. (Fig 11)

Fig 11



Burn through: A collapse of the molten pool due to excessive penetration, resulting in a hole in the weld run. (Fig 12)

Fig 12



BURN THROUGH

Gas Brazing & Soldering : principles, types fluxes & uses - Refer : Related theory for exercise 1.1.09

Weld defects - causes and remedies

Objectives: At the end of this lesson you shall be able to
- **explain the causes of weld defects**
- **state the remedies to prevent the defects.**

Welding defects: Possible causes and remedies

	Defect	Possible causes	Appropriate remedies
1	Fillet weld with insufficient throat thickness.	Incorrect angle of filler rod and blowpipe.	Maintain filler rod and blowpipe at the appropriate angles.
2	Excessive concavity in butt weld profile.	Excess heat build-up with too fast a speed of travel or filler rod too small.	Use the appropriate size nozzle and filler rod with the correct speed of travel.
3	Excessive penetration. Excess fusion of root edges.	Angle of slope of nozzle too large. Insufficient forward heat. Flame size and/or velocity too high. Filler rod too large or too small. Speed of travel too slow.	Maintain the nozzle at the correct speed of travel. Select correct nozzle size. Regulate flame velocity correctly. Use correct size of filler rod.
4	Burn through.	Excessive penetration has produced local collapse of weld pool resulting in a hole in the root run.	Maintain blowpipe at the correct angles. Check nozzle size, filler rod size. Travel at the correct speed.
5	Undercut along vertical member of filler welded Tee joint.	Incorrect angle of tilt used in blowpipe manipulation.	Maintain blowpipe at the Correct angle.
6	Undercut in both sides of weld face in butt joint.	Wrong blowpipe manipulation; incorrect distance from plate surface, excessive lateral movement. Use of too large a nozzle.	Use correct nozzle size, speed of travel and lateral blowpipe manipulation.
7	Incomplete root penetration in butt joint (single 'V' or double 'V').	Incorrect set up and joint preparation. Use of unsuitable procedure and/or welding technique.	Ensure joint preparation and set up are correct. Appropriate procedure and/or welding technique must be used.
8	Incomplete root penetration in close square Tee joint.	Incorrect set up and joint preparation. Use of unsuitable procedure and/or welding technique.	Ensure joint preparation and set up are correct. Appropriate procedure and/or welding technique must be used.
9	Lack of root penetration.	Incorrect joint preparation and set up. Gap too small. Vee preparation too narrow. Root edges touching.	Prepare and set up the joint correctly.
10	Lack of fusion on root and side faces of double Vee butt joint.	Incorrect set up and joint preparation. Use of unsuitable welding technique.	Ensure the use of correct joint preparation, set up and welding technique.
11	Lack of inter-run fusion.	Angles of nozzle and blowpipe manipulation incorrect.	Correct the angles of slope and tilt. Use blowpipe manipulation to control uniform heat build-up.

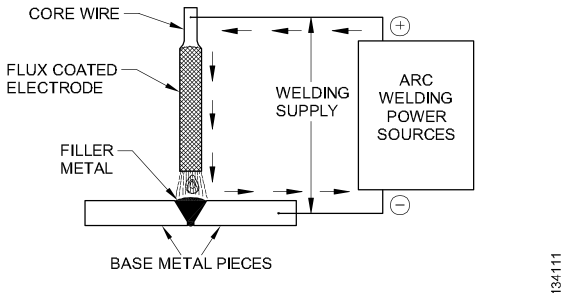
	Defect	Possible causes	Appropriate remedies
	Overlap		
12	Weld face cracks in butt and fillet welds.	Use of incorrect welding procedure. Unbalanced expansion and contraction stresses. Presence of impurities. Undesirable chilling effects. Use of incorrect filler rod.	Use correct procedure and filler rod. Ensure uniform heating and cooling. Check suitability and surface preparation of material before welding. Avoid draughts and use appropriate heat treatment.
13	Surface porosity and gaseous intrusions.	Use of incorrect filler rod and technique. Failure to clean surfaces before welding. Absorption of gases due to incorrectly stored fluxes, unclean filler rod. Atmospheric contamination.	Clean plate surfaces. Use correct filler rod and technique. Make sure the flame setting is correct to avoid gas contamination.
14	Crater at end of weld run. Small cracks may be present.	Neglect to change the angle of blowpipe, speed of travel or increase the rate of weld metal deposition as welding is completed at the end of the seam.	Reduce the angle of the blowpipe progressively with speed of travel to lower the heat input and deposit, and deposit sufficient metal to maintain the toe of the weld pool at the correct level until it has completely solidified.

Electrode types functions of filler coating factor, size of electrode

Objectives: At the end of this lesson you shall be able to
- **explain arc welding electrode**
- **explain the coating factor**

Introduction: An electrode is a metallic wire of standard size and length, generally coated with flux (may be bare or without flux coating also) used to complete the welding circuit and provide filler material to the joint by an arc, maintained between its tip and the work. (Fig 1)

Fig 1



FLUX COATED METALLIC ELECTRODE IN THE WELDING CIRCUIT

Different types of electrodes used are given in the Electrode chart.

Method of flux coating:

- Dipping
- Extrusion

Dipping method: The core wire is dipped in a container carrying flux paste. The coating obtained on the core wire is not uniform resulting in non-uniform melting; hence this method is not popular.

Extrusion method: A straightened wire is fed into an extrusion press where the coating is applied under pressure. The coating thus obtained on the core wire is uniform and concentric, resulting in uniform melting of the electrode. (Fig 2) This method is used by all the electrode manufacturers.

Coating factor (Fig 3)**:** The ratio of the coating diameter to the core wire diameter is called the coating factor.

$$= \frac{\text{Coating diameter}}{\text{Coating wire diameter}}$$

It is 1.25 to 1.3 for **light coated**,

1.4 to 1.5 for **medium coated**,

1.6 to 2.2 for **heavy coated**, and above 2.2 for super heavy coated electrodes.

Fig 2

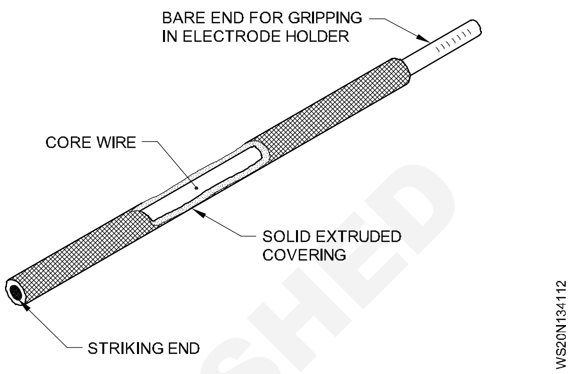
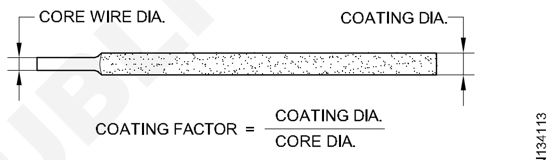


Fig 3



COATING FACTOR

Types of flux coating

- Cellulosic (Pipe welding electrode e.g. E6010)
- Rutile (General purpose electrode e.g. E6013)
- Iron powder (e.g. E7018)
- Basic coated (Low hydrogen electrode e.g. E7018)

Cellulosic electrode: Cellulosic electrode coatings are mainly made of materials containing cellulose, such as wood pulp and flour. The coating on these electrodes is very thin and the slag is difficult to remove from deposited welds. The coating produces high levels of hydrogen and is therefore not suitable for high-strength steels. This type of electrode is usually used on DC+ and suited to root pass welding of high pressure pipes.

Rutile electrodes: Rutile electrodes, are general-purpose electrodes have coatings based on titanium dioxide. These electrodes are widely used in the CG & M industry as they produce acceptable weld shape and the slag on deposited welds is easily removed. Strength of deposited welds is acceptable for most low-carbon steels and the majority of the electrodes in this group are suitable for general purpose CG & M.

Basic or hydrogen-controlled electrodes: Basic or hydrogen controlled electrode coatings are based on calcium fluoride or calcium carbonate. This type of electrode is suitable for welding high-strength steels without weld cracks and the coating have to be dried. This drying is achieved by backing at 450°C holding at 300°C and storing at 150°C until the time of use. By maintaining these conditions it is possible to achieve high strength weld deposits on carbon, carbon manganese and low alloyed steels. Most electrodes in this group deposit welds with easily removable slags, producing acceptable weld shape in all positions. Fumes given off by this electrode are greater than with other types of electrodes.

Iron powder electrodes: Iron powder electrodes get their name from the addition of iron powders to the coating which tend to increase efficiency of the electrode. For example, if the electrode efficiency is 120%, 100% is obtained from the core wire and 20% from the coating. Deposited welds are very smooth with an easily removable slag; welding positions are limited to horizontal, vertical fillet welds and flat or gravity position fillet and butt welds.

Composition/Characteristics Flux

Composition/characteristics flux: The coating of the welding electrodes consists of a mixture of the following substances.

Alloying substances: These substances compensate for the burning of manganese, ferro-silicon. The alloying substances are:

- ferro-manganese
- ferro-silicon
- ferro-titanium.

Arc stabilizing substances: These are carbonates known as chalk and marble. These are used for the stabilisation of the arc.

Deoxidizers: These substances prevent porosity and make the welds stronger. The deoxidising substances are iron oxide, lamitite, magnetite.

Slag forming substances: These substances melt and float over the molten metal and protect the hot deposited weld metal from the atmospheric oxygen and nitrogen. Also due to the slag covering, the weld metal is prevented from fast cooling. The slag forming substances are clay, limestone.

Fluxing/cleaning substances: These substances remove oxides from the edges to be welded and controls the fluidity of the molten metal. The cleaning substances are lime stone, chlorides, fluorides.

Gas forming substances: These substances form gases which aid the transfer of metal. They also shield the welding arc and weld pool. The substances are: wood flour dextrin and cellulose.

Binding and plasticizing substances: These substances help the applied coating to grip firmly around the core wire of the electrode.

These are: sodium and potassium silicates.

Purpose or function of flux coating: During welding, with the heat of the arc, the electrode coating melts and performs the following functions.

- It stabilizes the arc.
- It forms a gaseous shield around the arc which protects the molten weld pool from atmospheric contamination.
- It compensates the losses of certain elements which are burnt out during welding.
- It retards the rate of cooling of the deposited metal by covering with slags and improves its mechanical properties.
- It helps to give good appearance to the weld and controls penetration.
- It makes the welding in all positions easy.
- Both AC and DC can be used for the welding.
- Removes oxide, scale etc. and cleans the surfaces to be welded.
- It increases metal deposition rate by melting the additional iron powder available in the flux coating.

Types of electrodes for ferrous and alloy metals

Mild steel electrode: Mild steel is characterized by carbon content not exceeding 0.3%. Mild steel electrode core wire contains various alloying elements.

Carbon 0.1 to 0.3%

(Strengthening agent)

Keep carbon as low as possible.

Silicon above 0.5%

(Deoxidizes, prevents weld metal porosity.)

Manganese 1.65%

(Increases strength and hardness.)

Nickel

(Increases strength and notch toughness.)

Chromium

(Increases tensile strength and hardness. Lowers the ductility.)

Molybdenum 0.5%

(Increases hardness and strength.)

Indian Standard System laid down in IS:814-1991 a classification and coding of covered electrodes for metal arc welding of mild steel, and low alloy high tensile steel. Mild steel and low alloy high tensile steel electrodes are classified into seven recognised groups, depending upon the chemical composition of the flux coating.

Stainless steel electrodes: Selecting proper electrodes depends primarily on the composition of the base metal to be welded.

These electrodes are available with either lime or titanium coatings. The lime coated electrode is used only with DC reverse polarity. Titanium coated electrodes can be used in AC and DC reverse polarity, and will produce smoother and stable arc.

The coding system for stainless steel electrodes differs somewhat from that for the M.S. electrode. The I.S. 5206-1969 specification for corrosion-resisting chromium and chromium-nickel steel covered electrodes will give full details.

During welding, the electrode will tend to get red hot quickly. To avoid this, a 20 to 30% lower current than what is used for ordinary M.S. electrode is recommended.

Sizes of Mild Steel Electrodes

Objectives: At the end of this lesson you shall be able to
- **state the size, length and current setting of M.S. electrodes**
- **explain the functions of electrode**
- **state the BIS coding for M.S. electrode.**

The electrode size refers to the diameter of its core wire.

Each electrode has a certain current range. The welding current increases with the electrode size (diameter).

Electrode sizes

Metric

1.6mm

2.0mm

2.5mm

3.15mm

4.0mm

5.0mm

6.0mm

6.3mm

8.0mm

10.0mm

Standard length of electrodes: The electrodes are manufactured in two different lengths, 350 or 450mm.

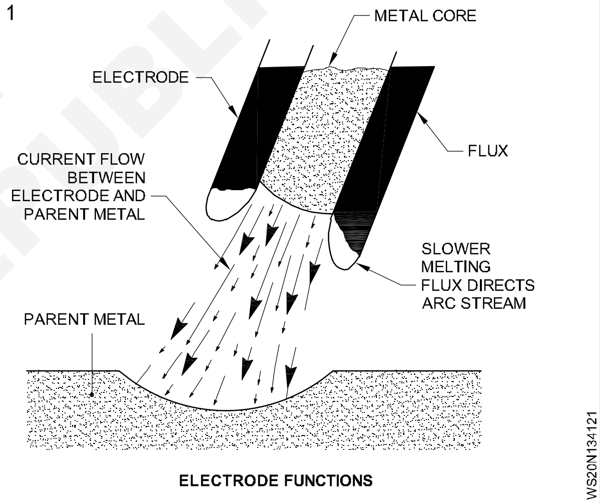
Functions of an electrode in shielded metal arc welding: The two main functions of an electrode in SMAW are: (Fig 1)

– The core wire conducts the electric current from the electrode holder to the base metal through the arc.

– It deposits weld metal across the arc onto the base metal.

The flux covering melts at a slower rate than the metal core and a cup is formed at the tip of the electrode which helps to direct the molten metal to the required spot.

Fig 1



ELECTRODE FUNCTIONS

For easy identification and selection of a suitable arc welding electrode for welding mild steel plates, the electrodes are coded by Bureau of Indian Standards (B.I.S). According to this B.I.S., the electrodes to be used for welding mild steel for training a beginner is coded as ER4211.

Types of electrodes: Electric arc welding electrodes are of three general types. They are:

Carbon electrodes

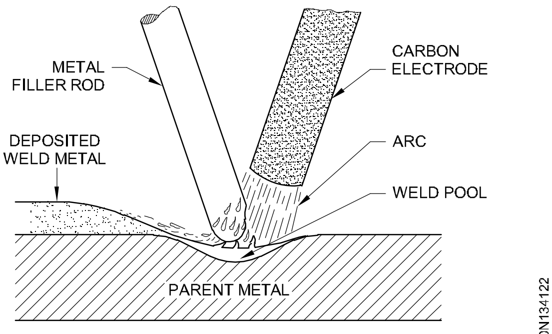
Bare electrodes

Flux coated electrodes

Carbon electrodes are used in the carbon arc welding process (Fig 2). The arc is created between the carbon electrode and the job. The arc melts a small pool in the job and filler metal is added by using a separate rod.

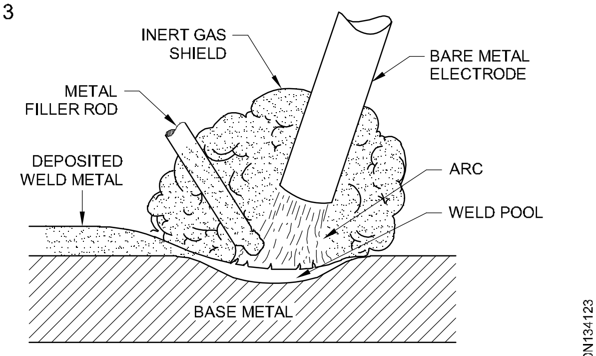
Normally the carbon arc has very little use of welding. Its main application is in cutting and gouging operations.

Fig 2



CARBON ARC PROCESS

Fig 3



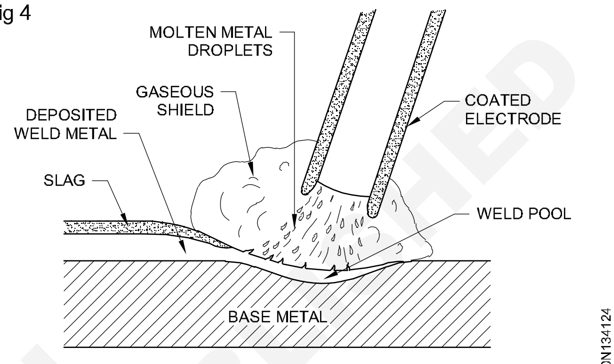
PROCESS USING BARE ELECTRODE & GASEOUS SHIELD

Bare electrodes are also used in some arc welding processes (Fig 3). An inert gas is used to shield the molten weld metal and prevent it from absorbing oxygen and nitrogen. Filler metal is separately added through a filler rod. Usually tungsten is used as one of the bare wire electrode. In Co_2 welding and submerged arc welding processes the mild steel bare wire electrode is also used as a filler wire.

Flux coated electrodes are used in the manual metal arc welding process for welding ferrous and non-ferrous metals. (Fig 4)

The composition of the coating provides the flux, the protective shield around the arc and a protective slag which forms over the deposited weld metal during cooling.

Fig 4



PROCESS USING FLUX COATED ELECTRODE

Effects of moisture pick up storage and baking of electrodes

Objectives: At the end of this lesson you shall be able to
- **explain about special purpose electrodes and their application**
- **state the necessity of baking a coated electrode**
- **store and handle the electrode properly for better weld quality.**

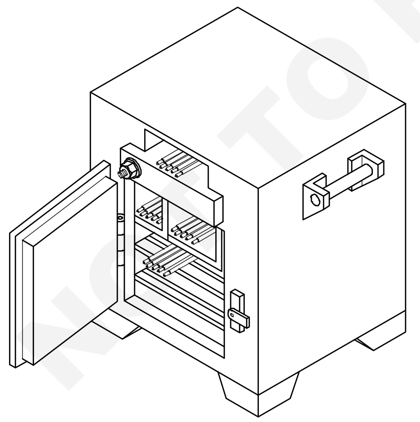
Storage of electrodes: The efficiency of an electrode is affected if the covering becomes damp.

- Keep electrodes in unopened packets in a dry store.
- Place packages on a duckboard or pallet, not directly on the floor.
- Store so that air can circulate around and through the stack.
- Do not allow packages to be in contact with walls or other wet surfaces.
- The temperature of the store should be about 5°C higher than the outside shade temperature to prevent condensation of moisture.
- Free air circulation in the store is as important as heating. Avoid wide fluctuations in the store temperature.
- Where electrodes cannot be stored in ideal conditions place a moisture-absorbent material (e.g. silica-gel) inside each storage container.

Store and keep the electrodes (air tight) in a dry place.

Bake the moisture affected/prone electrodes in an electrode drying oven at 110-150°C for one hour before using. (Fig 1).

Fig 1



ELECTRODE DRYING OVAN

Electrode coating can pick up moisture if exposed to atmosphere.

Baking electrodes: Water in electrode covering is a potential source of hydrogen in the deposited metal and thus may cause:

- Porosity in the weld
- Cracking in the weld.

Indications of electrodes affected by moisture are:

- White layer on covering.
- Swelling of covering during welding.
- Disintegration of covering during welding.
- Excessive spatter
- Excessive rusting of the core wire.

Electrodes affected by moisture may be baked before use by putting them in a controlled drying oven for approximately one hour at a temperature around 110 - 150°C. This should not be done without reference to the conditions laid down by the manufacturer. It is important that hydrogen controlled electrodes are stored in dry, heated conditions at all times.

Warning: Special drying procedures apply to hydrogen controlled electrodes. Follow the manufacturer's instructions.

Remember a moisture-affected electrode:

- has rusty stub end
- has white powder appearance in coating
- produces porous weld.

Always pick up the right electrode that will provide:

- **good arc stability**
- **smooth weld bead**
- **fast deposition**
- **minimum spatters**
- **maximum weld strength**
- **easy slag removal.**

Importance of pre heating, post heating and maintenance of inter pass temperature

Objectives: At the end of this lesson you shall be able to
- **explain the weldability of metals cast iron coper**
- **state the purpose of pre heating and post heating**
- **maintence of inter pass comperature.**

Weldability:

- The ferrite and Martin site structure on carbon steels are not suitable for welding. But, the crystal fine structure enables brazing.
- Austenitic steels are suitable for welding. In present days all types of steels are welded using inert gas shielded arc process.

Weldability of cast Iron:

Cast Iron is welded after performing preheating to a temperature of 200°C-210°C. On completion of first layer of welding, the same preheating is repeated to maintain the reinforcement of weld. Next, the whole job is evenly heated. This is called post-heating.

The job is cooled slowly, by covering under a heap of lime or ash or dry sand.

Weldability of copper:

99.9% pure copper with 0.01 to 0.08% oxygen in the form of cuprous oxide is known as electrolyte copper and this is not weldable.

A small quantity of phosphorous added to electrolyte copper to de-oxidise, so as to make it weldable.

The surface of the base metal is preheated to a fairly high temperature resulting in peacock neck blue colour; before the actual welding started.

Once the metal is cooled after welding, to reduce the grain size and locked up stresses, the pressuring is done.

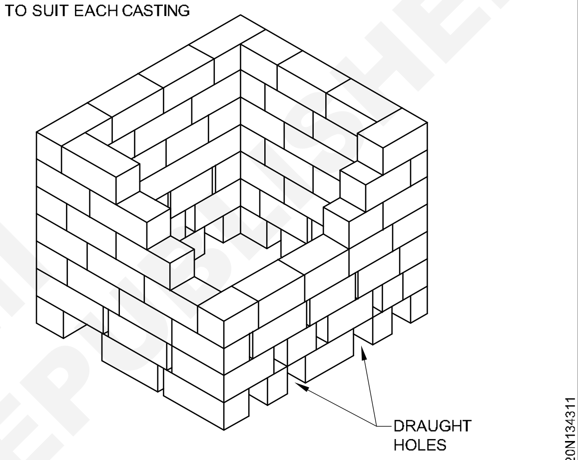
Preheating: Heating the job before welding operation is known as 'preheating'. The purpose of preheating of the cast iron job is to reduce cracking due to distortion. The rate of cooling, and gas consumption etc. are also reduced.

Small casting jobs may be preheated by the application of a blowpipe flame. But larger jobs should be preheated in a 'gas-furnace' or by means of a temporary charcoal furnace.

Methods of preheating

Preheating methods depend upon the size of the job and the technique used for welding. Preheating can be done in a temporarily built gas or charcoal furnace (Fig 1) blacksmith's forge and even by the oxy-acetylene flame. Heavy jobs can be preheated from the furnace and small jobs by a flame from a blowpipe or from the forge.

Fig 1



PREHEATING FURNACE

Types of preheating

The type of preheating depends on the size and nature of the job. There are three types of preheating.

- Full preheating
- Local preheating
- Indirect preheating

Full preheating: The process of heating the entire job before commencing the welding operation is known as full preheating. This is usually done in a furnace for heavy jobs. In this type of preheating the heat of the job will be retained during welding, and also it will cool down at a uniform rate.

Local preheating: In this type, the preheating is done only at the portion to be welded. This is usually done by playing the blowpipe flame just before starting the welding. (Fig 2) In case of welding a cracked cast iron wheel, preheat the area opposite to the area crack. (Fig 3)

Fig 2

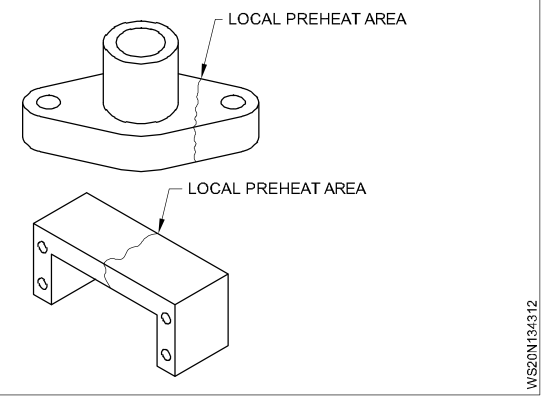
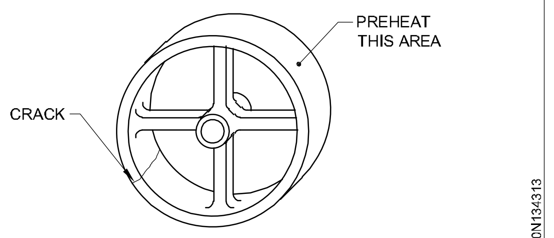


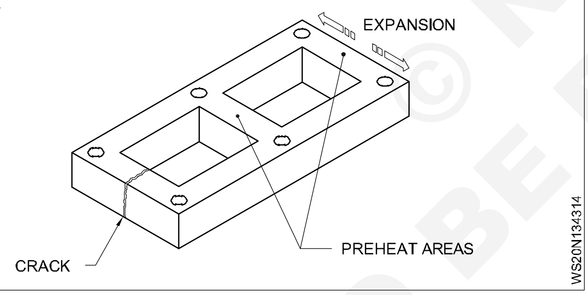
Fig 3



TECHNIQUE OF LOCAL PRE-HEATING

Indirect preheating: In this type, the preheating is being done on the area which may be affected by the uneven expansion and contracting due to the welding heat but not on the portion to be welded. This also can be done by the application of a blowpipe flame before commencing the weld. (Fig 4)

Fig 4



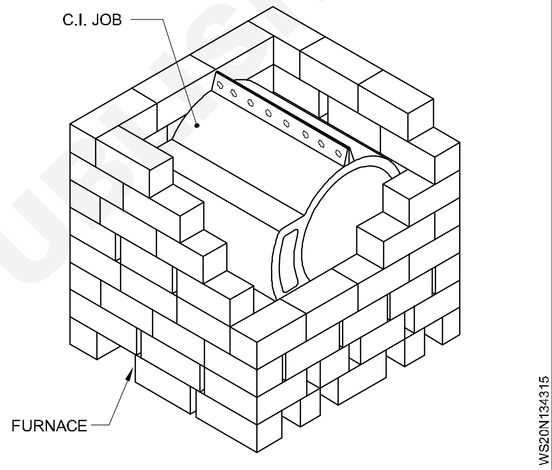
Purpose of post heating: If it is a bigger job, the welded job should be post heated in the same preheating furnace and allowed to cool slowly in the furnace itself so as to avoid any crack or any other distortion due to rapid cooling. (Fig 5)

The slag and oxide on the surface of the finished weld can be removed by scraping and brushing with a wire-brush after cooling. The weld should not be hammered as cast iron is brittle.

Maintenance of inter-pass temperature: The temperature of the preheated job can be checked by wax crayons. Marks are made on the cold job pieces by these crayons before preheating and after the job pieces reach the preheating temperature the marks will disappear.

This indicates that the job has been heated to the required preheating temperature. Different wax crayons are available for checking different temperatures. The temperature which is checked by the crayon will be marked on it.

Fig 5



Welding of low, medium and high carbon steel and alloy steels

Objectives: At the end of this lesson you shall be able to
- **state the composition of carbon percentage in low carbon steel and medium carbon steel**
- **state the type of flame needed for welding low carbon steel**
- **describe the method of welding low carbon steel**
- **explain the procedure for the welding of medium carbon steel.**

A plain carbon steel is one in which carbon is the only alloying element. The amount of carbon in the steel controls its hardness, strength and ductility. The higher the carbon the lesser the ductility of the steel.

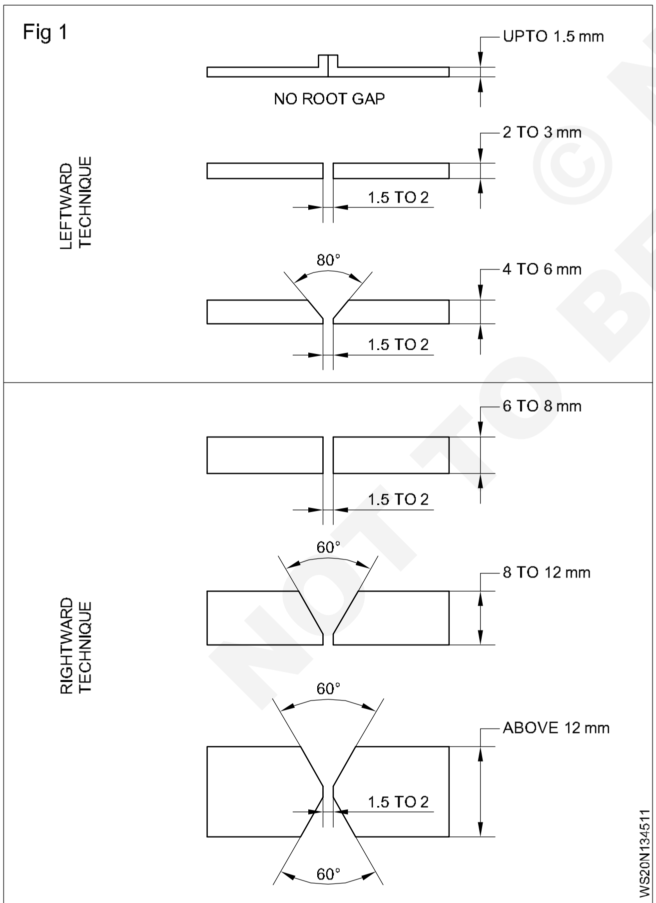
Carbon steels are classified according to the percentage of carbon they contain. They are referred to as low, medium and high carbon steels.

Low carbon steels: Steels with a range of 0.05 to 0.30 per cent are called low carbon steel or mild steel. Steels in this class are tough, ductile and easily machinable and quite easy to weld.

Welding technique: Up to 6 mm, leftward technique is a suitable one. Above 6 mm rightward technique is preferable.

Preparation: (Refer Fig 1 given below)

Fig 1



Type of flame: Neutral flame to be used.

Application of flux: No flux is required

After treatment: Most of them do not respond to any heat treatment process. Therefore except cleaning no post-heat treatment is required.

Medium carbon steel: These steel have a carbon range from 0.30 to 0.6 percent. They are strong and hard but cannot be welded as easily as low carbon steels due to the higher carbon content. They can be heat treated. It needs greater care to prevent formation of cracks around the weld area, or gas pockets in the bead, all of which weaken the weld.

Welding procedure: Most medium carbon steels can be welded in the same way as mild steel successfully without too much difficulty but the metal should be preheated slightly to 160°C to 320°C (to dull red hot). After completion of welding, the metal requires post-heating to the same preheating temperature, and allowed to cool slowly.

After cooling, the weld is to be cleaned and inspected for surface defects and alignment.

Plate edge preparation: Fig 1 shows the plate edge preparation depending on the thickness of the material to be welded.

High carbon steel: High carbon steels contain 0.6% to 1.2% carbon. This type of steel is not weldable by gas welding process because it is difficult to avoid cracking of base metal and the weld.

Welding procedure

The type of edge preparation, nozzle size, filler rod size, pitch of tack for different thickness of sheets to be welded are given in Table 1.

Start welding from the right hand edge of the joint and proceed in the leftward direction.

Keep the tip of the inner cone of the flame within 1 to 1.5 mm of the molten puddle, and hold the blowpipe at an angle of 80-90° to the work. (Fig 2)

In this way the filler rod which melts at a lower temperature than steel can flow forward and fill up the groove of the metal as it fuses. Fig 3 shows the type of edge preparation used for 3 mm thick metal.

Table 1

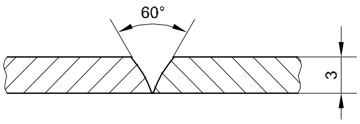
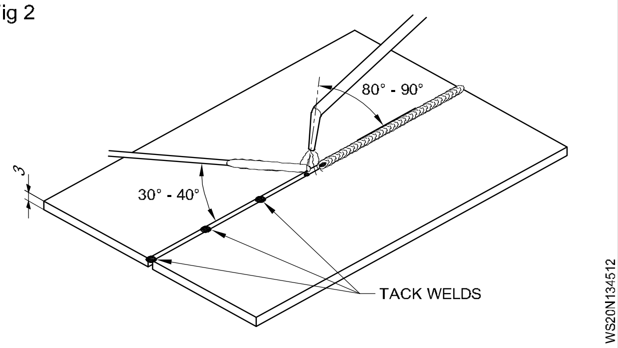
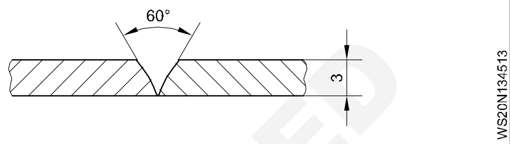
Thickness	Preparation	Assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1 mm	Square edge	No gap	20	1	1.2 mm
1.2 mm	Square edge	No gap	20	2	1.2 mm
1.5 mm	Square edge	No gap	25	2	1.6 mm
3 mm		No gap	45	5	3 mm

Fig 2



Add the filler rod by holding it close to the cone of the flame. Upon withdrawing it from the puddle remove it entirely from the flame until you are ready to dip it back into the puddle.

Fig 3



Care must be taken not to direct too much heat on the end of the filler rod to avoid easy melting and flowing.

Complete the weld in one pass on one side and avoid multi-pass welding so as to reduce the effect of heat on the weldment.

Alloy steel

Objectives: At the end of this lesson you shall be able to
- **state the necessity of alloying elements**
- **identify the common alloying elements**
- **describe the effects of each such element.**

Necessity of alloying elements: Certain elements are added to increase the mechanical properties of metals.

Common alloying elements: The following are some common alloying elements.

Carbon	Nickel
Manganese	Tungsten
Sulphur	Vanadium
Phosphorus	Molybdenum
Silicon	Effects:
Chromium	

Carbon: With the addition of a small amount of carbon to pure iron, significant changes in the mechanical properties of iron will take place. An increase in hardness and a reduction in its melting point are the more significant of the changes.

Manganese: This promotes soundness and eliminates gas holes. It gives a higher tensile strength and hardness to the metal without affecting the ductility. It controls the sulphur content.

Sulphur: Sulphur forms sulphide which makes steel vary brittle at high temperatures and controls hot shortness.

Phosphorus: The presence of phosphorus in steel vary brittle at high temperature and controls hot shortness.

Silicon: This does not directly affect the mechanical properties of the metal. It is generally present in small quantities up to 0.4% and combines with oxygen in the steel to form silicon dioxide. This floats to the top of the molten pool during production, thereby removing oxygen and other impurities from steel.

Chromium: Chromium is added to steel to increase hardness and abrasion resistance. Increases resistance to corrosion.

Nickel: This metal is added for shock resistance and is used with chromium to form a wide variety of stainless steel groups.

Tungsten: Tungsten increases hardness and toughness and will not change even at high temperature.

Vanadium: This increases hardness and toughness.

Molybdenum: Molybdenum gives hardness, toughness and anti-shock properties to steel.

Stainless steel types weld decay and weldability

Objectives: At the end of this lesson you shall be able to
- **explain the classification of stainless steel**
- **state the physical properties of stainless steel**
- **explain the welding procedure**
- **describe the weldability test of stainless steel**
- **state the effect of weld decay.**

Classification of stainless steel: Stainless steel is an alloy of iron, chromium, and nickel. There are many different classification of stainless steel according to the percentage of its alloying elements. Accordingly there are three main classifications for stainless steel.

One group is FERRITIC, which is non-hardenable and magnetic. The other group is MARTENSITE, which is hardenable by heat treatment and is also magnetic. The third group is 'AUSTENITIC' which is extremely tough and has ductility. This is the most ideal for welding and requires no annealing after welding. But it is mildly subjected to corrosive actions. The other groups ferrite and martensite are non-weldable. Usually the austenitic type of stainless steel is called 18/8 stainless steel which contain 18 percent chromium 8% nickel apart from the iron percentage. To eliminate corrosive action in this type of stainless steel stabilizing elements such as columbium, titanium, molybdenum, zirconium etc. are added in a small percentage. So, this weldable type of stainless steel is called a 'stabilized type' stainless steel. These elements also can be added to filler rods.

Physical properties of stainless steel: The coefficient of expansion of stainless steel of ferrite and martensite are approximately the same as carbon steel whereas the austenitic type of stainless steel has about 50 to 60% greater coefficient of expansion than carbon steel. So, while welding this type of stainless steel, distortion will be more. The heat conductivity is approximately 40 to 50% less than that of carbon steel for austenitic type.

All these types have a brighter colour without having any stain in appearance.

Types of stainless steel filler rods: Specially treated stainless steel filler rods, which contain stabilizing elements such as molybdenum, columbium, zirconium, titanium etc., are available.

The chromium percentage is also sometimes 1 to 1 1/2 percent more than in the base metal, so as to compensate the losses that may occur during the welding operation from the base metal. The melting point of the filler rod also will be 10° to 20°C less than the base metal. Filler rods of different sizes are available in the market.

Flux: A special type powdered flux which contains zinc chloride and potassium dichromate is available. During welding powered flux is to be made into a paste form by adding water and applied on the underside of the joint.

Method of controlling distortion: Since stainless steel has a much higher coefficient of expansion with lower thermal conductivity than mild steel, there are greater possibilities of distortion and warping.

Whenever possible clamps and jigs should be used to keep the pieces in line until they have cooled. And also a thick metal plate of copper should be used as a backing bar during welding so as to reduce distortion in the parent metal. Tacks at frequent intervals (i.e. pitch of tack is 20 - 25 mm) will also reduce distortion.

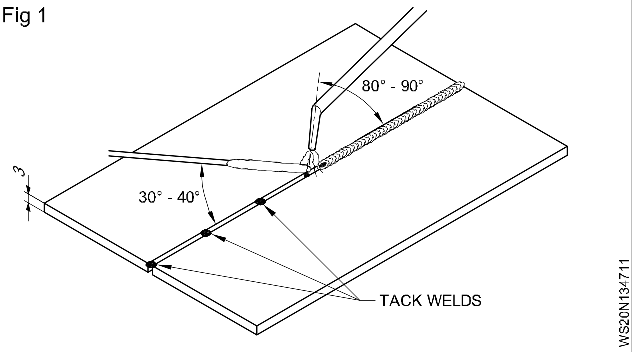
Welding procedure

The type of edge preparation, nozzle size, filler rod size, pitch of tack for different thickness of sheets to be welded are given in Table 1.

Start welding from the right edge of the joint and proceed in the leftward direction.

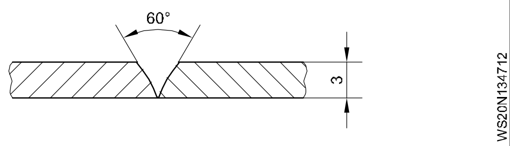
Keep the tip of the inner cone of the flame within 1 to 1.5 mm of the molten puddle, and hold the blowpipe at an angle of 80-90° to the work. (Fig 1)

Fig 1



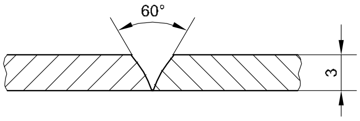
In this way the filler rod which melts at a lower temperature than steel can flow forward and fill up the groove of the metal as it fuses. Fig 2 shows the type of edge preparation used for 3 mm thick metal.

Fig 2



Add the filler rod by holding it close to the cone of the flame. upon withdrawing it from the puddle remove it entirely from the flame until you are ready to tip it back into the puddle.

Table 1

Thickness	Preparation	Assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1 mm	Square edge	No gap	20	1	1.2 mm
1.2 mm	Square edge	No gap	20	2	1.2 mm
1.5 mm	Square edge	No gap	25	2	1.6 mm
3 mm		No gap	40	5	3 mm

Care must be taken not to direct too much heat on the end of the filler rod to avoid easy melting and flowing.

Complete the weld in one pass on one side and avoid multi-pass welding so as to reduce the effect of heat on the weldment.

Success in welding stainless steel depends upon keeping the heat to a minimum. Re-tracking a hot weld produce excessive heat which is likely to increase the loss of the corrosion-resistant property in the stainless steel.

Cleaning after welding

Scale and oxide must be removed from the finished weld by grinding, polishing or by the use of a descaling of a solution as given below.

50 parts of water

50 parts of hydrochloric acid

1/2 percent PICKLETTE or FERROCLEANOL

The solution should be used at a temperature of about 50°C.

Always use a stainless steel wire brush for cleaning.

Weld decay - its effects and remedy

When austenitic stainless steel is heated to above 1100°C due to welding, the chromium and carbon will combine to form chromium carbide during cooling; whenever this happens chromium bases its resistance property to corrosion. So stainless steel will start rusting gradually near the weld area after welding is completed. This is called "Weld decay".

Weld decay can be eliminated by heat-treating the weldment. For this purpose a welded part should e reheated to 950° to 1100°C and quenched in water. Then the precipitate chromium carbide will be descaled from the boundaries of the welded part into the water.

Weld decay can also be avoided by adding alloying elements such as chromium, molybdenum, zirconium, titanium, etc. (called stabilizing elements) either in the parent metal or in the filler rod.

Weldability of stainless steel: The ferrite martensitic types of stainless steel are not a weldable quality, because of their crystalline structure, but are brazable. Austentic type stainless steel is a good weldable one. Nowadays the inert gas shielded arc is used very widely for welding all types of stainless steel.

Welding of brass

Objectives: At the end of this lesson you shall be able to
- **state the composition of brass**
- **state the selection of nozzle, flame and flux**
- **explain the necessity of oxidising flame and welding technique.**

Composition of brass: Brass is an alloy of copper and zinc in various proportion, possibly with the addition of other elements in very less percentage.

The percentage of zinc various from 1 to 50% which makes available 15 individual commercial brasses. These brasses containing 20 to 40% zinc have a variety of uses.

Melting temperature of brass: The melting point of copper is 1083°C and that of zinc is 419°C. Brass melts at intermediate temperatures. The greater the amount of copper the higher the melting point. The melting point of brass is generally around 950°C.

Types of brass:

All told there are over 60 types of brasses. These are broken down into three families of brass. The three main families of brass are copper - zinc brasses, tin brasses and leaded brasses.

Copper zinc brasses contain a mixture of copper (cu), zinc (ZN) and tin (Sn) leaded brasses are comprised of copper (Cu), zin (Zn) and lead

Brass properties

Brass often has a bright gold appearance

Brass has higher malleability than either bronze or zinc

Brass has desirable acoustic properties appropriate for use in musical instruments.

The metal exhibits low friction

Brass is a soft metal that may be used in cases when a low chance of sparking is necessary.

The alloy has a relatively low melting point.

It's a good conductor of heat

Brass resists corrosion, including galvanic corrosion from saltwater.

Brass is easy to cast.

Copper-Types-Properties and welding methods

Objectives: At the end of this lesson you shall be able to
- **describe the various types of copper**
- **state the physical properties of copper**
- **explain the welding procedure.**

Electrolyte copper: This type contains 99.9% pure copper with 0.01 to 0.08% oxygen in the form of cuprous oxide. (Cu_2O). This type of copper is not weldable.

De-oxidized copper: In this type a small quantity of phosphorous, a de-oxidising element is added to the electrolyte copper. This type of copper is weldable.

Characteristics of copper

Reddish in colour.

High thermal and electrical conductivity.

Excellent resistance to corrosion.

Excellent workability in either hot or cold condition and in forming wires, sheets, rods, tubes and castings.

Melting point: 1083°C.

Density: 8.98 g/cm^3

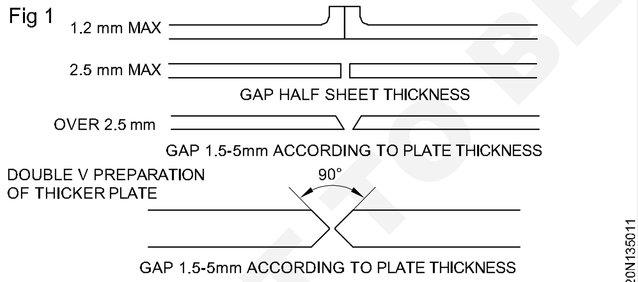
Coefficient of linear expansion (ic): 0.000017 mm/mm/°C

Edges preparation (Fig 1)

Up to 1.2 mm - edge or flange point.

Over 1.5 mm up to 2.5 mm - square butt with 50% of sheet thickness as root gap.

Fig 1



PREPARATION OF COPPER PLATES FOR WELDING

2.5 mm to 16 mm - a angle 'V' of 80°-90°.

Over 16 mm - Double 'V' preparation of 90°.

Types of cleaning

Mechanical cleaning is done to remove dirt and any other foreign material. Chemical cleaning is done by applying solutions to remove oil, grease, paint etc.

Filler rod and flux: A completely de-oxidized copper rod (copper-silver alloy filler rod) having a lower melting point than the base metal is used.

Flux: Copper-silver alloy flux is applied on the edges to be joined in paste form.

Nozzle size: Use a nozzle which is one size larger than that used for mild steel.

Flame: Adjust a strictly neutral flame.

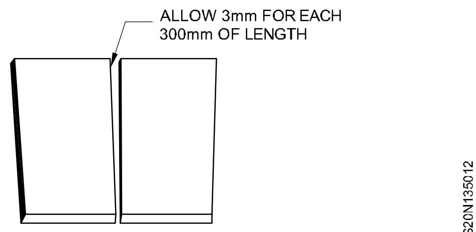
Effects of setting 'carburizing' or 'oxidising' flame

Too much oxygen will cause the formation of copper oxide and the weld will be brittle.

Too much acetylene will cause steam to form a porous weld.

Setting: 1.6 mm root gap between the sheets with a divergence allowance at the rate of 3-4 mm per 300 mm run. (Fig 2) Use wedge for welding long seam in copper. (Fig 3) No tacking is done.

Fig 2

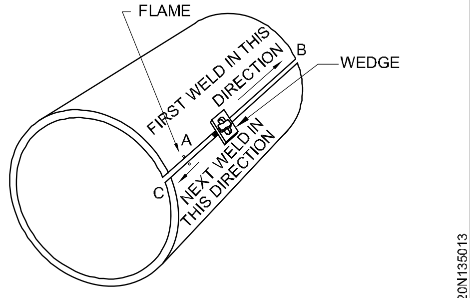


DIVERGENCE ALLOWANCE

Preheat: Surface of the base metal is raised to a fairly high temperature 750°C (peacock neck blue colour) before the actual welding is started.

Welding technique: Adopt leftward technique up to 3.5 mm thickness and rightward technique for 4 mm thickness and above. Usually the welding starts from a point 40 to 50 mm away from the right end of the job and after welding till the left end turn the job by 180° and weld the balance non-welded portion. Always welding is done towards the open end of the joint. (Fig 4)

Fig 3

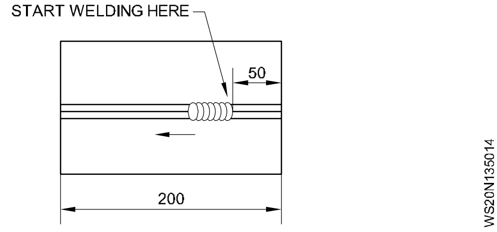


WELDING LONG SEAM IN COPPER

Control of distortion

Divergence allowance (as already stated in job setting) acts as an effective controlling distortion.

Fig 4



Chill plates or backing bar also prevents distortion.

After treatment

Peening is done in order to reduce the grain size and the locked up stresses. This is done when the metal is in hot condition.

Aluminium properties and weldability welding methods

Objectives: At the end of this lesson you shall be able to
- **explain the properties of aluminium and its alloys**
- **state the difficulties in welding of aluminium by oxy-acetylene process**
- **describe the joint design, importance of flux and welding procedure**
- **state the various process of welding aluminium**
- **explain the advantages and disadvantages of welding of aluminium by oxy-acetylene process.**

Aluminium propertie and weldability

Silvery white in colour.

Weighs only about one third as much as the commonly used low carbon steel.

Highly resistant to corrosion.

Possesses great electrical and thermal conductivity.

Very ductile, adaptable for forming and pressing operations.

Non-magnetic.

Melting point of pure aluminium is 659°C

Aluminium oxide has a higher melting point (1930°C) than aluminium.

Types

Aluminium is classified into three main groups.

- Commercially pure aluminium
- Wrought alloys
- Aluminium cast alloys

Commercially pure aluminium has a purity of at least 99% the remaining 1% consisting of iron and silicon.

Aluminium does not change in colour before it reaches the melting temperature. When the metal begins to melt, it collapses suddenly.

Molten aluminium oxidizes very rapidly form a heavy coating of aluminium oxide on the surface of the seam which has a higher melting point - 1930°C. This oxide must be thoroughly removed by using a good quality flux.

Aluminium, when hot, is very flimsy and weak. Care must be taken to support it adequately during the welding operation.

Joint design: Up to 1.6 mm, the edges should be formed to a 90° flange at a height equal to the thickness of the material.

From 1.6 to 4 mm it can be butt-welded provided the edges are notched with a saw or cold chisel. (Fig 1)

For welding heavy aluminium plates, 4 mm or more in thickness, the edges should be beveled to form 90° included angle with a root gap of 1.6 mm to 3 mm. (Fig 2)

Preparation, pitch of tack, nozzle, size, filler rod etc. are given in Table 1 for butt joints.

Fig 1

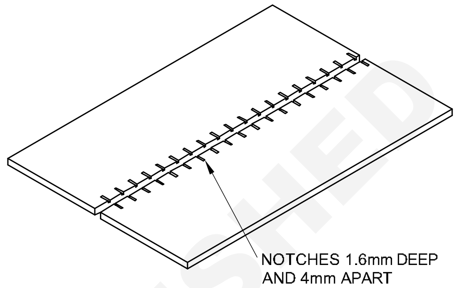
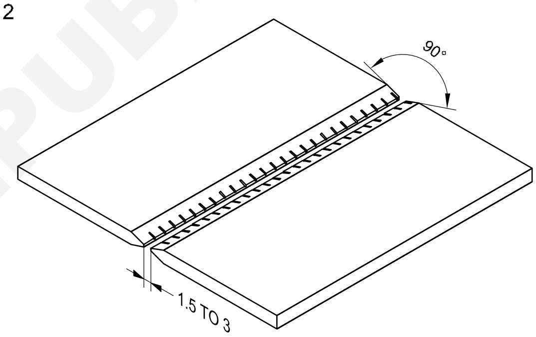


Fig 2



Importance of flux: Since aluminium oxidizes very rapidly, a layer of flux must be used to ensure a sound weld.

Aluminium flux powder is to be mixed with water (two parts of flux to one part of water).

The flux is applied to the joint by means of a brush. When a filler rod is used, the rod is also coated with flux.

On heavy sections, it is advisable to coat the metal as well as the rod for greater ease in securing better fusion.

Necessity of preheat: Aluminium and its alloys possess high thermal conductivity and high specific and latent heat. For this reason, a large amount of heat is required for fusion welding.

To ensure fusion and complete penetration to avoid cracking, and to reduce gas consumption, aluminium castings and assemblies in wrought alloys of above 0.8 mm are to be preheated.

Preheating temperature varies from 250°C to 400°C according to the size of the work, and can be done by using a torch or by keeping the job in the furnace where preheating is done.

Welding procedure: Please refer to Working Steps and Skill Information of Ex. No. 2.28/G-55.

Various processes of welding of aluminium

- Oxy-acetylene welding
- Manual metal arc welding
- TIG welding
- MIG welding
- Resistance welding
- Carbon arc welding
- Solid state welding:
- cold welding
- diffusion welding
- explosive welding
- ultrasonic welding.

Advantages of adopting oxy-acetylene process for welding of aluminium

Simple and low cost equipment

For welding thinner sheets, gas welding may prove to be economical.

Disadvantages

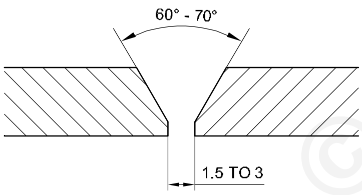
The flux residue, if not properly removed, may result in corrosion.

Distortion is greater than in arc welding.

Heat-affected zone is wider than in arc welding.

Welding speed is lower.

Table 1

Metal thickness	Preparation	Joint assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1	Square	No gap	25	1	2.5 mm
1.2	Square	No gap	40	2	2.5 mm
1.5	Square	No gap	40	2	2.5 mm
3		1.5 - 3 mm gap	75	5	3.15 mm

Metallic arc cutting and gouging

Objectives: At the end of this lesson you shall be able to
- **state the different arc cutting and gouging processes**
- **state the equipment and accessories**
- **explain the different electrodes and their properties.**

Different arc cutting and gouging processes

- Metallic arc cutting gouging process
- Carbon arc cutting process
- Air arc cutting process
- Plasma arc cutting process
- Oxy-arc cutting process
- Carbon arc gouging process

Metallic arc cutting - equipment and accessories

They are:

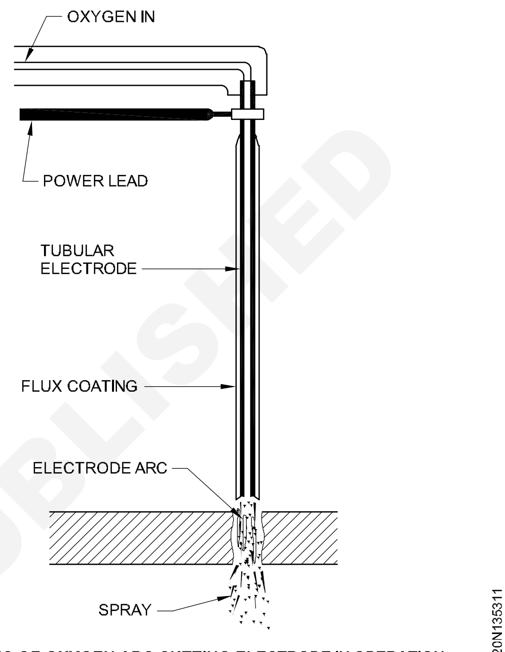
- AC or DC machines
- cables with lugs and earth clamp
- electrode holders
- shield or helmet with suitable glasses (Shade No. 14)
- chipper or chipping hammer
- apron, gloves, safety boots and white goggles.

Electrodes and their properties

Oxy-arc cutting electrode: This electrode is similar to the manual arc welding electrode and is coated with a flux, whose function is to provide an insulated sleeve to stabilise the arc and to make the products of combustion more fluid. The core wire, however, is in the form of a hollow tube through which a stream of oxygen is passed and designed holder, capable of conveying electric current to the electrode as well as oxygen to the arc, is used. (Fig 1)

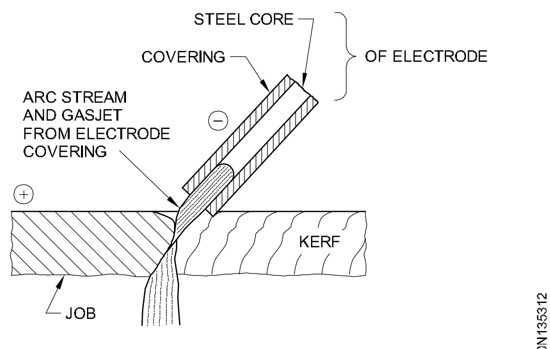
Metallic arc cutting and gouging electrodes: These electrodes are normally the same as welding electrodes or are sometime specially designed as cutting electrodes (Fig 2) at a current setting which is 20 to 50% higher than that normally used for a given size for welding. Although AC can be used, DC with electrode negative is preferred. Sometimes it helps to make the electrode slightly wet. Water in the coating reduces overheating of the electrode to some extent and disassociates in the arc to render it more penetrating.

Fig 1



SCHEMATIC OF OXYGEN ARC CUTTING ELECTRODE IN OPERATION

Fig 2



METAL ARC CUTTING

Tungsten arc cutting electrode: This is an arc cutting electrode, which is used in TIG and plasma arc cutting processes.

CURRENT SETTING FOR DIFFERENT SIZE ELECTRODES

Metal thickness		Electrode diameter		AC Range amps	DC (DCEN) amps
in.	mm	in.	mm		
1/8	3.2	3/32	2.4	40-150	75 - 115
1/8 - 1	3.2 - 25.4	1/8	3.2	125-300	150 - 175
3/4 - 2	19.1 - 50.8	5/32	4.00	250-375	170 - 500
1 - 3	25.8 - 76.2	3/16	4.8	300-450	—
3 and over	76.2 and over	1/4	6.4	400-650	—

Arc cutting and gouging procedure

Arc cutting procedure: Prepare the piece as per the requirements. Clean the surface to be cut. Mark and punch the line. Position the job in flat.

Choose the welding machine and set the polarity DCEN, if DC is used.

Select the electrode size according to the thickness of the material.

Set the current as per the requirements for the selected electrodes.

Strike the arc and move the electrodes up and down on the edge of the plate. As the metal melts brush it downwards with the arc. Feed the electrodes into the slot and make the molten metal to run away underneath. Use only half the electrode and keep it away to cool for use again.

Check the cut surface for its smoothness and uniformity.

Arc gouging procedure: Prepare the piece as per the requirements. Clean the surface to be gouged. Mark and punch the line. Position the job in flat.

Choose the machine and set the polarity DCEN if DC is used.

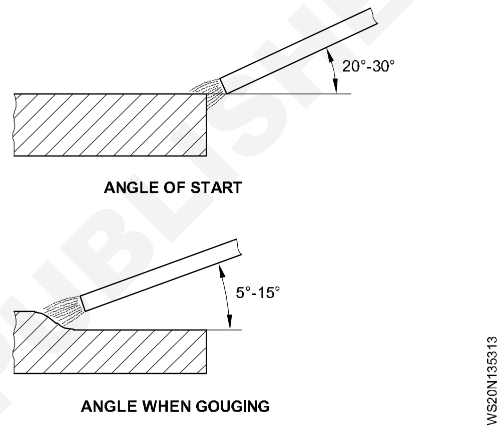
Select suitable sizes of electrodes and set the required current.

Strike the arc and as a molten pools is established, lower the electrode holder and reduce the angle between 5°-15° from 20°-30°. (Fig 3)

Move the electrode along the line of marking from the right to the left side of the plates and push the molten pool and slag away from the gouged groove.

Because of the rapid fusion due to the arc heat, move the electrode fast and control the gouging operation. Ensure that the angle of slope is not too steep, and avoid grooving too deeply. Maintain the angle of the electrode constant and the rate of travel uniform to obtain a groove of uniform width and depth.

Fig 3



Clean the surfaces.

Check the smoothness, depth and uniformity.

Advantages: Arc gouging procedure can be used when other cutting and gouging processes are not available.

In emergency it is more useful.

It can be used on metals which are difficult to cut by the oxy-acetylene cutting process.

(Cast iron, stainless steel, wrought iron, manganese steel and non-ferrous metals etc.)

Applications: Metallic arc cutting and gouging are used:

- to remove weld defects
- to make the groove on the root penetration for depositing sealing run
- to cut the scarp
- to remove rivets
- to pierce holes
- to remove casting defects and make grooves.

Cast Iron-properties-types welding methods of cast iron

Objectives: At the end of this lesson you shall be able to
- **explain the properties of cast iron and its types and cast iron welding technique.**

Cast iron is widely used in the manufacture of machine parts, since it has a good compressive strength and easy to make the castings. There are different problems in the welding of cast iron in comparison to mild steel, even though this is also in the group of ferrous metals.

Types of cast iron

There are four basic types of cast iron available.

- Grey cast iron
- White cast iron
- Malleable cast iron
- Nodular cast iron (or) spheroidal graphite iron

Grey cast iron: Grey cast iron is soft and tougher than the white cast iron which is hard and brittle. The good mechanical properties of grey cast iron are due to the presence of particles of free state carbon or graphite, which separate out during slow cooling. Grey cast iron is of a weldable type. It contains 3 to 4% of carbon.

White cast iron: White cast iron is produced from pig iron by causing the casting to cool very rapidly. The rate of cooling is too rapid and this does not allow the carbon to separate from the iron carbide compound. Consequently the carbon found in white cast iron exists in the combined form. This type of cast iron is very hard and brittle and is not weldable and also not easily machinable.

Malleable cast iron: Malleable cast iron is obtained by annealing white cast iron over a prolonged period of time, and then allowing it to cool slowly. This heat treatment results in greater resistance to impact and shock.

Nodular cast iron: It is also known as spheroidal graphite iron (SG iron). It is obtained by adding magnesium to the molten grey cast iron. The tensile strength and elongation of nodular iron is similar to that of steels which makes this iron a ductile material.

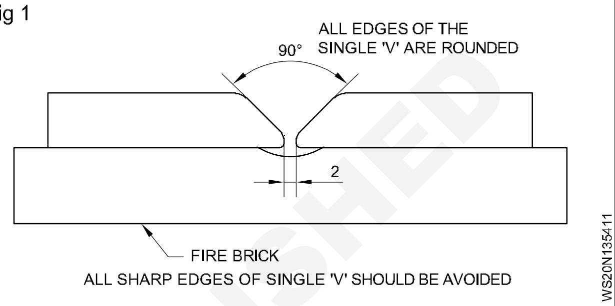
Properties of grey cast iron: Grey cast iron is mostly used in the manufacture of machine components. It has got good mechanical properties due to the free state carbon/graphite. The other constituents are silicon, sulphur, manganese and phosphorous. The grey cast iron has a much higher compressive strength than steel but has low ductility and tensile strength.

Since the carbon is in free graphite form it gives a grey colour to the fractured structure.

Method and types edge preparation: The edges of grey cast iron can be prepared by different methods such as chipping, grinding, machine and filing. The above methods are used according to the condition and type of the job.

Usually it is required to weld, a cracked casting or a butt joint. Also the thickness of the casting to be welded or repaired will be 6 mm and above. So usually a single V butt joint is prepared as shown in Fig 1.

Fig 1



Method of cleaning

There are two methods used for cleaning cast iron jobs.

- Mechanical cleaning
- Chemical cleaning

Mechanical cleaning is mostly used to clean the surface of the cast iron jobs.

In this method grinding, filing and wire brushing tec. are done.

The chemical cleaning process is applied to remove oil, grease and any other substances which cannot be removed by mechanical cleaning.

Flame (strict neutral flame): Nozzle no. 10 is used in the blow pipe and a strict neutral flame should be adjusted. Care should be taken that there is not even the slightest trace of oxygen which would cause a weak weld through oxidation.

Filler rod: A 5 mm size round or square high (super) silicon cast iron filler rods containing 2.8 - 3.5 percentage silicon are used for cast iron welding. The weld metal by this rod is easily machinable. (The S-CI 1 as per IS 1278 - 1972).

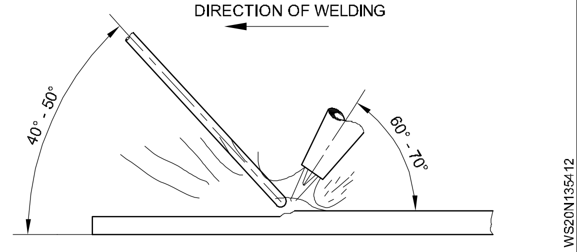
Flux: The flux should be of good quality to dissolve the oxides and prevent oxidation.

Cast iron flux is composed of borax, sodium carbonate, potassium carbonate, sodium nitrate and sodium bicarbonate. This is in a powder form.

Technique of cast iron welding: The welding operations should be performed on the preheated, dull red hot, cast iron piece. The preheating temperature for C.I welding varies from 200°C to 310°C.

The blowpipe angle should be 60° to 70° and the filler rod angle 40° to 50° to the line of weld. (Fig 2)

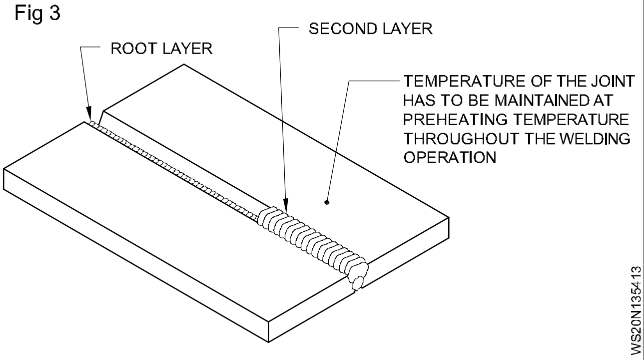
Fig 2



Using the leftward or forehead technique, the first layer should be complete by giving a slight weaving motion to the blowpipe but not to the filler rod. The hot rod end should be dipped into the powdered flux at intervals.

After the completion of the first layer, play the flame on the job so as to heat evenly and then deposit the second layer with a slight reinforcement of weld metal from the surface of the job. (Fig 3)

Fig 3



The technique of welding the second layer is the same as that for the first layer.

After completion of the second layer, play the flame again on the whole job for getting an even heat. This is called 'post heating'.

Then allow the job to cool slowly by covering with a heap of lime or ash or dry sand.

Selection of filler rod

Filler rod should be selected according to the:

– kind or type of metal to be welded, i.e. ferrous, non-ferrous, hard facing (Table 1).

  thickness of metal to be welded (including joint edge preparation) (Table 2)

– nature of joint to be made (i.e.), fusion welding or braze welding (non-fusion)

– welding technique to be used (leftward or rightward).

Table 1

Metals	Filler rods
Mild steel and wrought iron	Copper coated mild steel (C.C.M.S)
High carbon and alloy steel	High Carbon steel Silicon-manganese steel Wear-resisting alloy steel 3.5% Nickel steel
Stainless steel	Columbium stainless steel
Cast iron	Super silicon cast iron Ferro silicon cast iron Nicotectic cast iron
Copper and its alloys (brass, bronze)	Copper-silver alloy Silicon-brass, silicon-bronze Nickel bronze Manganese bronze
Aluminium and its alloys	Pure aluminium 5% Silicon aluminium alloy 10-13% Silicon aluminium alloy

Table 2

Thick-ness mm	Edge preparation mm	Root gap	Dia. of filler rod mm
0.8	Square	-	1.6
1.6	Square	2.4	1.6
2.4	Square	3.2	1.6
3.2	80° Vee	3.2	2.4
4.0	80° Vee	3.2	3.2
5.0	80° Vee	3.2	4.0

More the thickness of the metal welded, more the diameter of the filler rod used. Less the number of weld runs deposited, less the distortion and faster the welding.

Structural welding

Objectives: At the end of this lesson you shall be able to
- **brief overview of all the subjects covered under the syllabus.**

Out line of the Subject to be recovered.

This is an annual syllabus.The concept included in the syllabus is to train trainees in modern welding techniques in the syllabus as follows.

This includes GMAW,GTAW,FCAW,SAW welding and how trouble shoot it, the structure welding and it's types, of metals used. Weld performance and welding tests and inspections cover the most important subjects such as WPS - The course should be fully understood and utilized.

Structural Welding

Structural welding involves creating a variety of welds with different components material to create, fabricate, and erect welded structures. Structural Welding has its own (set of codes, blueprints, and types of weld joints)

Structural welders require a specific set of skills involving balanced measurements and precision to do an effective job. In this article, I"ll cover several issues concerning structural welding, it's requirements, and its results.

Importance of Structural Welding

Structural welding is used to create metal framework for buildings, bridges, vehicles, and variety of other complex structures. Structural Welding is also used to cut a d repair beams, columns and girders.

Structural welding is used in various industries, including construction, manufacturing, shipbuilding, mining, oil and gas distribution, vehicle manufacturing, aerospace, military, and heavy industries.

Structural welding has become a significant part of today's industry because of all theinnovations create for residential housing and commercial buildings.

Welding process brief description, classification and application

Objectives: At the end of this lesson you shall be able to
- **applications as various welding process brief description, classification and application.**
- **state the welding terms & Definitions.**

> Note
>
> **This topic is covered in previous topic lesson 1.1.07**

Welding terms & definition

> Note
>
> **This topic is covered in previous topic lesson 1.1.08**

Principles Of Shielded Metal ARC Welding (SMAW)

Objectives: At the end of this lesson you shall be able to
- **advantages and it's limitations**
- **principles of shielded metal arc welding**

Electric welding: This is a process of welding in which the heat energy is obtained from electricity.

When electric current passes through a, medium material it generates heat.

The amount of heat generated depends upon:

- the amount of current passing through the medium
- the changes taking place in the medium
- the resistance of the medium.

By adjusting current and resistance, sufficient heat can be produced to melt the metals.

Principle of shielded Metal Arc Welding

An electric arc is maintained between the end of a coated metal electrode and work piece.

The flux covering melts during welding and forms gas and slag to shield the arc molten weld pool. The flux also provides a method of a adding scavengers, deoxidizers and alloying elements to the weld metal

Various Name Stick Electrode welding,

Electric Arc welding,

Shielded Metal Arc welding (SMAW)

Manual Metal Arc welding (MMAW)

Popularly known as Arc welding

IIt is a manual & ancient welding process, 100 years old

Main parts in SMAW

- Welding Machine
- Electrode Holder
- Ground Clamp(Earth)
- Welding Cables

Types of power source

1 AC welding Transformer

2 DC motor Generator

3 Rectifier set

4 Inverter

SMAW advantages / Disadvantages

Advantages:

1 Field or shop use; less sensitive to wind and dirt

2 Wide range of consumables

3 All positional; flexible

4 Very portable; can reach limited access areas

5 Simple, inexpensive equipment

Disadvantages:

1 High skill factor

2 Slag inclusions

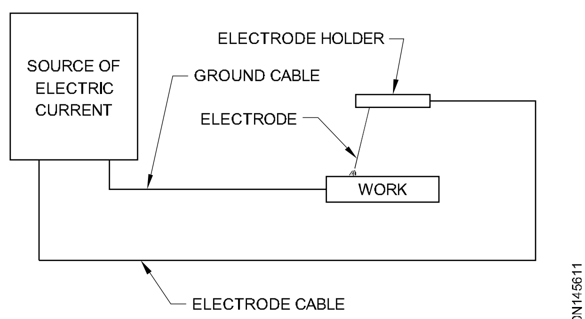
3 Low deposition rate and operating factor

4 High level of fume

5 Hydrogen control

6 Can't weld low melting point (e.g.pb,sn,zn) or reactive metals (e.g.ti)

Fig 1



SIMPLE WELDING CIRCUIT

Types of welding joints

Objectives: At the end of this lesson you shall be able to
- **types of welding joints and brief description.**

The five basic weld joints include the butt joint, the lap joint, the corner joint, and the edge joint. The butt joint occurs when two members are placed side-by-side or butt together.

BUTT JOINT

A butt weld is one of the simplest and versatile types of weld joint designs. The joint is formed simply by placing two pieces of metals end-to-end…

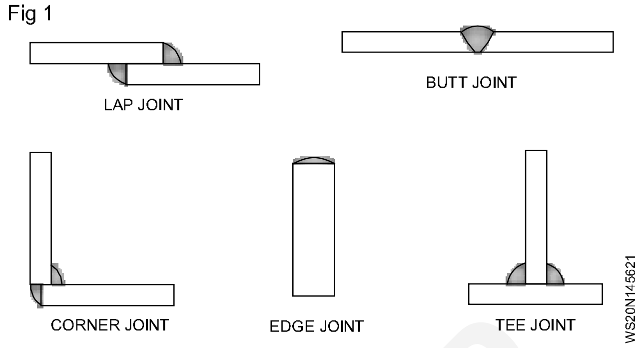
Lap Joint Welding

Lap welding joints are essentially a modified version of the butt joint. They are most commonly used to joint two pieces with differing thickness together. Welds can be made on one or both sides.

Corner Joint

Corner joint welding refers to instances in which two materials meet in the "Corner" to form an L -shape. You can use corner joints to construct sheet metal parts, including frames, boxes, and similar applications.

Fig 1



TEE JOINt

Tee joints are formed when two pieces intersect at a 90?angle. This results in the edges coming together in the center of a plate or component in a 'T' shape. Tee joints are considered to be a type of fillet weld.

Edge Joint

In an edge joint ,the metal surfaces are placed together so that the edges are even. One or both plates may be formed by bending them at an angle. The purpose of a weld join parts together so that the stresses are distributed.

Basic Electricity applicable to welding

Objectives: At the end of this lesson you shall be able to
- **define simple electrical terms**
- **differentiate between electric current, pressure and resistance & AC and DC.**
- **state OHM's law and its application.**

Note: This topic is covered in previous topic lesson 1.2.12

Arc welding power source Ac/DC advantages and disadvantages types of metal and their characteristics

Objectives: At the end of this lesson you shall be able to
- **Arc welding power source selection criteria SMAW, MIG / MAG -invertor machines**
- **AC / DC Advantages and Disadvantages**
- **types of metal and their characteristics.**

Some General Terms to Understand

Insulation class- The temperature withstanding capability of the insulation materials.

Power factor- Ratio of active power used to the total power drawn from the system.

Efficiency- Power utility factor of the machine expressed as a % output to input. It accounts for losses in the system particularly transformer losses. In welding power sources 'no load' loss is a very important criteria because power source arc-on time is hardly 25% in a shop floor situation.

Ip classes define the degree of protection provided by the closure and is indicated by various 2-digit numbers such as 22,23,54 etc.

The first digit defines the degree of protection with respect to person and solid ingress.

The degrees range from, 0-6 where 0 means no protection & 6 means Dust proof.

The second digit defines the degree of protection with respect to harmful ingress of water. The degrees range from 0-8 where 0 means no special protection & 8 means protection against submersion (Hermetically sealed).

Power Source Selection Criteria General:

Copper or Aluminum conductors-A total non-issue class of insulation.

Input power - 3 phase or 2 line of 3 phase Duty cycle. pertaining, IP class, power factor, Efficiency.

Power source selection criteria SMAW:

Type of welding current-AC or DC or both amperage range determined by size & type of electrode.

Open circuit voltage (OCV) - high OCV desirable from the stand point of arc initiation & arc maintenance. But electrical hazard factors & high cost are to be considered. Welding positions - If vertical & overhead welding are planned, slope adjustment of the V-A curve is desirable.

Power source selection criteria MIG/MAG:

Maximum & minimum electrode wire diameter. Welding job thickness. welding position joining materials, Circularity of joints - Pulsed/non-pulsed, preciseness of parameter control-step-controlled or step less. Dip transfer/spray transfer, shielding Gas Inductance level required

Inverter its concept and application

Inverters: Mains voltage is rectified to DC. The inverter converts to the high frequency AC. The transformer changes the HF AC to suitable welding voltage. The AC is rectified. Various filters remove the disturbing frequencies and ripples in the DC current. The entire process is monitored by a control circuit. This gives the machine ideal static and dynamic characteristic. A CDC voltage is available for welding purpose through a microprocessor based real time adaptive process control.

Why inverters: Traditional power sources have the following disadvantages:

Higher weight due to low frequency of operation (50Hz) larger volume occupying more workspace. Features of, inverter power sources,

- Very light and compact-portable.
- Power consumption reduced by 40-50%
- Can quickly modify static, and dynamic output characteristics for multi-process capability.
- Excellent arc stability.
- TIG welding can be done at 1 ampere.

- Hot start and adjustable arc force for SMAW, GMAW-pulse and synergic MIG welding.
- Possible to achieve spray transfer at lower currents.
- High switching frequencies of 50,000 hertz facilitates microprocessor based real time adaptive process control.

Arc welding power sources:

1 A/C welding Transformer.

2 D/C welding Generator

3 AC / DC Rectifier.

4 Inverter type welding M/C.

Advantages and disadvantages of AC and DC welding

Objectives: At the end of this lesson you shall be able to
- **compare the advantages and disadvantages of AC welding**
- **compare the advantages and disadvantages of DC welding.**

Advantages of AC welding

A welding transformer has

- a low initial cost due to simple and easy construction
- a low operating cost due to less power consumption
- no effect of arc blows during welding due to AC
- low maintenance cost due to the absence of rotating parts
- higher working efficiency
- noiseless operation.

Disadvantages of AC welding

It is not suitable for bare and light coated electrodes.

It has more possibility for electrical shock because of higher open circuit voltage.

Welding of thin gauge sheets, cast iron and non-ferrous metals (in certain cases) will be difficult.

it can only be used where electrical mains supply is available.

Advantages of DC welding

Required heat distribution is possible between the electrode and the base metal due to the change of polarity (positive 2/3 and negative 1/3).

It can be used successfully to weld both ferrous and non-ferrous metals.

Bare wires and light coated electrodes can be easily used.

Positional welding is easy due to polarity advantage.

It can be run with the help of diesel or petrol engine where electrical mains supply is not available.

It can be used for welding thin sheet metal, cast iron and non-ferrous metals successfully due to polarity advantage.

It has less possibility for electrical shock because of less open circuit voltage.

It is easy to strike and maintain a stable arc.

Remote control of current adjustment is possible.

Disadvantages of DC welding

DC welding power source has:

- a higher initial cost
- a higher operating cost
- a higher maintenance cost
- trouble of arc blow during welding
- a lower working efficiency
- noisy operation in the case of a welding generator
- occupies more space.

Types of metals and their characteristics:

Metals can be divided into two main groups: ferrous metals are those which contain iron and non-ferrous metals that are those which contain no iron. Pure Iron use as an engineering material because it is too soft and ductile.

Characteristics metals

1 Metals are malleable

2 Metals are ductile.

3 They are good conductor of heat and electricity.

4 They are lustrous or shiny.

5 They hard and strong.

6 They cannot be cut easily.

7 They are solids except mercury which is a liquid.

8 They have high melting and boiling point.

9 They have high densities.

10 They are sonorous.

For Example: Iron, copper, aluminium, zinc, gold, silver, sodium, potassium, nickel, cobalt, tin, mercury etc.

Characteristics of Non-metals:

1 Non-Metals are not malleable.

2 Non-Metals are not ductile.

3 They are bad conductor of heat and electricity.

4 They are not lustrous or shiny.

5 They can be cut easily.

6 They are solids, liquid and gases at room temperature.

7 They have low melting and boiling point.

8 They have low densities.

9 They are not sonorous.

For Example Carbon, sulphur, helium, hydrogen, phosphorous, fluorine, chlorine etc.

Classification of steel and their weldability.

Objectives: At the end of this lesson you shall be able to
- **state the main classification of steels**
- **explain the effect of carbon content in steel**
- **describe the uses of various types of carbon steel.**

Weldability of steels

Composition of carbon percentage in low carbon and medium carbon steel

Classification of steel: The classification of steel is mainly based on the chemical composition of various elements like traces of sulphur, phosphorus, silicon, manganese with a percentage of less than 1% carbon content in steel.

Thus, the steel is classified as follows,

1 Carbon steel

2 Alloy steel

Effects of carbon content in steel: Steel can be defined as an alloy of carbon and iron, in which carbon is in a combined state. The carbon content is a very important factor to get the desired properties of steel.

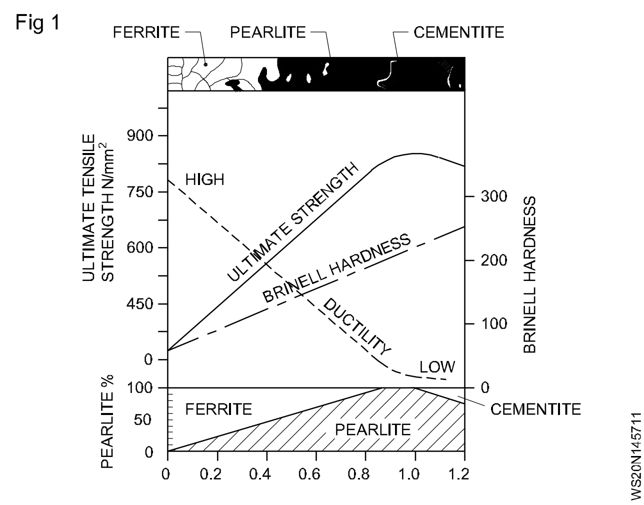
Carbon: Carbon is a very important constituent of steel. The addition of carbon at varying proportions modifies the characteristics of iron and makes it harder, stronger and of greater use in the engineering industry. Slight variations in the carbon content of steel lead to great differences in the properties of steel. Depending upon the properties it is put to different uses. (Table 1)

Ferrite is a very weak solid solution of carbon and iron with about 0.006% carbon. This is a very soft and ductile constituent. (Fig 1) Pearlite contains alternate layers of ferrite and cementite. This laminated structure makes pearlite stronger. As the carbon content increases, the pearlite structure formation is also increased, and this increases the tensile strength and hardness.

It may be noted from the figure that addition of carbon beyond 0.83% cementite will not exist in the combined form but appear around the crystal boundaries. Carbon, existing in this form, reduces in tensile strength and ductility but the hardness continues to increase even beyond 0.83% of carbon.

Table 1

Name	Group	Carbon content %	Examples of uses
Wrought iron	Wrought iron	Less than 0.05	Chain for lifting tackle, crane hooks, architectural iron work.
Dead mild steel	Plain carbon steel	0.1 to 0.15	Sheet for pressing out such shapes as motor car body panels. Thin wire, rod, and drawn tubes.
Mild steel	Plain carbon steel	0.15 to 0.3	General purpose workshop bars, boiler plates, girders.
Medium carbon steel	Plain carbon steel	0.3 to 0.5 0.5 to 0.8	Crankshaft forgings, axles. Leaf springs, cold chisels.
High carbon steel	Plain carbon steel	0.8 to 1.0 1.0 to 1.2 1.2 to 1.4	Coil springs, chisels used in woodwork. Files, drills, taps and dies. Fine edge tools (knives etc).



Heat affected zone and requirement for preheating and maintaining inter pass temperature

Objectives: At the end of this lesson you shall be able to
- **describe the effects of heat on the properties of metals.**

Heat Affected Zone (HAZ): The energy applied to create a weld joint is dissipated by conduction to the base metal, welding fixtures and the environment. That part of the base metal experiencing various thermal cycles is called the heat affected zone (HAZ)

During welding, the HAZ does not undergo welding but experiences complex thermal and stress alterations. The imposition of welding thermal cycles on the base material causes in the properties of the HAZ.

A welding thermal cycle is characterized by heating rate, peak temperature and cooling rate. Thermal cycles are also affected by heat input, preheating temperature, plate thickness and joint geometry.

Weld joint: A weld joint consists of several zones.

1 Weld metal or mixed zone which is essentially a solified structure.

2 Unmixed zone in the base metal adjacent to the fusion line where the base metal has melted but is not mixed with the filler material.

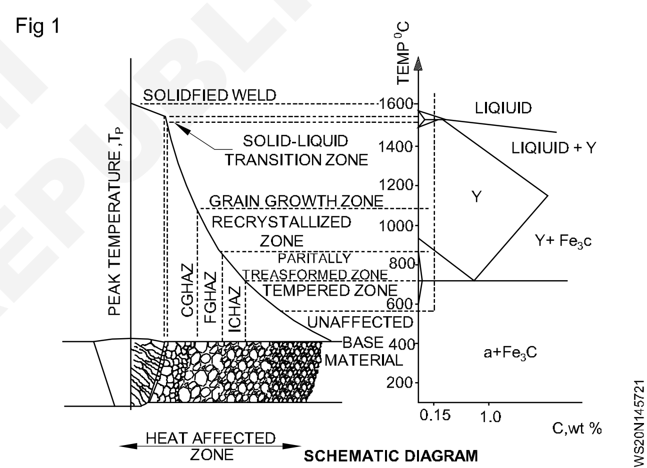
3 Partially melted zone which has been thermal cycles with peak temperatures and,

4 Heat affected zone which has not melted but is exposed to thermal cycles with temperature less than the solids temperature.

Each zone because of its characteristic micro structural features has different properties.

Heat affected zone microstructure: The relevant portion of the iron-carbon phase diagram along with a schematic sketch of a weld and HAZ is shown in Fig.2

The region of the HAZ where extensive grain growth of the weld metal takes place is referred to as coarse grained HAZ (CGHAZ) 1300°C.



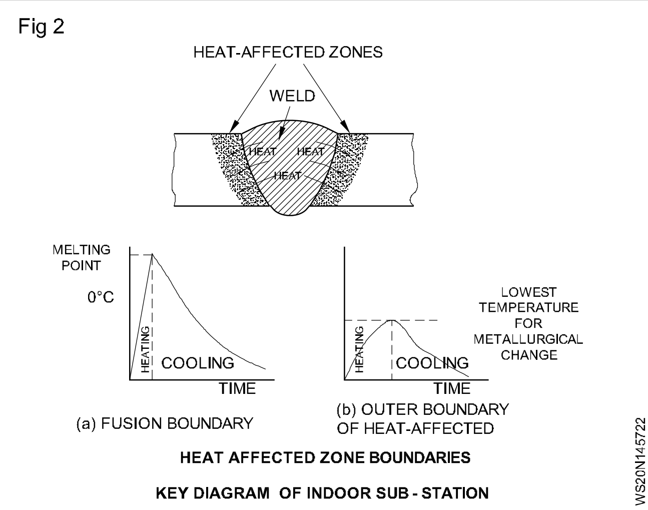
The region of the HAZ next to it,where peak temperature is in the range of 900-1200°C and austenite grain size remains small, is called fine grained HAZ (FGHAZ).

CGHAZ is having maximum hardness and poor toughness properties compared to the rest of the HAZ. So the preheat temperature used to reduce the cooling rate.

Heat affected zone and how to avoid risk of cracking

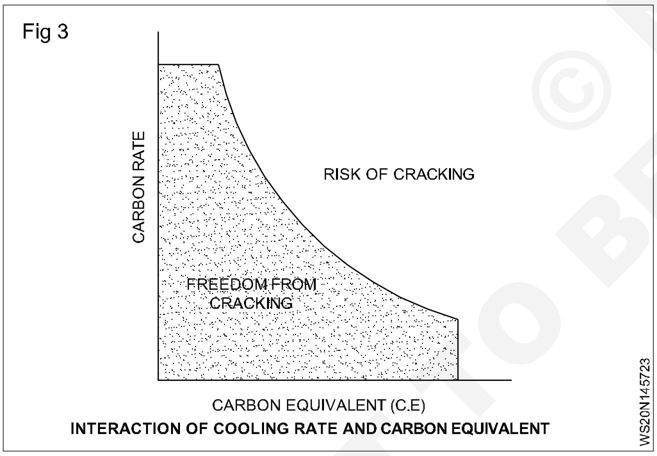
The region of the parent metal, which undergoes a metallurgical change as a result of the thermal cycle is called heat affected zone. A typical HAZ is shown in Fig 3.

If the carbon equivalent (CE) exceeds 0.4,the welding situation changes due to the possibility of cracking in the heat affected zone and due to increase in volume of martensite, cracks will usually develop the phenomenon called underbead cracking.



The normal structural steel has a hardness of 190-200 BHN. In HAZ,depending upon thickness,carbon content,hardness of 350-450 BHN may be reached. The level of hardness depends upon cooling rate. The risk of cracking is higher when hardness exceeds a certain level corresponding to higher rate of cooling.

The interaction of cooling rate and carbon equivalent is illustrated in Fig 4. At low levels of carbon equivalent fast rates can be tolerated before there is risk of cracking; except in thick section, HAZ cracking is rarely experienced with CE values below 0.39%. At high levels of CE,say around 0.48%,there is high risk of cracking even at slower cooling rates.



However, Appropriate preheating of the parent metal and or low levels of hydrogen in the weld metal can eliminate this problem.

Higher level of hydrogen is harmful. Hydrogen is absorbed in the molten weld pool from a variety of sources, moisture in the flux covering of an electrode or in the shielding gas, grease on the joint faces and so on. Hydrogen can flow (diffuse) readily through hot steel and pass from the weld pool in to the HAZ causing a major risk of cracking.

Gas shielded processes such as MAG and TIG are inherently low in hydrogen with levels 5-10 ml/100 gram and are thus effective in avoiding cracking.

Heat input and the thickness of the metal in the joint affect the cooling rate in the unit.

In thick sections cooling rate is faster than in thin. Preheating temperature slows down the cooling rate through the temperature range within which a hardened structure is formed i.e., 300-200°C. Preheat also helps to reduce the risk of cracking by allowing any hydrogen in the heat affected zone to flow into the parent metal where hardening has not taken place.

The interdependence of principal factors i.e., CE, cooling rate (heat input, joint type and thickness), hydrogen conent and preheat (temperature of parent metal during welding) governing the risk of HAZ cracking is complex.

The problem of underbead cracking can eaily be overcome by preheating the weld joint just prior to welding or by choosing a proper low hydrogen electrode.

Purpose of preheat: There are four reasons why preheat is useful in weld fabrication. They are

a The use of preheat lowers the cooling rates in the weld metal and in the heat affected zone. This results in a more ductile metallurgical structure, one that will resist weld cracking.

The slower the cooling rate permits hydrogen to diffuse out harmlessly, without causing cracking.

Preheat reduces shrinkage.

It also brings same steels above the temperature where brittle fracture might occur during welding.

No steel is immune to hydrogen-induced cracking. Additionally, preheat can be used to help ensure specific mechanical properties, such as notch toughness.

Welding Symbols and their importance

Objectives: At the end of this lesson you shall be able to
- **necessity of weld symbol and welding symbol**
- **elementary symbols and supplementary symbol.**

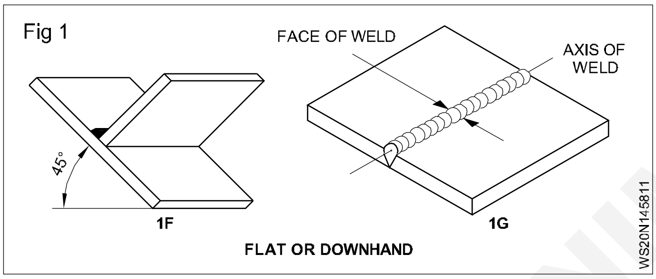
Note: Refer R.Theory for Exercise 1.2.21

Welding positions and necessity of positional welding

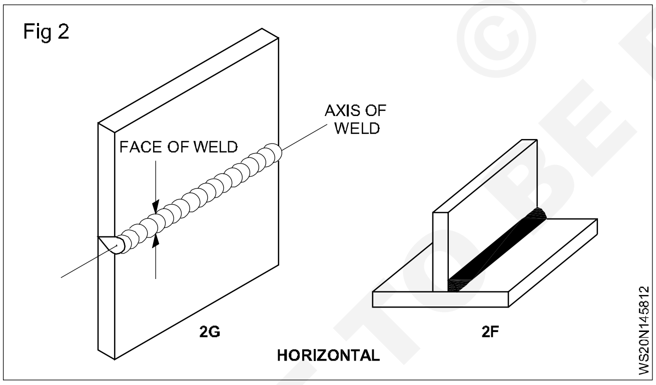
Objectives: At the end of this lesson you shall be able to
- **define weld slope and weld rofation with resfect to butt and fillet joint**
- **various weld positions with respect to stope and retation asper I.s.**

Basic welding positions

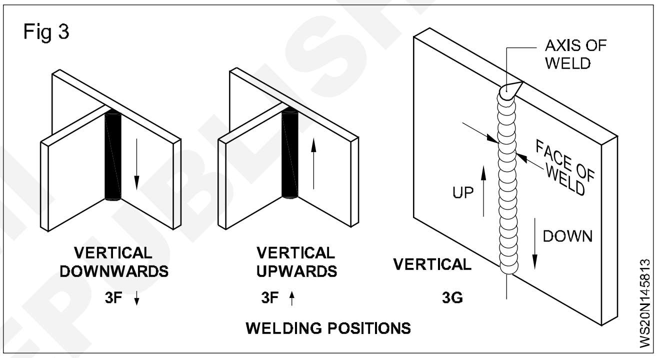
- Flat or down hand position (Fig 1)



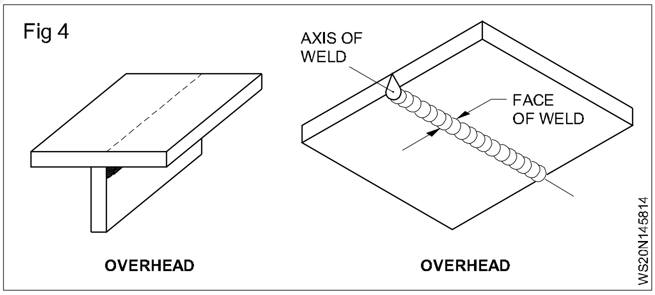
- Horizontal position (Fig 2)



- Vertical position (Vertical up and down) (Fig 3)



- Overhead position (Fig 4)



All welding action takes place in the molten pool, formed in the welding joint/welding line.

The position of the welding joint line and the weld face in respect of ground axis indicates the welding position.

All joints may be welded in all positions.

Weld slope and rotation

Objectives : At the end of this lesson you shall be able to
- **define and explain weld slope and weld rotation with respect to butt and fillet joint**
- **illustrate the various weld positions with respect to slope and rotation as per I.S.**

Welding position: All welding is to be done in one of the four positions mentioned below.

1 Flat or down hand

2 Horizontal

3 Vertical

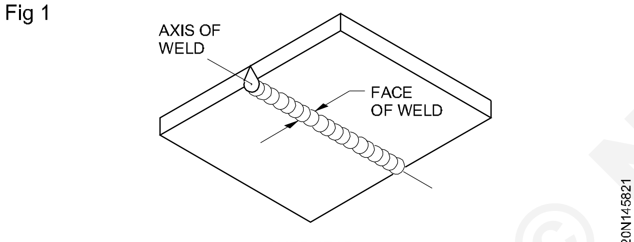
4 Overhead

Each of these positions can be decided by the angle formed by the axis of the weld and the weld face with the horizontal and vertical plane respectively.

Axis of weld: The imaginary line passing through the weld center lengthwise is known as axis of the weld. (Fig 1)

Face of weld: Face of weld is the exposed surface of a weld made in a welding process on the side from which the welding is done. (Fig 1)

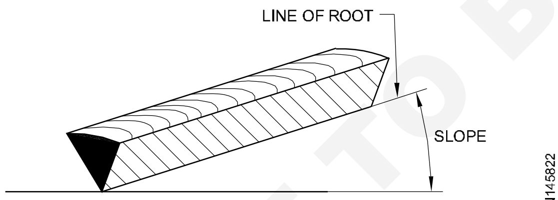
Fig 1



OVERHEAD

Weld slope (Fig 2): It is the angle formed between the upper portion of the vertical reference

Fig 2



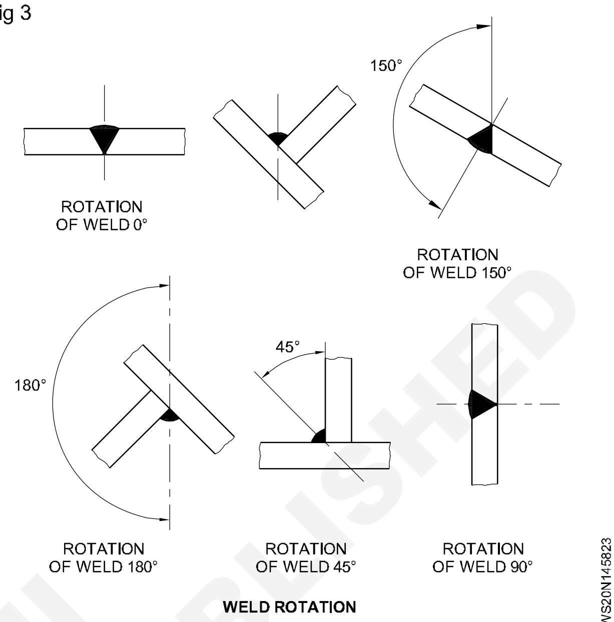
WELD SLOPE

Weld rotation (Fig 3): It is the angle formed between the upper portion of the vertical reference plane passing through the line of the weld root and that part of the plane passing through the weld root and a point on the face of the weld equidistant from both the edges of the weld.

Slope and rotation (Fig 4)

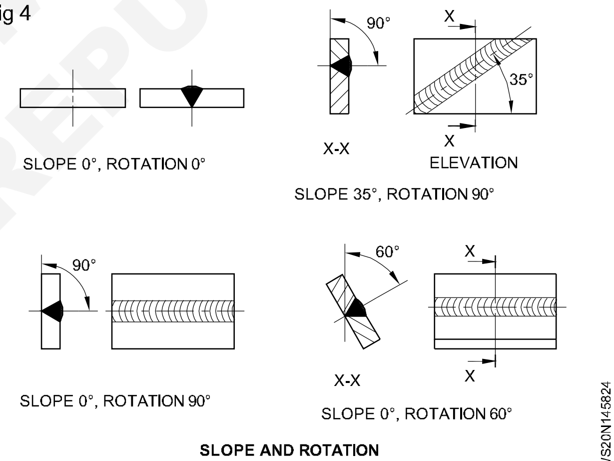
Weld in flat position. (Fig 5)

Fig 3



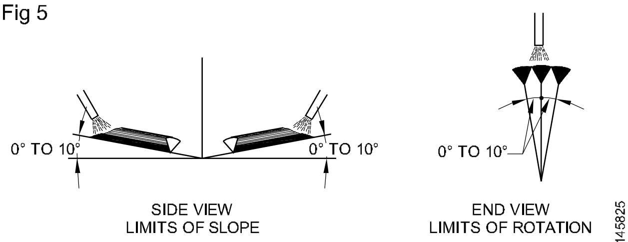
WELD ROTATION

Fig 4



SLOPE AND ROTATION

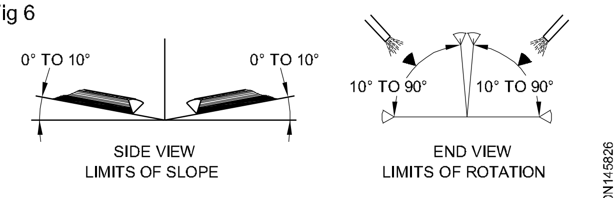
Fig 5



WELD IN FLAT POSITION

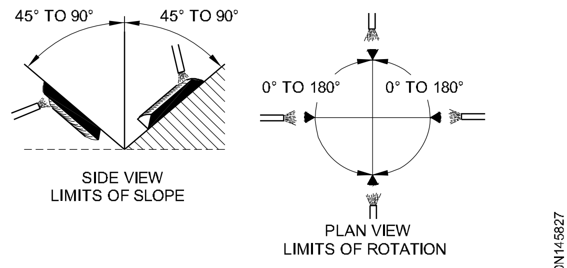
Weld in horizontal and vertical position. (Fig 6 & 7)

Fig 6



WELD IN HORIZONTAL POSITION

Fig 7



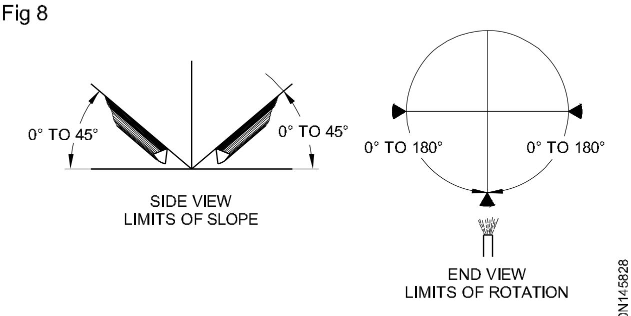
WELD IN VERTICAL POSITION

Weld in overhead position. (Fig 8)

Weld slope and weld rotation in respect of all the four positions are shown above.

Definitions of welding positions with respect to their slope and rotation angles a Table is given below.

Fig 8



WELD IN OVERHEAD POSITION

Definition of welding position

Position	Symbol	Slope	Rotation
Flat or down hand	F	Not exceeding 10°	Not exceeding 10°
Horizontal	H	Not exceeding 10°	Exceeding 10° but not beyond 90°
Vertical	V	Exceeding 45°	Any.
Overhead	O	Not exceeding 45°.	Exceeding 90°.

Weld joint edge preparation.

Objectives: At the end of this lesson you shall be able to
- **necessity of materials preparation for welding.**
- **Necessity of Edge preparation.**

Note: Refer R.Theory for Exercise 1.1.10

Welding procedure and techniques – tack welding, root run welding, intermediate and cover pass welding, cleaning, checking etc.

Objectives: At the end of this lesson you shall be able to
- **procedure – Tack, root run, intermediate and cover parts welding.**
- **cleaning and inspection for welding.**

Tack welding:

Tack welds are small and temporary welds that hold parts together ready for final welding.

Tack welds maintain the desired alignment and gap between the pieces of metal being joined.

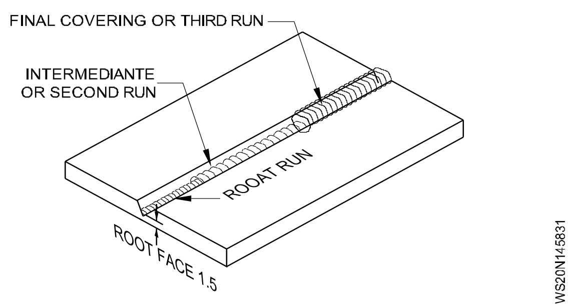
Root run welding:

The first weld bead placed in the weld joint is known as root run welding

Intermediate and cover pass welding:

The second intermediate weld pass is called a filler pass. The final weld pass is the cover pass.

Fig 1



Tack Welding Work

Tack welds are small welds that are spaced out along the workpieces. They are typically made from small beads of the same material that will be used for your final weld. The number of tack welds you need depends on the size of the materials you are joining together.

Tack Welding procedure and Distortion Control

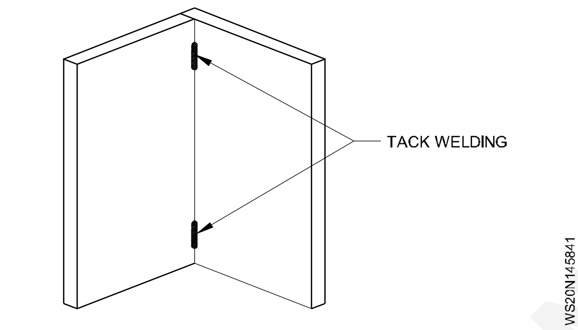
In order to create an effective weld it is important to clamp the workpieces together. This can be achieved with fixtures or with tack welds. These clamping methods will stop the pieces from moving, ensuring the join is done in the correct alignment and location.

Tack welds are usually performed using the same materials and process as for the final weld, except often at a lower power level or heat input. For example, an electron beam can create tack welds ahead of a later, higher powered, final electron beam weld.

Tack welding performs several important functions, including:

- Holding components in place ready for joining
- Ensuring the components are correctly aligned.
- Improving the function of fixtures or eliminating the need for them entirely. (Fig 2)

Fig 1

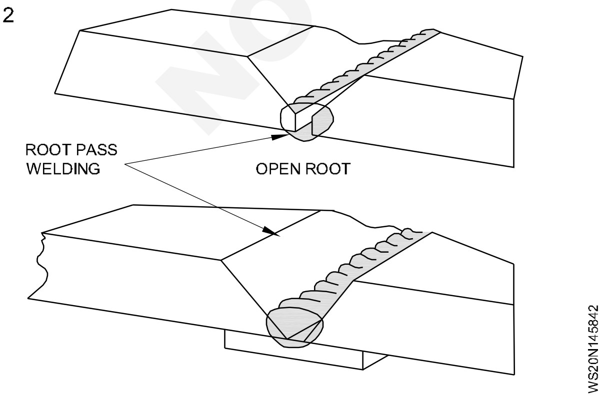


- Maintaining the desired joint gap and preventing movement of the workpieces.
- Helping to control distortion during final welding.
- Ensuring the mechanical strength of the assembly whether hoisted, moved, or turned.

Root Pass (Fig 3)

The **root pass** is the first weld bead of a multiple pass weld. The root pass;fuses the two parts together and establishes the depth of weld metal penetration. A good root pass is needed to obtain a sound weld. The root may be either open or closed, using a backing strip of backing ring.

Fig 2



The backing strip used in a closed root may remain as part of the weld, or it may be removed. Because leaving the backing strip on a weld may cause it to fail due to concentration of stresses along the backing strip, removable backup tapes have been developed. Backup tapes are made of high-temperature ceramics, that can be used to increase penetration and prevent burn through. The tape can be peeled off after the weld is completed. Most welds do not use backing strips.

Filler pass

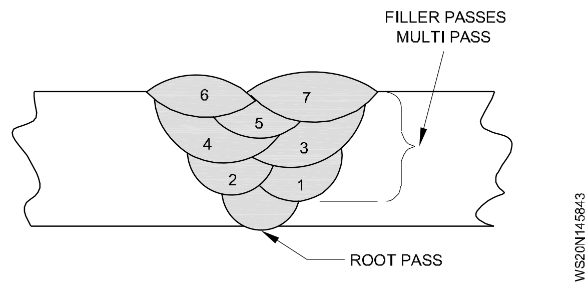
After the root pass is completed and it has been cleaned, the groove is filled with weld metal. These weld beads make up the filler pass. More than one pass is often required.

Filler passes are made with stringer beads or weave beads. For multiple pass welds, the weld beads must over – lap along the edges. They should overlap enough so that the finished bead is smooth. Stringer beads usually overlap about 50% ,and weave beads overlap approximately 25%.

Each weld bead must be cleaned before the next bead is started. Slag left on the plate between welds cannot be completely burned out because filler welds should be made with a low amperage setting. Deep penetration will slow the rate of buildup in the joint. Deeply remelting the previous weld metal may weaken the joint. All that is required of a fillerweld is that it be completely fused to the base metal.

Chipping, wire brushing, and grinding are the best ways to remove slag between filler weld passes. After theweld is completed, it can be checked by ultrasonic or radiographic nondestructive testing Most schools are not equipped to do this testing. Therefore, a quick check for soundness can be made by destructive sting. One method of testing the deposited weld metal is by cutting and cross sectioning the weld with an abrasive wheel andinspecting the weld. Another fast way to inspect filler passes is to cut a griove through the weld with a gougingtip. Watch the hot metal as it is washed away. The black spots that appear in the cut are slag inclusions. If only a few small spots appear, the weld probably will pass mosttests. But““if a long string or large pieces of inclusions appear, the weld will most likely fail (Fig 4)

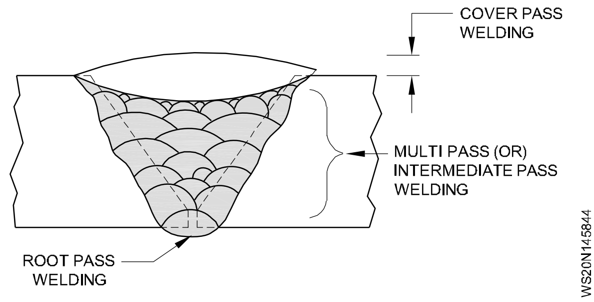
Fig 3



Cover Pass

The last weld bead on a multipass weld is known as the cover pass. The cover pass may use a different electrode weave, or it may be the same as the filler beads. Keepingthe cover pass uniform and neat looking is important Most welds are not tested, and often the inspection pro-gram is only visual. Thus, the appearance might be the only factor used for accepting or rejecting welds.““The cover pass should be free of any visual defects such as undercut, overlap, porosity, or slag inclusions should be uniform in width and reinforcement. A cover pass should not be more than 1/8 in. (3 mm) wider than the groove opening, Fig 5. Cover passes that aretoo wide do not add to the weld strength.

Fig 4



Cleaning and inspection

Clean the welded joint thoroughly from both sides

Inspect the weld size, surface defects root penetration and distortion.

Welding tools and accessories

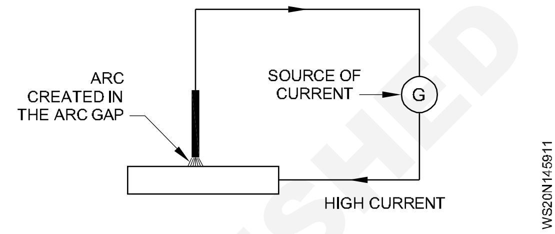
Objectives: At the end of this lesson you shall be able to
- **identify the welding arc tools and accessories**
- **explain the function of each accessory.**

Note: This topic covered in previous topic lesson 1.1.06

Principle of arc welding

When high current passes through an air gap from one conductor to another, it produces very intense and concentrated heat in the form of a spark. The temperature of this spark (or arc) is app. 3600°C, which can melt and fuse the metal very quickly to produce a homogeneous weld. (Fig 1)

Fig 1



Metal transfer across the arc (Characteristics of arc)

Objective: At the end of this lesson you shall be able to
- **explain the factors involved in the transfer of metal across the arc due to arc characteristics.**

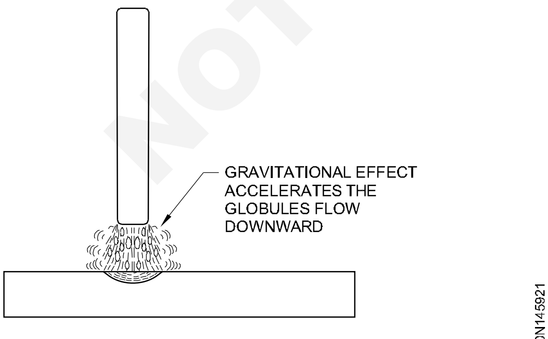
The electric arc has different arc characteristics which help in the transfer of metal across the arc. They are:

- gravity force
- gas expansion force
- surface tension
- electromagnetic force.

Gravity force (Fig 1): Molten globules formed at the arcing end of the electrode travel downwards towards the job in the molten pool.

Gravitational force helps the transfer of metal flat or down hand position and thus the deposition rate of weld metal is increased.

Fig 1

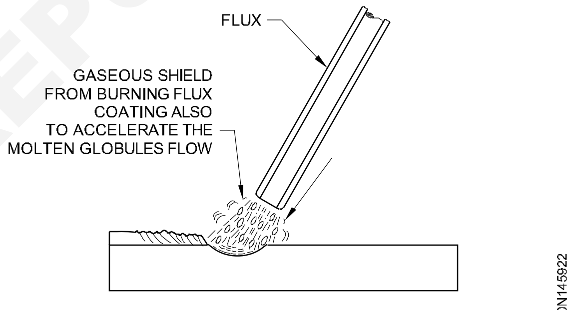


GRAVITY FORCE

Gas expansion force (Fig 2): Flux coating on the electrode melts due to the arc heat, resulting in the:

- Production of carbon monoxide and hydrogen mainly

Fig 2



GAS EXPANSION EFFECT

- Formation of a sleeve of the flux at the arcing end due to a little higher melting point of the flux coating than the core wire.

These gases expand and gain velocity. The flux sleeve direct these gases to flow in the direction of the molten metal. The gases flowing from the tip of the electrode have a pushing effect. Thus the metal globules are carried deep into the weld pool and influence penetration.

This effect of expanded gases is more useful in positional welding in metal transfer and influences penetration

Surface tension (Fig 3): It is the characteristic (Force) of the base metal to attract and retain the molten metal in it. This effect is more useful in the case of positional welding.

The short arc promotes more surface tension effect.

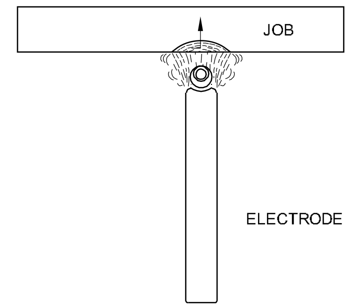


Fig 3

Electromagnetic force (Fig 4): The current passing through the electrode forms magnetic lines of force in the form of concentric circles. This force exerts a pinch effect on the molten metal globule formed at the arcing end of the electrode. The globule is detached from the electrode and reaches the molten pool under the influence of the magnetic force.

This effect is more useful in positional welding.

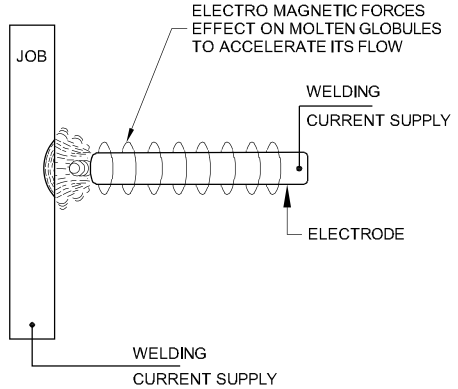


Fig 4

Polarity types and application

Objective: At the end of this lesson you shall be able to
- **importance of polarity types and application.**

Note: This topic covered in previous topic lesson 1.2.23

Arc length.

Objective: At the end of this lesson you shall be able to
- **Identify the different types of arc lengths..**

Note: This topic covered in previous topic lesson 1.2.22

Welding fixture and clamps.

Objective: At the end of this lesson you shall be able to
- **State purpose of fixtures & clamps & uses.**

Welding Fixtures

The main purpose of fixture is to locate, support and hold the workpiece in position firmly to obtain a precise product from a process.

A welding fixture is designed in a way to support and locate the components to be welded to avoid distortion and weld stresses.

Welding fixture (Fig 1)

One of the simplest type of welding fixture.

This design eliminates the excess fixture material from the weld area to minimize the heat loss, while providing the sufficient support and locating points.

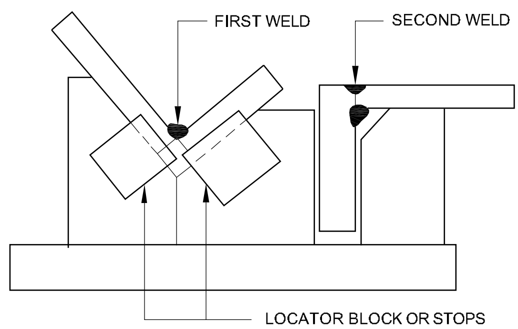
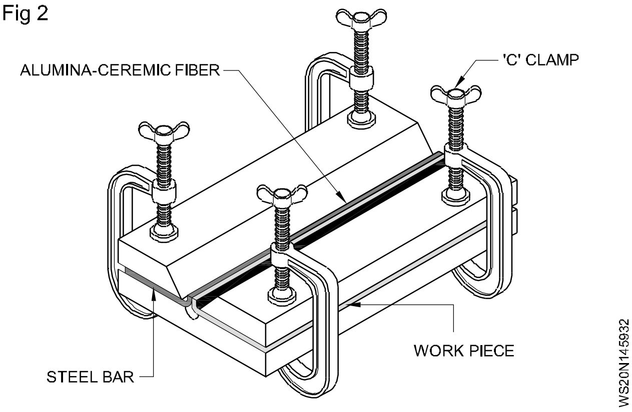


Fig 1

C- Clamps holds the workpieces to steel support bars. (Fig 2)

Fig 2



Welding clamps

Welding clamps are used to hold components or work parts temporarily together while performing operations like welding, woodworking, carpentry etc

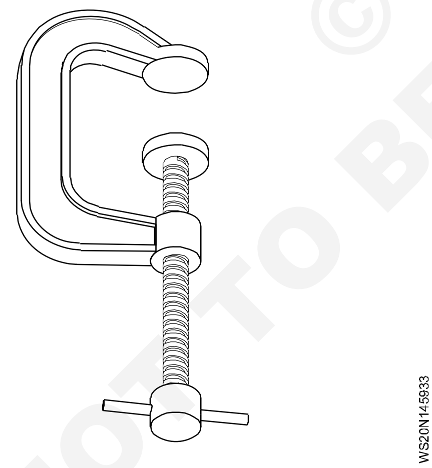
Types of weld clamps

There are clamps of different sizes and shapes each serving a specific purpose. Here are the most commonly used weld clamps.

C Clamps (Fig 3)

The Carriage Clamps or C Clamp is the most widely used welding clamp to hold the parts together using some pressure. The clamp holds the part by turning the screw towards the part. The C clamp is also called a G clamp.

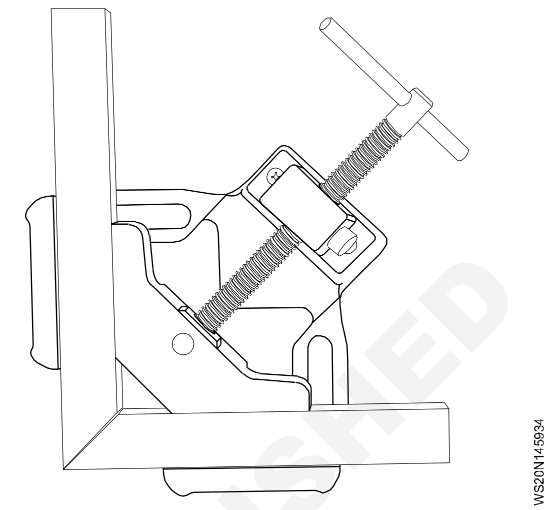
Fig 3



Two – Axis Clamp (Fig 4)

The tow – Axis welding angle clamp lets you hold work parts at an angle accurately. The work part with non – uniform thickness can be held by this clamp easily. You can quickly align the workpiece to be welded to be welded at an angle of 90 degrees accurately.

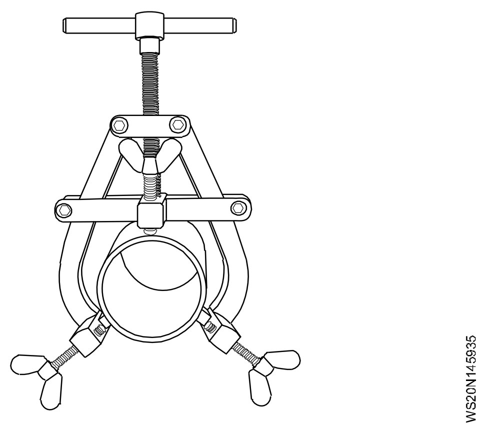
Fig 4



Pipe clamp (Fig 5)

The clamp holds the part by turning the screw towards the part. They are quick, easy and safe to operate which are used for centeringand alignment of the steel pipes before pipe welding.

Fig 5



Coated electrodes Types, Description Standard Size and length of electrodes

Objectives: At the end of this lesson you shall be able to
- **types of flux coating and Method of flux coating**
- **state the electrode size and length.**

Note: This topic is covered in previous topic lesson 1.3.41

Selection of electrodes and coating factor

Objectives: At the end of this lesson you shall be able to
- **select suitable electrode to weld a particular job**
- **sate the necessity of baking a coated electrode**
- **state the store and handle the electrode properly for better weld quality.**

Coating factor

Selection of an electrode is very important in order to get joint welded with the required strength.

Selection factors““Properties of base metal: Top quality weld should be as strong as the base metal.

Select an electrode that is recommended as per the properties of the base metal: (Fig 1)

Fig 1

BASE METAL	ELECTRODE SELECTED
MILD STEEL	MEDIUM COATED RUTILE M.S. ELECTRODE
MEDIUM CARBON STEEL	HEAVY COATED LOW HYDROGEN M.S. ELECTRODE
STAINLESS STEEL	COLUMBIAM BASED STABILISED STAINLESS STEEL ELECTRODE
COPPER	HEAVY COATED BRONZE ELECTRODE

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The size of the electroge depends on

- thickness of metal to be welded
- edge preparation of joints
- Select as per the availability of the welding machine
- root fun, intermediate or covering nun
- wolding position

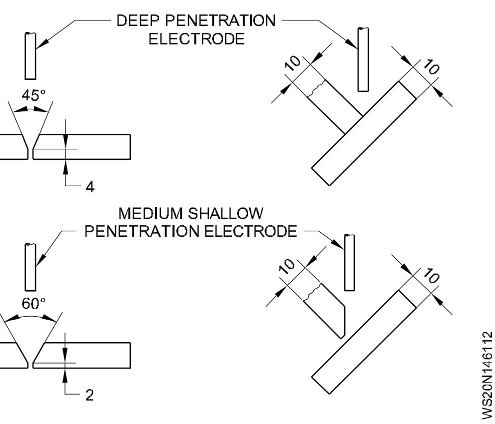
Neverusealargerdia electrode than the thickness of base Metal

Joint design and fit up

Select:

- Deep penetration electrodes for insufficiently beveled joints
- Medium penetration electrodes for open and sufficiently bevelled joints (Fig 2)

Fig 2

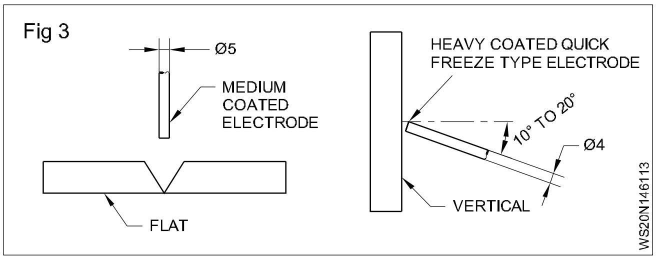


Welding position: Electrodes are manufactured for differ ent positions to produce better welds

Select an electrode as per the welding position. (Fig 3)

Welding current: Electrode. are available for use with.

Fig 3



AC or DC (straight or reverse polarity) AC and DC (both)

Select as per the availability of the welding machine

Production efficiency: The deposition rate of electrode is important in production work. So select an iron powder electrode for production work

Faster the weld, lower the cost.

Select the electrode, which is designed for the particular production work.

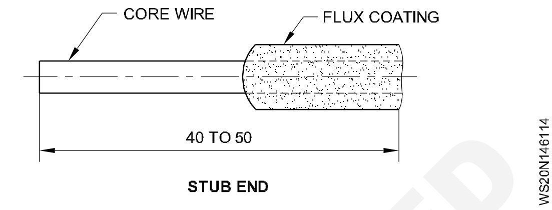
Usage and storage of electrodes

Electrodes are costly, therefore, use and consume every bit of them

Do not discard STUB ENDS more than 40-50 mm length (Fig 4)

Electrode coating can pick up moisture it exposed to atmosphere

Fig 4



Electrode storage and necessity of backing

Objectives: At the end of this lesson you shall be able to
- **store and handle the electrode property for better weld quality**
- **state the necessity of baking a coated electrode.**

Note: This topic is covered in previous topic lesson 1.3.42

Effect of heat on weldment's

Objective: At the end of this lesson you shall be able to
- **HZ and effect of heat on weldment's.**

During metal welding, the metal absorbs the generated heat. This heat transmits away from the welded area through the metal body, as metal is a good heat conductor.

A zone is formed between the melted metal and the unaffected base metal called the heat affected zone (HAZ). In this Zone, the metal is not melted but the heat has led to changes in the metal's micro structure. These changes in structures can reduce the metals strength.

It is very important to understand that the HAZ accounts for reduced strength to design safe applications. The weakest sections of a structure exist in the HAZ.

A structure is as strong as its weakest point. Therefore recognising the HAZ may be the difference between the success and failure of a particular part.

Effect of Heat on Weldments

The heat affected zone leads to structural changes in the metal that weaken the part in this area. A metal's mechanical properties such as fatigue resistance, distortion, and surface cracking are affected.

Let us take a look at the different effects of the HAZ on the metal.

Metallurgical & Chemical Changes

In metal welding, the metal absorbs the heat at a very high rate. The cooling provided by the Coolant is also immediate. This can significantly change a metal's micro structure and properties in the affected area.

Example the (production of hot rolled steels) has similar results.

Chemical changes are also seen as different phases are created next to each other depending on the specific temperatures achieved by the different sections of the metal.

Corrosion

Stainless steel may even corrode in the heat affected zone. Extreme heat leads leads to precipitation of chromium carbides near the grain boundaries. This reduces the chromium content of stainless steel below 10.5 percent.

The results is the loss of self-passivation (the ability to recreate a protective layer of chromium oxide to prevent corrosion) Causing intergranular Corrosion. It also loses its property of being stainless and in extreme cases, the metal will turn black.

Welding distortion and stresses

Objectives: At the end of this lesson you shall be able to
- **causes and types of distortion.**

Note: This topic in covered in previous topic lesson. 1.2.33

Method of controlling distortion by various method. Method of relieving stress on weldments.

Objectives: At the end of this lesson you shall be able to
- **explain the control of distortion.**
- **various welding stress relief treatments.**

Note: This topic in covered in previous topic lesson. 1.2.33

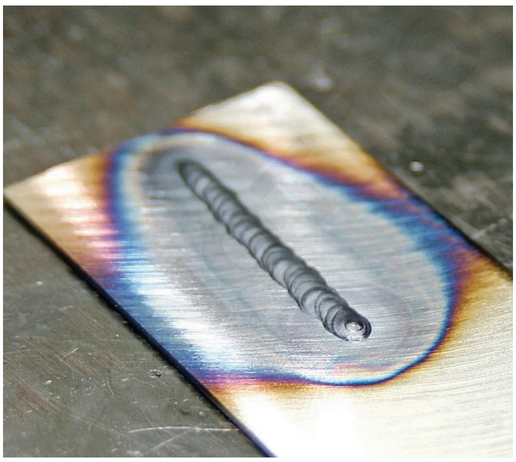
Advantages of welded over riveted structures.

Objectives: At the end of this lesson you shall be able to
- **advantages of welded structure riveted structures**
- **disadvantage of riveted structures.**

Advantages of welded over riveted structures.

There are advantages as well as disadvantages of choosing welded joints over riveted joints. (Fig 1) We shouldn't join all surfaces by either by using welding processes or by using riveted joints. Depending upon need, one need to choose joining method. (Fig 2,3)

Fig 1



Advantages:

1 The welded structures are usually light in weight.

2 The welded joints provide high efficiency, which is not possible in the case of riveted joints.

3 Alterations and additions can be made easily in the existing structures.

4 Welded structures are smooth in appearance, therefore it looks pleasing.

5 A welded joint has a great strength. Often a welded joint has the strength of the parent metal itself.

6 It is easily possible to weld any part of a structure at any point. But riveting requires enough clearance.

7 The process of making welding joints takes less time than the riveted joints.

8 Shape like cylindrical steel pipes can be easily welded. But they are difficulty for riveting.

9 The welding provides very strong joints. Which can’t be bended easily. This is in line with the modern trend of providing rigid frames.

Disadvantages:

1 For making weld joints using weld symbols requires a highly skilled labour and supervision.

2 Since there is an uneven heating and cooling in welding process during fabrication, therefore the members may get distorted or additional stresses may develop.

3 Since no provision is kept for expansion and contraction in the frame, therefore there is a possibility of cracks developing in it.

4 The inspection of defects in welding work is more difficult than riveting work.

Fig 2

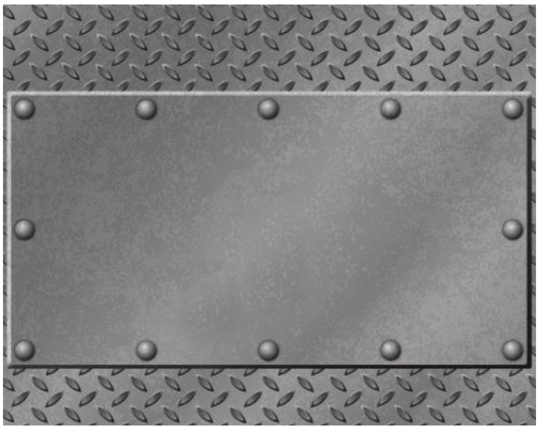


Fig 3

Types of Steel sections

Objectives: At the end of this lesson you shall be able to
- **to know about steel section**
- **Indian standard steel section for structural uses.**

Types of steel sections forms used in structural fabrication and their standard size (Fig 1)

Structural size:

Is a versatile material that can be fabricated into many different shapes to support different needs. Engineers and builders rely on structural stainless for the supports of their buildings as well as other uses. It is important to understand the standard shapes, as well the ability to customize structural steel to fit your unique design and support needs.

- American standard beam
- Angle section
- Bearing pile
- Channel section
- Hallow steel section
- Beam section
- Tee section
- Pipe section

American standard Beam

The American standard beam contains a rolled section with two narrow flanges with a connecting web. These beams are designed by height and weight so the builder has the right details about the capabilities of the beam. For example, W 24 x90 would indicate a beams are used for many different support systems and are one of the most popular beam shapes.

Angle Beams

Angle beams are also called L – shaped beams, as these beams form an L - shape, with two straight legs connected at 90 degree angle. The legs may be equal or unequal in length. Angle beams have many different applications, but are primarily used for bracing.

Bearing pile

Bearing pile beams are composed of H- shaped beams and are used to support deep foundations. H- shaped beams and driven into the ground to provide foundation piling and transfer the bulk of the weight to the tip of the pile.

Channel Beams

Channel beams, also referred to as C - shaped beams, feature top and bottom flanges with a connecting web. These beams are usually used as a cost – effective support for shorter

Hallow steel section

Hallow steel section beams look like large tubes or pipes, since, as the name indicates, the cross sections are hallow. These beams come in many shapes, such as elliptical, rectangular, and round. Engineers often use these beams within load bearing columns.

I Beam

Although I-beams and H – beams are sometimes used interchangeably, they are not the same. Both have two parallel flanges with a vertical web, but I – beams are tapered. This type of beam effectively resists shearing forces at the web and the flanges resist bending forces. These beams are cost – effective and used as structural supports in many buildings.

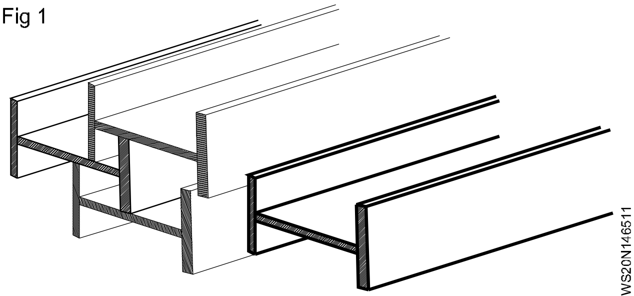
Pipe

A pipe is simply a hallow, tube – like structure that can come in many sizes to work with the overall structure and support system to carry water, oil, or gas. Piping can be highly customized and integrated into any support system

Tee

Tees are also referred to as T – beams are steel beams that have been cut longitudinally through the web, resulting in a T shaped cross section, with the flange at the top of the cross section. Although I – beams are still considered one of the strongest structural shapes for load – bearing needs.

Fig 1



Importance of Structural welding and workmanship

Objectives: At the end of this lesson you shall be able to
- **to know about importance as structural welding and workmanship**
- **types of structural welding and their uses..**

Structural welding

Structural welding involves creating a variety of welds with different component materials to create, fabricate, and erect welded structures. Structural welding has its own set of codes, blueprints, and types of weld joints.

Structural welders require a specific set of skills involving balanced measurements and precision to do aneffective job. In this article, I'll cover several issues concerning structural welding, its requirements, and its results.

Importance of Structural welding and workmanship

Structural welding is used to create metal frameworks for buildings, bridges, vehicles and a variety of other complex structures. Structural welding is also used to cut and repair beams, columns, and grinders.

Structural welders is used in various industries, including construction, manufacturing, shipbuilding. Mining, oil and gas distribution, vehicle manufacturing, aerospace, military and heavy industries.

Structural welding has become a significant part of today's industry because of all the innovations created for residential housing and commercial buildings.

Create the connections between beams and columns to stabilize a building

- Prepare structures, parts and materials for welding
- Perform welding activities for large structures
- Make precise welded connections
- Follow engineering specifications, sketches, drawings, blueprints and written irections
- Inspect weld to ensure they're not damaged, have proper dimensions and are freefrom defects
- Repair and replace damaged beams and other types of structural components
- Use complex software to figure out the exact angles of the beams
- Install welded steel supports, beams, griders and columns
- Power supply equipment
- Military, shipbuilding and aeronautical applications
- Manufacture of moving vehicles in construction, automotive,agriculture.

Welding processes used in structural welding

Commercial – grade steel is the most widely used metal in structural welding. It offers much better durability and is more sustainable under stress than most other metals.

Another benefit is that it is quite lightweight compared to other metals like aluminium and iron. Steel is also quite economical.

There are mainly three types of welding processes involved in steel structural welding; stick welding, stud welding and flux core arc welding.

Flux core welding offers a few unique benefits that make it preferable over other types of welding:

· Flux core welding does not require an additional shielding gas

· It is ideal for welding in outdoor environments even in windy conditions

· Other types of structural welding have a higher chance of porosity than flux core welding

· When you have the right filler material available. FCAW is all about positioning; it is quite easy to learn and apply

Flux core welding is vastly used in industries that require high speed, consistent welding

Necessity of qualifying welders, welding operator and tack welders

Objectives: At the end of this lesson you shall be able to
- **To know about Necessity of qualifying welders, welding operators and lack welders.**

Introduction:-

Welder, welding operator and welder qualification tests determine the ability of those tested to produce acceptably sound welds with the process, material and procedure called for the test. Qualification tests are not intended to be used as a guide for welding during actual construction, but rather to assess whether an individual has a certain minimum level of skill. The test does not determine what an individual normally will or can do in production. For this reason, complete reliance should not be placed on qualification testing of welders. The quality of all production welds should be determined by inspection during and following completion of the actual welding.

Various codes (such as American welding Society (AWS) D1.1 structural welding code and ASME boiler and pressure vessel code section ix), specifications, and governing rules generally prescribe similar though frequently somewhat different methods or details for qualifying welders, welding operators, and tackers. The applicable or required standard should be consulted for specific details and requirements.

Qualification of welders, welding operators and tack welders

The term "qualification" means that a welder or welding operator or tack welders has met the requirements of a given standard and is qualified to perform welding within the scope of that standard. Certified welders must possess the skills necessary to produce sound weld, which is visually acceptable and also meets testing requirements.

Welder's welding operators and tack welders need to be qualified

All the codes and standard have the main objective of verifying the welder's ability to deposit sound weld. The sound weld means weld that is free from welding defects such as crack, lack of fusion, lack of penetration, etc. Sound weld doe not mean free from imperfections such as porosity or slag inclusion. These imperfections are allowed but within limits only as specified in their respective acceptance criteria in the applicable code or the standards.

Steps for welder qualilfication

Before you make a welder qualification, you need to know the following welding conditions that will guide you to choose various essential variables for WQT:

Welding process to be used

- Type of welding joint
- Material P Number and type (either plate or pipe)
- Electrode classification, its F-number
- Weld thickness to be deposited
- Welding position
- Weld progression

The exact job responsibilities of a welder greatly depend on the type of job they are hired to perform. Some of the most common tasks are:

Using torches and arcs to weld various pieces of metal together

Operating a wide range of welding equipment depending on each job situation

Analyzing their equipment and taking appropriate measures in case they discover any defects

Monitoring various welding processes and making sure the heat doesn't change the materials size and shape

Making sure all welding work complies with safety standards and industry specifications

Assembling and disassembling each welding component before and after a job.

Qualifying the welding procedure

Objectives: At the end of this lesson you shall be able to
- **know about necessity of our qualifying the welding procedure.**

Qualification of welding procedures

Welding procedure qualification verifies compatibility of materials and techniques able to produce welded components that are in compliance with welding codes and have acceptable mechanical properties.

In order to achieve an accurate welding procedure specification, and assess welding procedures on a qualification weld. The qualification weld is then inspected by the following mechanical and non mechanical tests in preparation of the procedure qualification report (PQR):

Different strength testing such as tensile strength testing and proof load testing

- Non - destructive testing
- Bend testing
- Macro etching
- Charpy impact testing
- Metallurgical analysis
- Hardness testing
- Slow bend testing
- Rolling load testing
- Material fatigue testing

Positions of test plates

Objectives: At the end of this lesson you shall be able to
- **positions of test plates**
- **positions of grooved weld.**

Positions of test plates for fillet welds and groove welds

Positions of test plates

There are two types of position in test plates

1 plate position for fillet weld

2 plate position for groove weld

Plate Positions for fillet weld:

There are also four types of plate to plate fillet weld technique

1 F or Flat position:

Plates so placed that the weld is deposited with its axis horizontal and its throat vertical. As shown in below figure.

2 For Horizontal position:

Plates are so placed that the weld is deposited with its axis horizontal on the upper side of the horizontal surface ad against the vertical surface. As shown in the below figure.

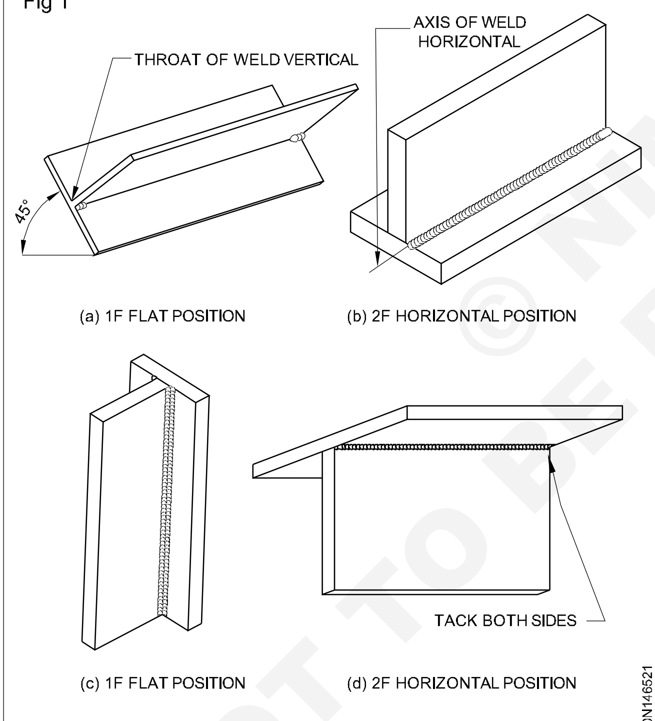
3 F or vertical position:

Plates so placed that the weld is deposited with its axis vertical as shown in the below figure.

4 F overhead position:

Plates so placed that the weld is deposited with its axis horizontal on the underside of the horizontal surface and against the vertical surface. As shown in below figure.

Fig 1



FILLET WELD

PLATE POSITIONS FOR GROOVE WELD:

There are four types of welding positions in plate to plate groove welding technique. This are following:

1G or Flat position:

Plate in a vertical plane with the axis of the weld vertical. Refer to the figure shown below

2G or Horizontal position :

Plate in a vertical plane with the axis of the weld horizontal. Refer to the figure shown below

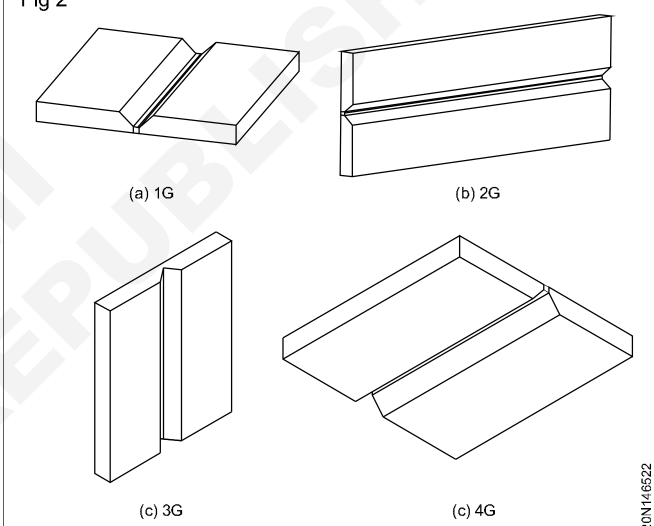
3G or vertical position :

Plate in a vertical plane with the axis of the weld vertical. Refer to the figure shown below

4G or vertical position :

Plate in aHorizontal plane with the axis of the weld metal deposited from underneath as shown in the below figure.

Fig 2



GROOVE WELD

Types of fillet welded and groove welded joints on statically loaded structures

Objectives: At the end of this lesson you shall be able to
- **types of fillet weld groove welded joints**
- **static load on structure.**

Fillet welds

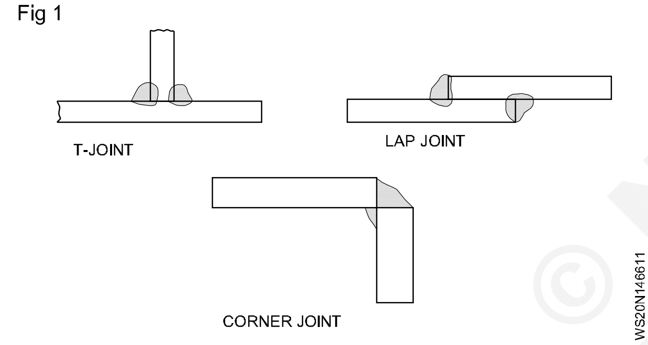
In fillet type weld, the two metal pieces are joined with each other having their surfaces at right angle (90 degree angle between the surface forming fillet)

Types of fillet welded joints

1 Single fillet weld joints are generally made in lap joints, T joints and corner joints. The strength of single fillet joints depends upon the size of the fillet.

2 Double fillet weld joint is also used for making T joints, lap joints, and corner joints. double fillet welded joints develop good strength as compared to single fillet joints. Hence they are used for fatigue type of loading.

Fig 1



Groove weld:

The weld groove is a channel in the workpiece or between the openings of two workpieces which will contain the weld metal.

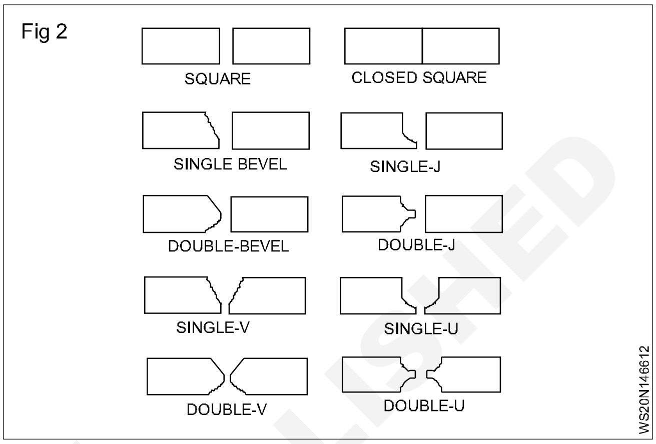
There can be different types of groove welds (Like single groove welds, double groove weld etc.) depending upon the type of applications

Single groove welds are made on the single side of the workpiece and they are not used for bending or fatigue load as they fail due to stress concentration on the weld root.

Double groove welds are those weld in which the weld is made on both the sides. This type of weld develops more strength and they can be used for fatigue loads.

Types of Groove welded joints

Fig 2



Static load on structure

A static load is a mechanical force applied slowly to an assembly or object. Static loads do not change over time but remain constant, allowing tests to be conducted to determine the maximum loads that can be with stood by structures such as bridges or floors in tower blocks. static loading can also be used to work out the strength of different types of material.

Static loads differ from dynamic loads, where forces are applied rapidly and can change.for example, a car park with no vehicles moving is being subjected to a static load, bu when the vehicles are moving around the load becomes dynamic.

A static is one which varies very slowly

Static load

Force that has constant size position and direction on or with in a structure

Study of static loads helps determine the maximum allowable load to be applied to the structure

Resistance due to internal clastic forces of structure

In static problem response due to static loading is displacement only

Static not moving

Static load: forces on a non-moving structure

Static load

Force that has constant size position and direction on or with in a structure

Study of static loads helps determine the maximum allowable load to be applied to the structure

Resistance due to internal clastic forces of structure

In static problem response due to static loading is displacement only

Static not moving

Static load: forces on a non-moving structure

Static load vs, dynamic load

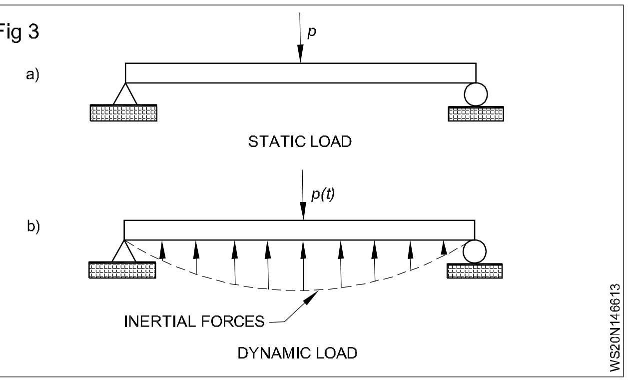
A static load is a load that is either constant or applied over a long period of time. All bead loads are static loads

A dynamic load is a load that is variable and appalled over a short period of time

Bridges (or strictures in general) respond to static and dynamic loads very dofferently

Dynamic and static loading are both considered in structural analysis, which is concerned with how physical structures behave when subjected to force. These forces can range from vehicles and people to furniture, wind, snow or even earthquakes.

Fig 3



These forces can be either or dynamic, depending on how they are applied. It the force has enough acceleration compared to the natural frequency of the structure (i.e. they are applied quickly), then they are dynamic. If they are applied slowly, or don't move at all, then they are static. Dynamic loads are determined with dynamic analysis and static loads with static analysis.

Dynamic loads tend to have a greater impact on a structure than static loads due to the equation of force.

Force = mass x acceleration

While dynamic loads, like traffic moving across a bridge or gusts of wind, will change with time, they are often treated like static loads to simplify structural engineering calculations.

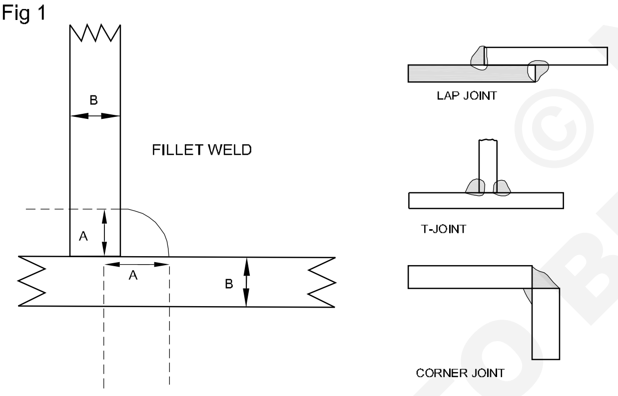
Types of fillet welded and groove welded joints on dynamically loaded structures

Objectives: At the end of this lesson you shall be able to
- **types of fillet weld and groove welded joints**
- **dynamically loaded structures**
- **static load vs dynamic load.**

Fillet weld (Fig 1)

- The most common and easiest type to produce in structural steel field welding
- Often used in welded connections with T, lap and corner joint configurations, though it can be found throughout a project.
- Is generally visually inspected and rarely requires additional quality assurance testing
- Widely used on jobsites, but typical applications using fillet welds include shear tabs, cover plates, bracing connections and columns bases, as well as seam and stitch welds.
- Welders can often complete these faster and do more of them compared to more difficult groove welds.

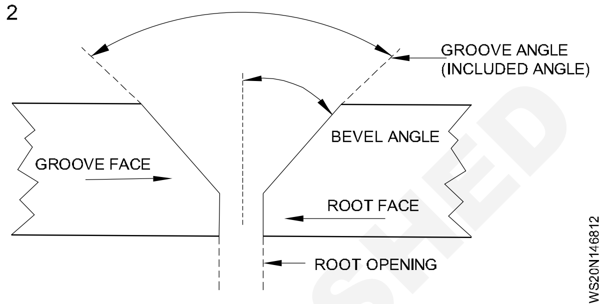
Fig 1



Groove weld (Fig 2)

- Can be partial joint penetration (PJP) or complete joint penetration(CJP) depending on the strength requirements.
- Often used for moment connections, column splices and connections at hallow structural steel (HSS) members.
- Takes more time to complete and requires highly skilled welders
- Typically requires special bevelling
- Requires additional testing and verification to ensure weld quality, especially for CJP groove welds.

Fig 2



Dynamically loaded

Also known as a ' live load, 'a dynamic load is one that changes in direction, position and magnitude, creating varied forces on a structure. This is different from a static load.

For example, if you stand still on a floor, you create a static load, but if you stand still on a floor, you create a static load, but if you jump up and down and move around the floor,you create a dynamic load.

Types of dynamic load include people, traffic, earthquakes, wind, waves, and blasts. Any structure can be subjected to dynamic loading and the changes that come with a dynamic load can be random, periodic or a combination of the two.

Dynamic loading is best understood with a comparison with static loading.

A dynamic load a one which changes which changes with time fairly quick im comparision

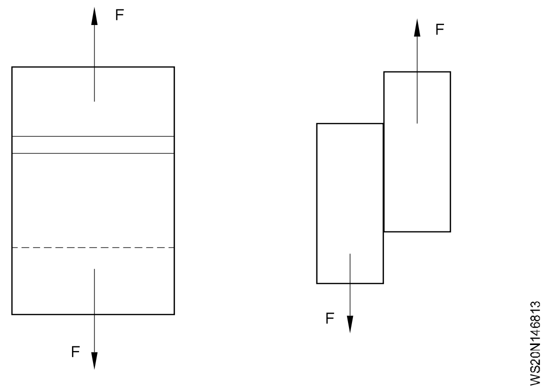
To a structure's natural frequency

Dynamic load is the maximum recommended thrust load which should be applied to the screw or actuator while in motion. The dynamic load capacity is how much an actuator

A dynamic load is one that constantly changes ,such as with effect of people jumping up and down in a cable car. These changes can be random, periodic or a combination of the two,, dynamic loads are characterised as loads that vary, often delivering greater forces than with static loads as a result.

A transverse fillet weld is one that is perpendicular to the force applied as seen in the image below.

Fig 3



Because the load is perpendicular to the weld it is considered a tensile load. The formula we need to use to determine the load carrying capacity of the weld is:

$$\sigma t = \frac{F}{A}$$

σt is the tensile strength of the weld (determined by the filler metal being used) in PSI.

F is the force the weld can handle, in other words, the strength of the weld in IBF

A is the effective area of a weld is calculated by multiplying the length of the weld times the throat of the weld. For design purpose we use the theoretical throat as shown below (Fig 4)

Dynamically load

A force on a structure that changes size position or direction. Study of dynamic load help determine the stresses at the different points of the structure due to changing conditions over time.

Fig 4

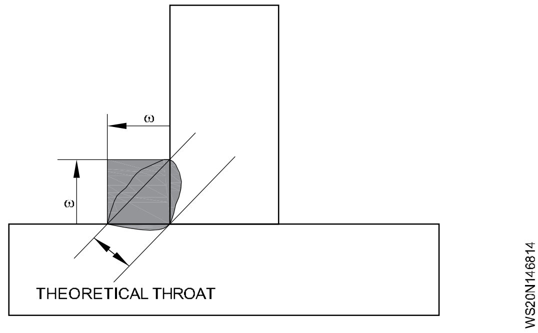
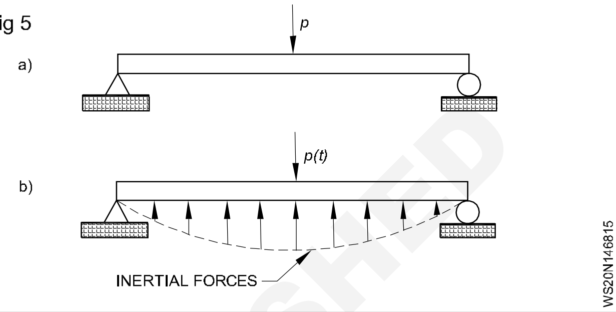


Fig 5



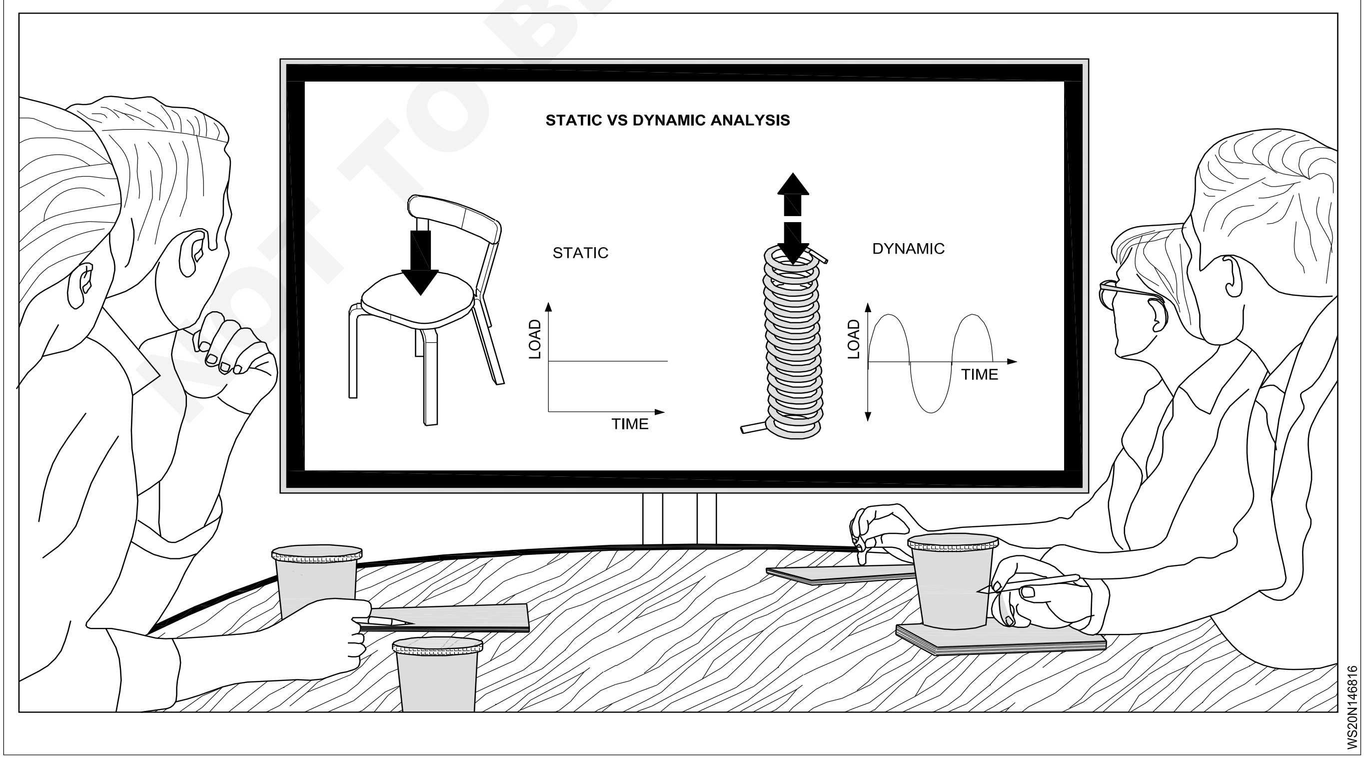
Accelerations producing inertia forces (inertia forces form a significant portion of load equilibrated by the internal elastic forces of the structure)

In dynamic problem: responsed due to dynamic loading is displacement,velocity and acceleration.

Dynamic : In motion or changing.

Dynamic load : Forces changing due to movement of structure.

Fig 6



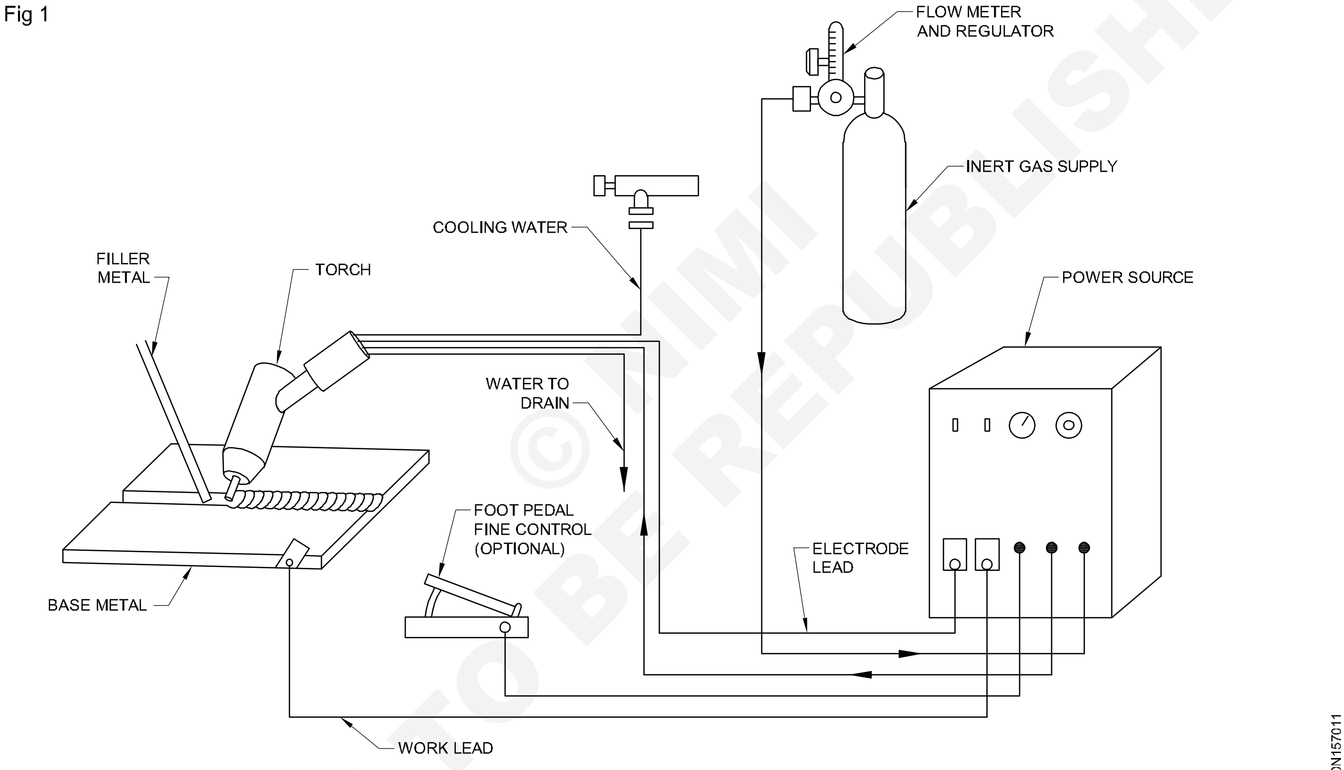
GTAW process and equipment

Objectives: At the end of this lesson you shall be able to
- **identify the GTAW equipment**
- **name the parts of a GTAW equipment**

TIG welding equipment (Fig 1)

– An AC or DC arc welding machine.
– Shielding gas cylinders or facilities to handle liquid gases
– A shielding gas regulator
– A gas flowmeter
– Shielding gas hoses and fittings
– A welding torch (electrode holder)
– Tungsten electrodes
– Welding filler rods
– Optional accessories
– A water cooling system with hoses for heavy duty welding operations
– Foot rheostat (switch)

Fig 1



A DIAGRAMMATIC DRAWING OF A COMPLETE GAS TUNGSTEN ARC WELDING

GTAW torches - types, parts and their functions

Objectives: At the end of this lesson you shall be able to
- **state the purpose of the torch and its parts**
- **state the care and maintenance of torches.**

GTAW torch

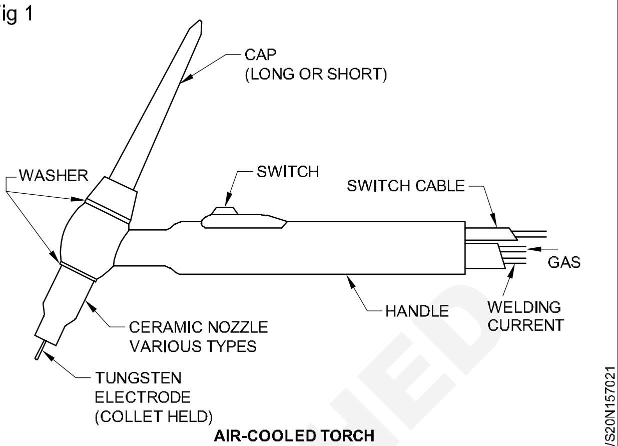
Torch: There is a variety of torches available varying from light weight air cooled to heavy duty water cooled types. Figs1 & 2. The main factors to be considered in choosing a torch are:

– Current carrying capacity for the work in hand

– Weight, balance and accessibility of the torch head to the work in hand.

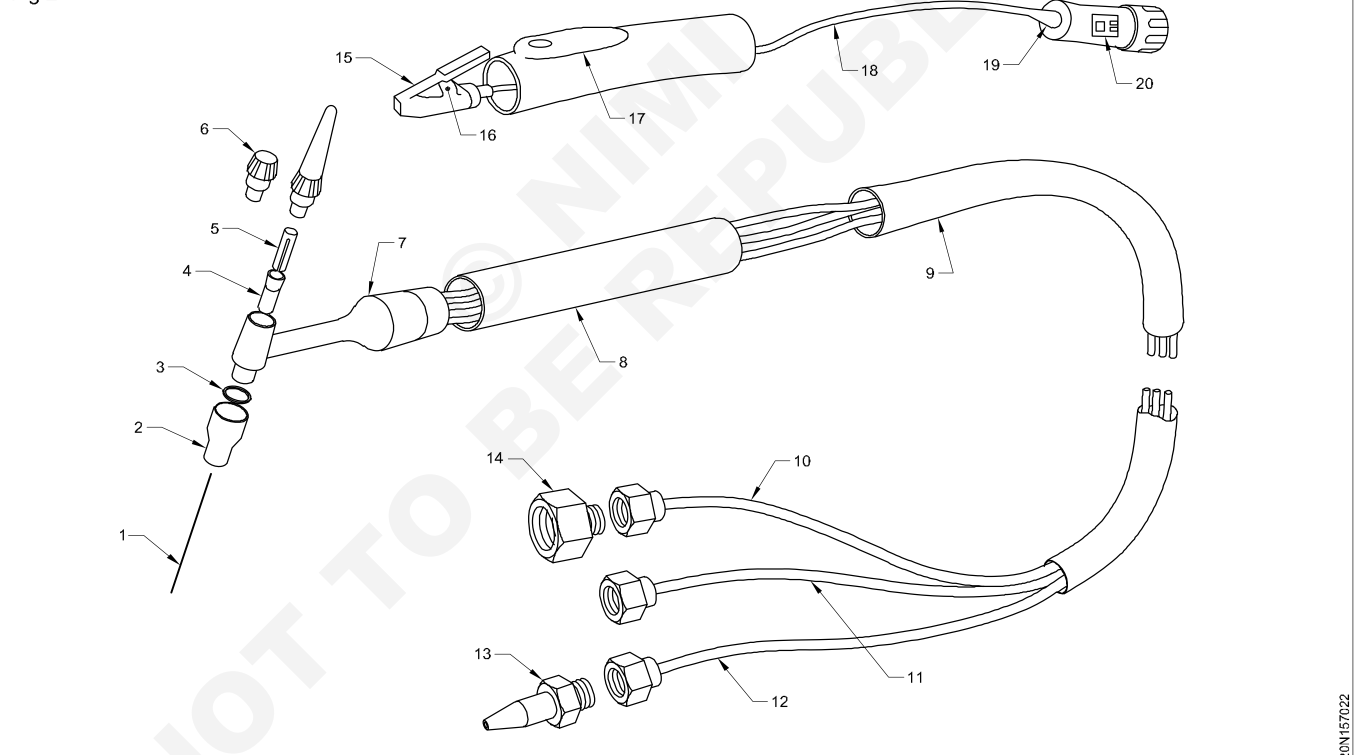
The torch body holds a top loading compression-type collet assembly which accommodates electrodes of various diameters. They are securely gripped, yet the collet is easily slackened for removal or reposition of the electrode. As the thickness of plate to be welded increases, size of torch and electrode diameter must increase to deal with the larger welding currents required.

Fig 1



AIR-COOLED TORCH

Fig 2



WATER COOLED TORCH

Parts of water cooled torch Fig.2

1 Thoriated or Zirconiated tungsten electrode
2 Ceramic shield/nozzle 3. "O" ring
4 Collet holder
5 Collet
6 Electrode cap (short & long)
7 Body assembly
8 Sheath
9 Hose assembly cover
10 Argon hose assembly
11 Water hose assembly
12 Power cable assembly
13 Adaptor (power cable)
14 Adaptor (argon gas hose)
15 Switch actuator
16 Switch
17 Switch retaining sheath
18 Cable (2 core)
19 Insulating sleeve
20 Plug

The function of the TIG torch is to

1 hold the electrode tungsten

2 deliver welding current to the tungsten via a welding power cable

3 deliver shielding gas to the TIG torch nozzle. The nozzle then directs the shielding gas to cover the weldpool protecting it from contamination from the surrounding air.

4 often will be the way of getting the welder control circuit to the operation, eg on/off and/or amperage control.

5 the TIG torch can be watercooled. Hoses in the TIG lead will supply cooling water to the TIG torch head assembly.

6 the TIG torch length will allow a distance from the TIG power source and workpiece.

TIG torches come in different styles depending on the brand being selected. But they all have things in common -

1 aircooled or watercooled

2 current rating. The operator must select the correct amperage rating TIG torch.

Cooling of the TIG torch

Some torches are constructed in such a way that it is the flowing shielding gas that cools the torch. However, the torch also gives off heat to the surrounding air.

Other torches are constructed with cooling tubes. Water-cooled torches are mainly used for welding with larger current intensities and AC-welding.

Usually a water-cooled TIG torch is smaller than an air-cooled torch designed to the same maximum current intensities

Using a TIG torch that is not sufficiently rated for the machine may result in the TIG torch overheating. A TIG torch wiith an excessive rating may be larger and heavier than a lower amperage TIG torch.

The TIG torch is made up of

1 **Leads -** The lead will be set up for either aircooled or watercooled. It will be at a length suitable to do the job, eg 4 metre, 8 metre, etc. The lead will be made up of a power cable, gas hose and water leads in and out if the TIG torch is watercooled. The lead may also include a control lead.

2 **Collet -** To hold the tungstan rods. Collet may vary with different brands of TIG torches.

3 **Ceramic Nozzles -** The nozzle's job is to direct the correct gas flow over the weldpool.

4 **Back Caps -** The back cap is the storage area for excess tungsten. They can come in different lengths depending on the space the torch may have to get into (eg. long, medium and short caps).

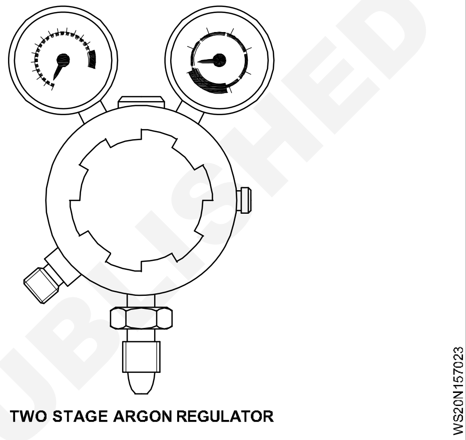
Please make sure when ordering a TIG torch to tell the supplier the amperage rating, whether water- or air-cooled, and the fitting that is to go on the end of the TIG torch lead suitable to fit the TIG power source it will be used from. This may include power cable fit up, gas fittings and control plug fittings.

Gas regulator & flowmeter

Gas regulator, flowmeter (Fig 3 & 4): The gas regulator reduces the pressure in the argon cylinder from 175 or 200 bar down to 0-3.5 bar for supply to the torch.

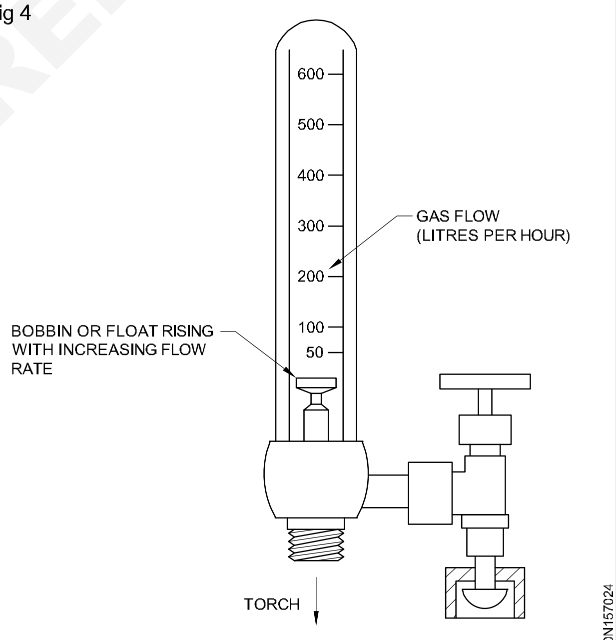
The flowmeter which has a manually operated needle valve, controls the argon flow from 0-600 litres/hour to 0-2100 litres/hour according to type.

Fig 3



TWO STAGE ARGON REGULATOR

Fig 4



ARGON FLOWMETER

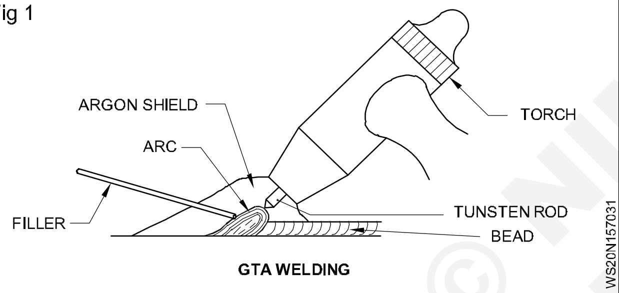
Advantages of (GTAW) Welding process

Objectives: At the end of this lesson you shall be able to
- **state the principle of GTAW process**
- **state its application and uses**
- **state the advantages and disadvantages of GTAW.**

Process description (Fig.1)

Gas Tungsten Arc Welding (GTAW), also known as tungsten inert gas (TIG) welding is a process that produces an electric arc maintained between a nonconsumable tungsten electrode and the part to be welded. The heat-affected zone, the molten metal, and the tungsten electrode are all shielded from atmospheric contamination by a blanket of inert gas fed through the GTAW torch. Inert gas (usually Argon) is inactive or deficient in active chemical properties. The shielding gas serves to blanket the weld and exclude the active properties in the surrounding air. Inert gases, such as Argon and Helium, do not chemically react or combine with other gases. They pose no odor and are transparent, permitting the the welder maximum visibility of the arc. In some instances Hydrogen gas may be added to enhance travel speeds.

Fig 1



The GTAW process can produce temperatures of up to 3000° F. The torch contributes heat only to the workpiece. If filler metal is required to make the weld, it may be added manually in the same manner as it is added in the oxyacetylene welding process, or in other situations may be added using a cold wire feeder.

GTAW is used to weld steel, stainless steel, nickel alloys, titanium, aluminum, magnesium, copper, brass, bronze, and even gold. GTAW can also weld dissimilar metals to one another such as copper to brass and stainless steel to mild steel.

Advantages of GTA welding

- Concentrated Arc - Permits pinpoint control of heat input to the workpiece resulting in a narrow heat-affected zone.
- No Slag - No requirement for flux with this process; therefore no slag to obscure the welder's vision of the molten weld pool.
- No Sparks or Spatter - No transfer of metal across the arc. No molten globules of spatter to contend with and no sparks produced if material being welded is free of contaminants.
- Little Smoke or Fumes - Compared to other arc-welding processes like stick or flux cored welding, few fumes are produced. However, the base metals being welded may contain coatings or elements such as lead, zinc, copper, and nickel that may produce hazardous fumes. Keep your head and helmet out of any fumes rising off the workpiece. Be sure that proper ventilation is supplied, especially in a confined space.
- Welds more metals and metal alloys than any other arc welding process.
- Good for welding thin material.
- Good for welding dissimilar metals together.

Disadvantages of GTA welding

- Slower travel speeds than other processes.
- Lower filler metal deposition rates.
- Hand-eye coordination is a required skill.
- Brighter UV rays than other processes.
- Equipment costs can be higher than with other processes.
- Concentrations of shielding gas may build up and displace oxygen when welding in confined areas - ventilate the area and/or use local forced ventilation at the arc to remove welding fumes and gases. If ventilation is poor, wear an approved air-supplied respirator.

Power source types AC/DC

Objectives: At the end of this lesson you shall be able to
- **state the necessity of a suitable power sources**
- **state the different types of power sources used**
- **state the application of different power sources.**

Power sources

TIG welding power sources have come a long way from the basic transformer types of power sources which were used with add-on units to enable the power source to be used as a TIG unit, eg high frequency unit and/or DC rectifying units.

The basics of TIG welding has almost remained the same, but the advent of technology TIG welding power sources have made the TIG processes more controllable and more portable.

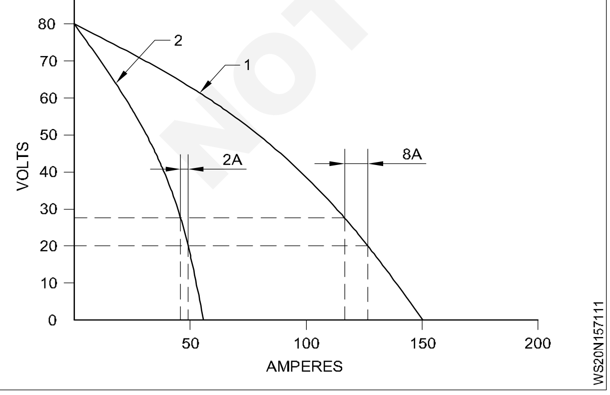
The one thing that all TIGs have in common is that they are CC (Constant Current) type power sources. This means only output adjustment will control the power source amps. The voltage will be up or down depending on the resistance of the welding arc.

Characteristerics of power fource :The output slope or voltampere curve A, a change from 20 volts to 25 volts will result in a decrease in amperage from 135 amps to 126 amps. With a change of 25 percent in voltage, only a 6.7 percent change occurs in the welding current in curve A. Thus if the welder varies the length of the arc, causing a change in voltage, there will be very little change in the current and the weld quality will be maintained. The current in this machine, even though it varies slightly is considered constant (Fig 1).

This is called drooping characteristic power source. Also called constant current (CC)power source.

This type of power source is used in SMAW & GTAW process.

Fig 1

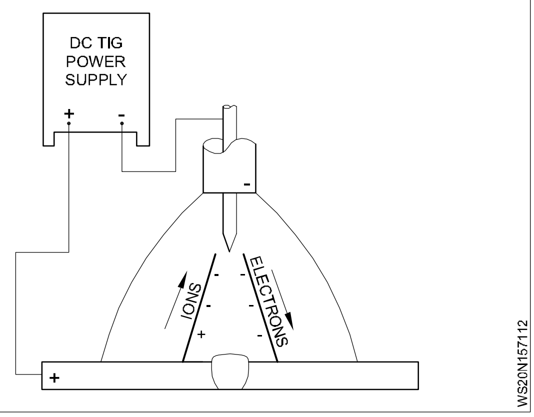


Types of welding current used for GTAW: When TIG welding, there are three choices of welding current. They are: Direct Current Straight Polarity, Direct Current Reverse Polarity, and Alternating Current with High Frequency stabilisation. Each of these has its applications, advantages, and disadvantages. A look at each type and its uses will help the operator select the best current type for the job. The type of current used will have a great effect on the penetration pattern as well as the bead configuration. The diagrams below, show arc characteristics of each current polarity type.

DCSP - Direct Current Straight Polarity (Fig 2) : (The tungsten electrode is connected to the negative terminal). This type of connection is the most widely used in the DC type welding current connections. With the tungsten being connected to the negative terminal it will only receive 30% of the welding energy (heat). This means the tungsten will run a lot cooler than DCRP. The resulting weld will have good penetration and a narrow profile.

CURRENT TYPE	DCSP
Electrode Polarity	Electrode Negative
Oxide Cleaning Action	No
Heat Balance in the Arc electrode end	70% at work end 30% at
Penetration Profile	Deep, narrow
Electrode Capacity	Excellent

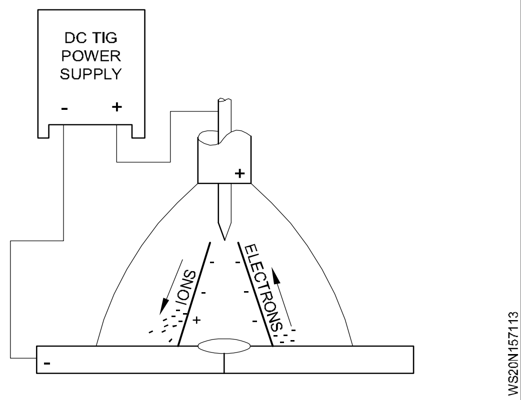
Fig 2



DCRP - Direct Current Reverse Polarity (Fig 3) : (the tungsten electrode is connected to the positive terminal). This type of connection is used very rarely because most heat is on the tungsten, thus the tungsten can easily overheat and burn away. DCRP produces a shallow, wide profile and is mainly used on very light material at low amps.

CURRENT TYPE	DCRP
Electrode Polarity	Electrode Positive
Oxide Cleaning Action	Yes
Heat Balance in the Arc	30% at work end 70% at electrode end
Penetration Profile	Shallow, wide
Electrode Capacity	Poor

Fig 3



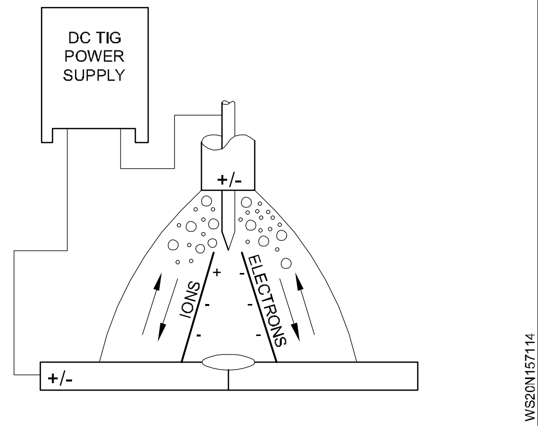
AC - Alternating Current (Fig 4) is the preferred welding current for most white metals, eg aluminium and magnesium. The heat input to the tungsten is averaged out as the AC wave passes from one side of the wave to the other.

On the half cycle, where the tungsten is positive electron welding current will flow from base material to the tungsten. This will result in the lifting of any oxide skin on the base material. This side of the wave form is called the cleaning half. As the wave moves to the point where the tungsten becomes negative the electrons (welding current) will flow from the welding tungsten to the base material. This side of the cycle is called the penetration half of the AC wave form.

Because the AC cycle passes through a zero point the arc goes out. This can be seen with fast film photography. At this point the arc would stay out if it wasn't for the introduction of HF (high frequency). High frequency has very little to do with the welding process; its job is the re-ignition of the welding current as it passes through zero. HF is also often used for starting the welding arc initially without the tungsten touching the workpiece. This helps on materials that are sensitive to impurities. HF start can also be used on DC welding current to initially start the welding current without the tungsten touching the workpiece.

CURRENT TYPE	ACHF
Electrode Polarity	Alternating
Oxide Cleaning Action	Yes (once every half cycle)
Heat Balance in the Arc	50% at work end 50% at electrode end
Penetration Profile	Medium
Electrode Capacity	Good

Fig 4



AC - Alternating Current - Square Wave (Fig 5)

With the advent of modern electricity AC welding machines can now be produced with a wave form called Square Wave. The square wave has the benefit of a lot more control and each side of the wave can be, in some cases, controlled to give a more cleaning half of the welding cycle, or more penetration.

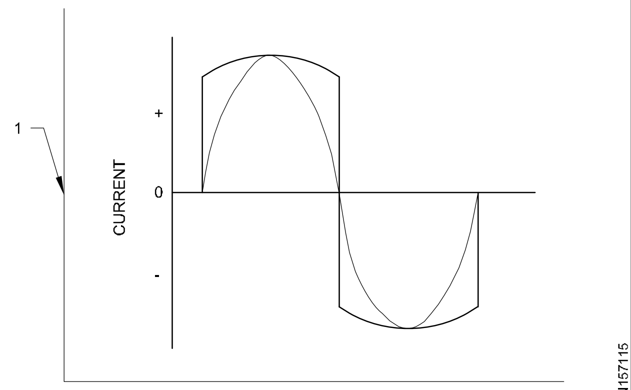
Once the welding current gets above a certain amperage (often depends on the machine) the HF can be turned off, allowing the welding to be carried on with the HF interfering with anything in the surrounding area.

Extended Balance Control (Fig 5 ,6 & 7)

AC balance control allows the operator to adjust the balance between the penetration (EN) and cleaning action (EP) portions of the cycle. Some inverters have adjustable EN as great as 30 percent to 99 percent for control and fine-tuning of the cleaning action.

For instance, if the operator sets EN at 60 percent, it means that 70 percent of the AC cycle is putting energy into the work, while 40 percent of the cycle is cleaning.

Fig 5



1. SQUAREWAVE IMPOSED OVER SINE WAVE

Pulsed TIG (Fig 8)

In this type of power source, the supply current is not constant and it is being fluctuated from low level to high level. This causes low heat input to the metal and hence distortion effect will be less.

Fig 6

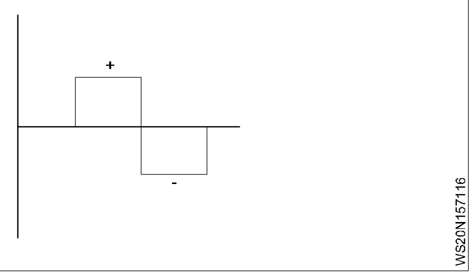
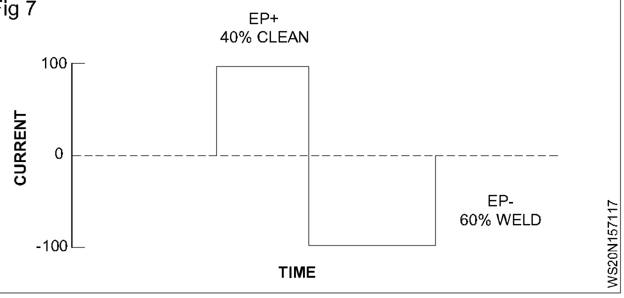


Fig 7



Pulsed TIG has the advantages of

1 better penetration with less heat

2 less distortion

3 better control when welding out of position

4 Easy to use on thin materials

The down side is - more set-up cost and more operator training.

Pulsed TIG consists of

Peak Current - This is set up higher than for non-pulsed TIG.

Background Current - This is set lower than peak current and is the bottom current the pulse will drop to, but must be enough to keep the arc alive.

Pulses Per Second - This is the number of times per second that weld current reaches peak current.

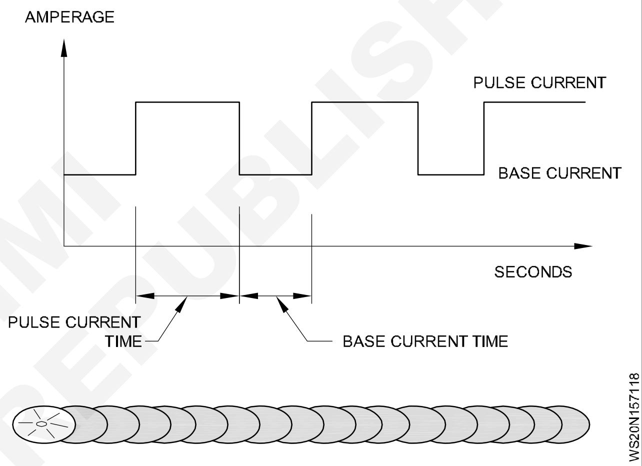
% on Time - This is the pulse peak duration as a percentage of the total time, which controls how long the peak current is on for before dropping to the background current.

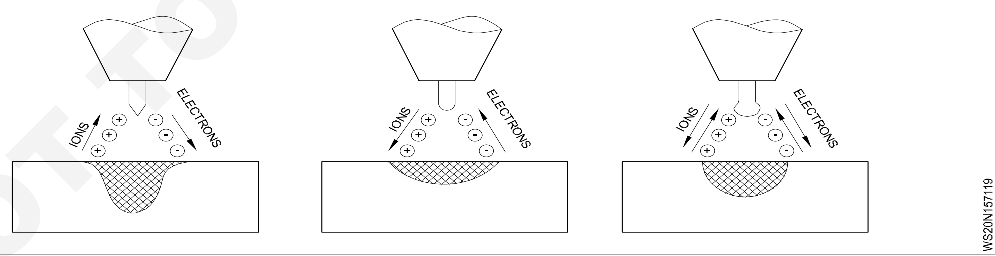
The pulse and base current periods are also controllable.

When welding is done with pulsing welding mode the weld is in principle a row of spot welds overlapping to a lerger or smaller extent depending on the welding speed.

Many double-current machines are equipped with a control function which makes it possible to modify the curve of the alternating current in balance between thew positive and the negative semi-periods.

Fig 8



Current Type	DCEN	DCEP	AC (Balanced)
Electrode Polarity	Negative	Positive	
Electron and ion flow Penetration Charateristics	Fig 9 		
Oxide Cleaning Action	No	Yes	Yes-once every Half Cycle
Heat Balance in the arc (approx.)	70% at work end 30% at electrode end	30 % at work end 70% at electrode end	50 % at work end 50 % at electrode end
Penetration	Deep Narrow	Shallow Wide	Medium
Electrode Capacity	Excellent e.g., 1/8 in. (3.2 mm) 400 A	Poor e.g. 1/4 in. (6.4 mm) 120 A	Good e.g. 1/8 in. (3.2 mm) 225 A

AC/DC welding rectifier its construction

Objectives: At the end of this lesson you shall be able to
- **types of polarity and applications.**

Constructional features of AC/DC welding rectifier: A welding rectifier set is used to convert AC welding supply into DC welding supply. It consists of a step down transformer and welding current rectifier cell with a cooling fan. (Fig, 1) The rectifier cell consists of a supporting plate made of steel or aluminium (Fig.2) which is plated with a thin layer of nickel or bismuth, sprayed with SELENIUM or SILICON. It is finally covered with an alloyed film of CADMIUM, BISMITH and TIN.

The coating of nickel or bismuth over the supporting plate serves as one electrode (ANODE) of the rectifying cell. The alloyed film (of cadmium, bismuth and tin) serves as another electrode (CATHODE) of the rectifying cell. The rectifier acts as a non-return valve and allows current to flow one side of it as it offers very little resistance and on the other side it offers very high resistance to the flow of the current. Hence the current can flow in one direction only.

Fig 1

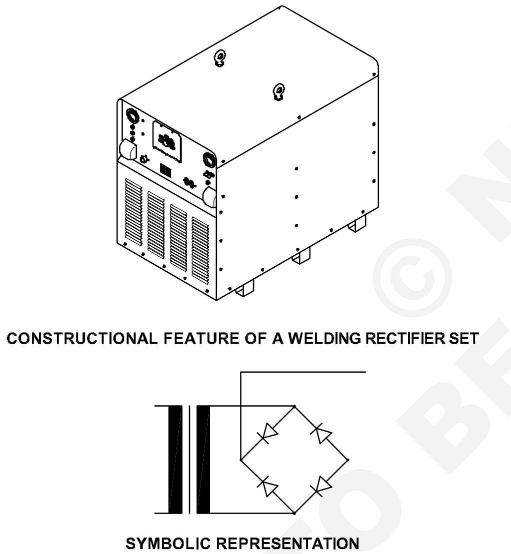
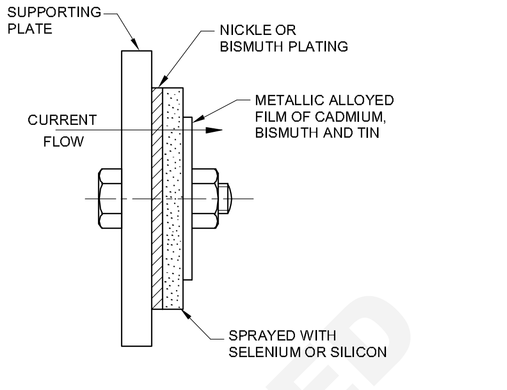


Fig 2



Working principle: The output of the step down transformer is connected to the rectifier unit, which converts AC to DC. The DC output is connected to positive and negative terminals, from where it is taken for welding purposes through welding cables. It can be designed to provide either AC or DC welding supply by operating a switch provided on the machine.

Care and maintenance of rectifier welding set

Keep all the connections in tight condition.

Lubricate the fan shaft once in 3 months.

Do not adjust the current or operate the AC/DC switch when the welding arc is 'on'.

Keep the rectifier plates clean.

Check and clean the set at least once in a month.

Keep the air ventilation system in good order.

Never run the machine without the fan.

Tungsten electrode type size and uses electrode

Objectives: At the end of this lesson you shall be able to
- **state the types of electrodes and size electrodes**
- **tungsten electrodes seuection and preparation**
- **state the colour codification.**

Electrodes for TIG welding

For TIG welding the applied electrode is mainly made of tungsten.

Pure tungsten is a very heat resistance material with a fusion point of approximately 3,380^{0}C.

By alloying tungsten with a few per cent of a metal oxide the conductivity of the electrode can be increased which has the advantage that it can thereby resist a higher current load.

The alloyed tungsten electrodes therefore have a longer lifetime and better ignition properties than electrodes of pure tungsten.

The most frequently used metal oxides used for alloying of tungsten are:

- Thorium oxide ThO_2
- Zirconium oxide ZrO_2
- Lanthanum oxide LaO_2
- Cerium oxide CeO_2

Colour indications on tungsten electrodes

As the pure tungsten electrodes and the different alloyed ones look the same, it is impossible to tell the difference between them. Therefore a standard colour indication on the electrodes has been agreed.

The electrodes are marked with a particular colour on the last 10 mm.

The most commonly used types of tungsten electrodes are:

- Pure tungsten is marked with green colour. This electrode is especially used for AC welding in aluminium and aluminium alloys.
- Tungsten with 2% thorium is marked with red colour. This electrode is mostly used for welding of non-alloyed and low-alloyed steels as well as stainless steels.
- Tungsten with 1% lanthanum is marked with black colour. This electrode is equally suited for welding of all TIG weldable metals.

Colour code and alloying elements for various tungsten electrode alloys

AWS classifications	Colour*	Alloying element	Alloying oxide	Current type
EWP	Green	Pure	-	AC/DC
EWCe-2	Orange	Cerium	CeO_2	AC/DC
EWLa-1	Black	Lanthanum	$La2O_3$	AC/DC
EWTh-1	Yellow	Thorium	ThO_2	DC
EWTh-2	Red	Thorium	ThO_2	DC
EWZr-1	Brown	Zirconium	ZrO_2	AC

- Colour may be applied in the form of bands, dots, etc, at any point on the surface of the electrode.

Electrode dimensions

Tungsten electrodes are available in different diameters from 0.5 to 8 mm. The most frequently used dimensions for TIG welding electrodes are 1.6 - 2.4 - 3.2 and 4 mm.

The diameter of the electrode is chosen on basis of the current intensity, which type of electrode that is preferred and whether it is alternating or direct current.

Grinding angle

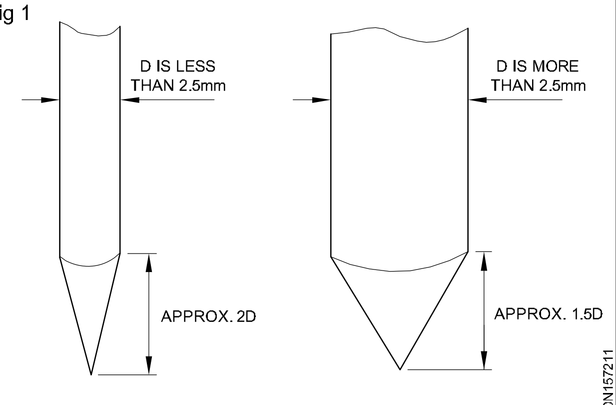
An important condition for obtaining a good result of TIG welding is that the point of the tungsten electrode must be ground correctly.

When welding is done with direct current and negative polarity, the electrode point should be conical in order to obtain a concentrated arc that will provide a narrow and deep penetration profile.

The following thumb rule indicates the relation between the diameter of the tungsten electrode and the length of its ground point.

A small pointed angle gives a narrow weld pool and the larger the pointed angle the wider the weld pool (Fig 1).

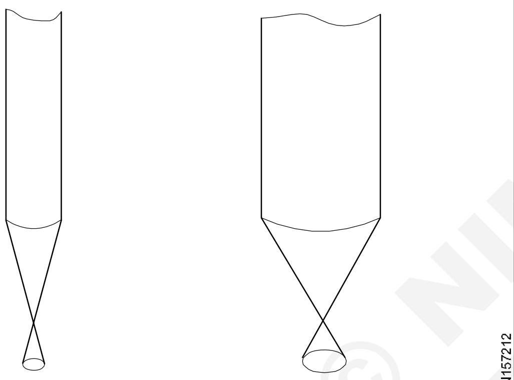
Fig 1



EXAMPLE OF GRINDING OF TUNGSTEN ELECTRODES FOR DC WELDING

The pointed angle also has an influence of the penetration depth of the weld (Fig 2).

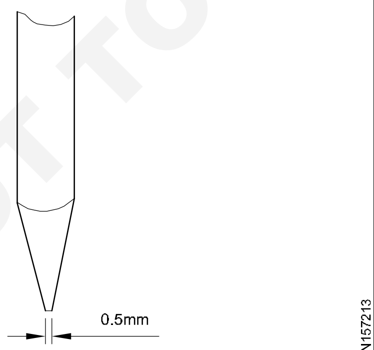
Fig 2



CONNECTION BETWEEN THE POINTED ANGLE AND THE WELD POOL

Blunting the electrode point to make a flat area with a diameter of about 0.5 mm can increase the lifetime of the tungsten electrode (Fig 3).

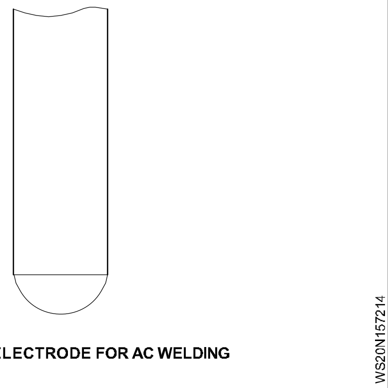
Fig 3



FLAT ELECTRODE POINT

For AC TIG welding the tungsten electrode is rounded as during the welding process it is so heavily loaded that it is melted into a half globular form (Fig 4).

Fig 4



TUNGSTEN ELECTRODE FOR AC WELDING

Grinding of the tungsten electrode

When grinding the electrode its point must point in the direction of the rotation of the grinding disc so the grinding traces will lie lengthways the electrode (Fig 5, 6, 7).

Fig 5

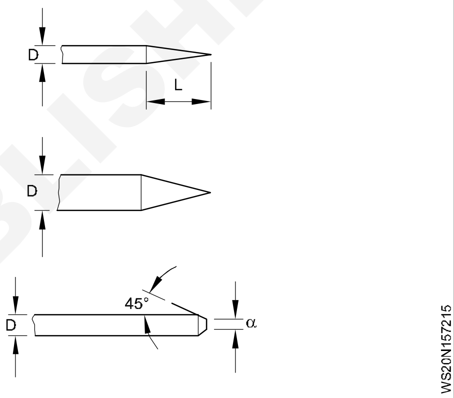
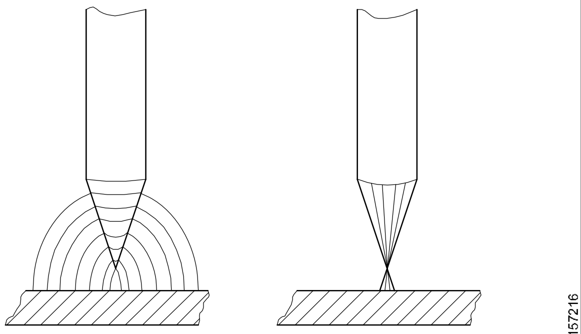
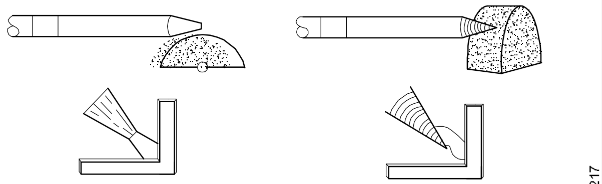


Fig 6



WRONG GRINDING RIGHT GRINDING

Fig 7

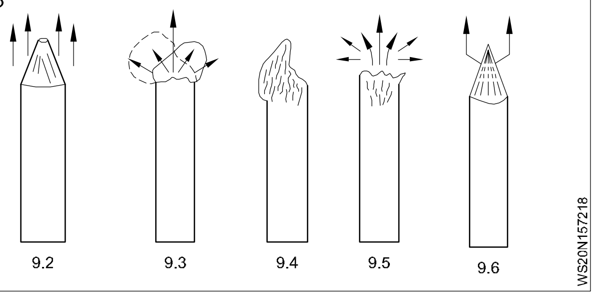


IDEAL TUNGSTEN PREPARATION STABLE ARC

WRONG TUNGSTEN PREPARATION WANDERING ARC

Electrode condition: Fig. 8 shows tungsten electrode conditions associated with TIG welding.

Fig 8



Comments

a Well sharpened and healthy electrode (color 'silver white') and used with normal current. Sharpening to a cone (without a point) allows a rapidly forming and stable arc, centered in relation to the electrode.

b The point of the electrode has melted under the action of too great a current. The point is deformed, the arc is erratic and poorly directed because the ball 'vibrates' during welding. Welding is therefore difficult, if not impossible.

c The electrode has been used without protection of argon shielding gas. The flow has been cut off too soon. The electrode has turned blue, is contaminated with oxygen and disintegrates rapidly. It is necessary to reshape it.

d This fault occurs mostly in the welding of light alloys with an electrode of thoriated tungsten and a low current. The current must be increased to form a ball shape at the electrode tip. If this is not done the arc will remain 'erratic.

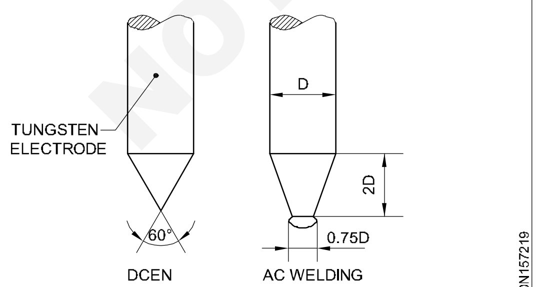
e Electrode point too sharp. Rapid wear occurs since the point carries current densities which are too high. this leads to systematic inclusions of tungsten in the weld which are highly visible on radiographics.

Tungsten selection and preparation

Base metal type	Welding current	Electrode type	Shield gas
Aluminium alloys and Magnesium alloys	AC/HF	Pure (EW-P)	Argon
		Zirconiated(EW-Zr)	Argon
Copper Alloys, Cu-Ni alloys and nickel alloys	DCSP	2% Thoriated (EW-Th2	Argon
		2% Ceriated(EW-Ce2	Argon, Helium mixture
Mild steels, Carbon steels, alloy steels and Titanium alloys	DCSP	2% Thoriated (EW-Th2)	Argon
		2% Ceriated(EW-Ce2	Argon, Helium mixture
		2% Lanthanated (EWG-Th2)	Argon

GTAW electrodes: The electrode is made of tungsten or an alloy of it and this provides easy arc starting and steady arcing. The Fig.9 show the recommended tip shape for DC EN polarity and AC polarity for TIG welding.

Fig 9



RECOMMENDED ELECTRODE TIP

The common varieties of the tungsten electrodes are

– pure tungsten

– 1% or 2% thorium oxide and tungsten

Tungsten with thorium oxide is used welding with DC. An addition of 1% or 2% thorium oxide increases the maximum current carrying capacity by approx. 45-50% for a given electrode and does not form hemispherical blobs as does the pure tungsten.

Thoriated tungsten electrodes are however preferred for DC as the arc wanders when used on AC. Red and yellow colour bands are used widely to indicate 2% and 1% alloyed thoriated tungsten electrodes. The current carrying capacity depends upon the type of shielding gas (whether argon or helium).

GTAW - types of shielding gases

Objectives: At the end of this lesson you shall be able to
- **types of properties of argon gas**
- **compare the performance characteristics of argon and helium gas for TIG welding**
- **identify an argon gas cylinder and ceramic nozzles**
- **state the uses of argon and helium gas.**

Shielding gases

Chemical activity of shielding gases: The behaviour of gases in welding is related to their chemical activity so it is convenient to group them according to this activity.

Inert gases: These are argon and helium. Other inert gases such as krypton, Radon, xenon and neon have been tried, but their low availability results in them being expensive. Also their characteristics do not, at present, give them any particular advantage.

Argon and helium are monatomic (their molecule contains only one atom) and do not react with other bodies (in the arc plasma) and hence the designation 'inert'. This precious property allows them to protect the electrode and molten metal against the atmospheric gases. However they are not suitable in every case. Pure argon for example does not allow a smooth droplet transfer when welding carbon steels. To obtain the desired transfer mode it is necessary to add a certain proportion of oxygen or carbon di oxide.

The different ionisation potential of argon and helium cause them to behave differently.

Properties of argon and helium gas

These gases are colourless, odourless.

Argon is heavier than air and helium is lighter than air.

They do not chemically react with any metals in hot or cold conditions.

They give a good shielding action for molten metal from the atmosphere.

Gases for TIG welding of aluminium

Argon gas

An argon cylinder is identified by the peacock blue colour painted on it.

Quality : Argon gas of welding quality should be used.

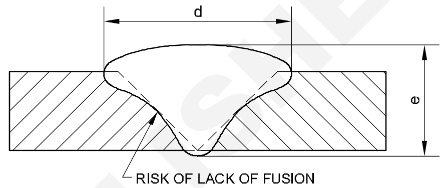
The rate of flow of argon should be adequate to obtain a clean weld. This depends on several factors such as type of parent metal, current used, shape and size of nozzle, type of joint and whether the work is done indoors or outdoors. Generally a higher rate of flow is required with higher welding currents, for outside corner joints, edge welds and work outdoors. Generally flow rates 2 to 7 litres per minute will be found sufficient to weld all thicknesses.

If tungsten inert gas welding has to be done outdoors during inclement weather, especially during period of high wind, the welding area should be effectively protected. Draughts tend to break the gas shielding, resulting in porous and oxide contaminated welds.

The penetration profile of argon shielded welds has a characteristic shape in the form of a finger.Fig.1

Helium: Helium is used mainly in TIG welding and is normally used with direct current whatever the metal being welded (light alloys, copper, etc.)

Fig 1



PROFILE TYPICAL OF ARGON SHIELDED WELD ($\frac{d}{e}$ = 2.5)

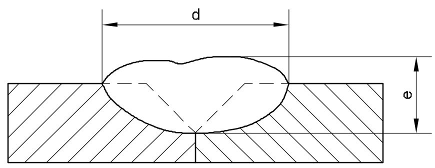
WS20N157311

The main advantages of helium shielding are:

- Increase in welding speeds
- More intense local heating, important with metals which are good conductors of heat
- Fig.2 shows the penetration, profile typical of a helium shielded weld

Argon gas gives more penetration than helium gas.

Fig 2



PROFILE TYPICAL OF HELIUM SHIELDED WELD ($\frac{d}{e}$ = 3.5)

WS20N157312

Characteristics and comparative performance of argon and helium as shielding gases

Argon

Low arc voltage : Results in less heat; thus argon is used almost exclusively for manual welding of metals less than 1.6mm thick.

Good cleaning action: Preferred for metals with refractory oxide skins, such as aluminium alloys or ferrous alloys containing a high percentage of aluminium.

Easy arc starting: Particularly important in welding of thin metal.

Arc stability is greater than with helium

Low gas volume: Being heavier than air, argon provides good coverage with low gas flows and it is less affected by air drafts than helium

Vertical and overhead welding: Sometimes preferred because of better weld puddle control but gives less coverage than helium.

Automatic welding: May cause porosity and undercutting with welding speeds of more than 60cm per min. Problem varies with different metals and thicknesses and can be corrected by changing to helium or a mixture of argon and helium.

Thick work metal: For welding metal thicker than 5mm a mixture of argon and helium may be beneficial

Welding dissimilar metals: Argon is normally superior to helium

Helium

High arc voltage: Results in a hotter arc, which is more favorable for welding thick metal (over 5mm) and metals with high heat conductivity.

Small heat affected zone: With high heat input and greater speeds, the heat affected zone can be kept narrow. This results in less distortion and often in higher mechanical properties.

High gas volume: Helium being lighter than air, gas flow is normally 1 1/2 to 3 times greater than with argon. Being lighter, helium is more sensitive to small air drafts, but it gives better coverage for overhead welding and often for vertical position welding.

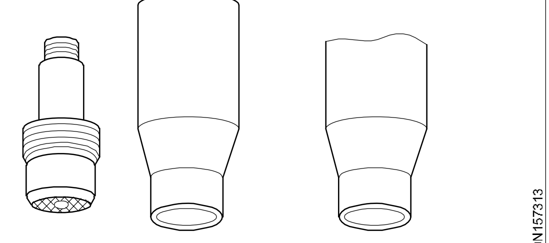
Automatic welding: With welding speeds of more than 60cm per min. welds with less porosity and undercutting may be attained (depending on work metal and thickness).

Comparision between argon and helium shielding

Argon	Helium
1 Smoother arc.	1 Smaller heat affected zone.
2 Easy starting.	2 Best for thicker metal welding due to higher arc voltage.
3 Best for thinner metal welding due to lower arc voltage.	3 Better for welding at higher speed.
4 Good cleaning action while welding Al.	4 Gives better coverage in vertical and overhead positions.
5 Heavier than air - Lower flow rates.	5 When used in back shieldings flatens the root face.
6 Lowe cost, more availability.	
7 Better for welding dissimilar metals.	
8 Better control of puddle on positional joints.	

Ceramic shields/nozzles: Gas nozzles are usually designed for installation into a particular type of torch and generally do not adapt to another make or model. They come in all sizes, shapes and materials. Gas nozzles are reasonable in cost, therefore they should be replaced when they become unusable. A nozzle which has chips or cracks or a metal build up on the outlet end should be discarded. These types of defects can alter the gas flow pattern from the nozzle and cause contamination of the weld metal. Typical nozzle configuration are shown in Fig 3.

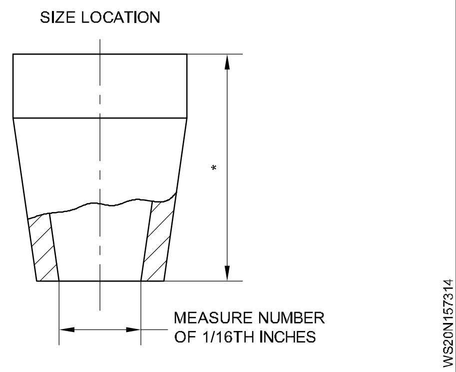
Fig 3



COMMON GAS NOZZLE AND GAS NOZZLE WITH GAS LENS

Nozzles are identified by the size of the orifice (opening) and the length of the nozzle as shown in Fig 4 Each torch manufacturer assigns part numbers to the various nozzles for individual type torches and these must be used when ordering for replacement of nozzles.

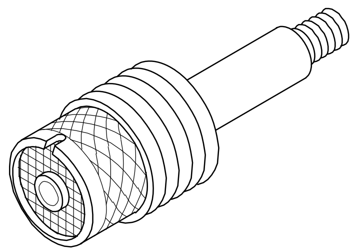
Fig 4



Size in mm	No.
5	No.3
6.3	No.4
8	No.5
10	No.6
11	No.7
12.5	No.8
14.5	No.9
16	No.10
18	No.11
20	No.12

Gas lens: The gas lens device allows the welder to use a longer electrode extension than with a standard nozzle. The device uses a series of stainless steel wire mesh screens to 'firm up' the argon gas column. This aids in maintaining a blanket of inert gas around the tungsten and over the weld area. This is very helpful when wind drafts are present, or the tungsten must be extended due to the location of the weld area. Use of the gas lens requires a special gas lens collet body and gas nozzle. A gas lens device is shown in Fig. 5 & 6.

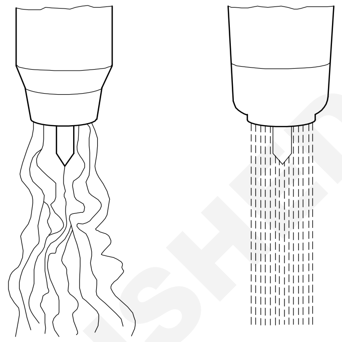
Fig 5



GAS LENS USE A STAINLESS STEEL SCREEN TO ESTABLISH A COLUMN OF SHIELDING GAS RATHER THAN A BLANKET OF GAS

WS20N157315

Fig 6



FLOW OF SHIELDING GAS

WS20N157316

Preparation for TIG welding under drift condition

Objectives: At the end of this lesson you shall be able to
- **sate cleaning and preparation of metal for welding.**

Preparation for TIG welding under drift condition

TIG welding is the preferred process for getting attractive beads that have a smooth, consistent texture. The biggest drawback to TIG welding is that there is no flux or cleaning agent involved. That means that the metal are TIG welding must be spotless before that can start welding it. Unlike other processes, you must clean the metal before TIG welding.

Clean shiny metal will take a strong bead from TIG. Drift, rusted, oily or otherwise contaminated metal won't hold a weld.

Here is a partial list of things can't in TIG weld:

Rust

- Aluminium oxide
- Mill shade
- Paint
- Grease

Drift

There are two processes are need to use: mechanical and chemical mechanical processes include grinding, filling, sanding, sandblasting and treatment that physically remove the surface of the metal. Chemical processes solvents and acids to remove paint, oil, grease and aluminium oxide.

Mechanical cleaning

The first step to prepare metal for TIG welding is mechanical cleaning. You need to remove the surface contaminants from the surface physically. Tools you can use for mechanical cleaning include wire brushes, angle grinders, sanders, and bench grinders. Each has its place, depending on the surface condition and the size and shape of the stock. Let's take a look a look at a

Chemical cleaning

Once you have removed the rust and dirt, you need to remove any grease oil, paint, or other chemicals that are left along the joint. These are all chemicals that can be ground (chemical cleaning have removed the rust and dirt that means grease, oil, paint or other chemicals) left along the joint.

Cleaning solution:

Acetone

Denatured alcohol

Citrus degreaser

Commercial cleaners

Necessity of back purging

Objectives: At the end of this lesson you shall be able to
- **advantages of back purging**
- **types of back purging gase's**
- **necessity of back purging.**

Weld purging

Weld purging is a process where oxygen is evacuated from a pipe, tank, or chamber using a noble gas such as argon or nitrogen. This process prevents oxygen from entering the weld pool, which can cause poor quality and loss of corrosion resistance.

Backing gas also known as purge gas, is provided mainly to prevent oxidation of root pass weld from inside the pipe

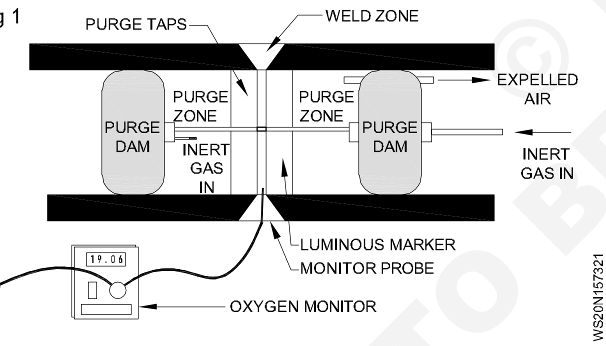
Purpose of purging;

Purging ensures that you have control over which gases are in your gas delivery system, and therefore which gases are being exposed to internal components, sensors, or other equipment. It also helps to prevent unwanted reactions from taking place, which can greatly increase the service life of related components.

Inert gases;

Unwanted gas is generally removed by flushing with an inert gas. Argon is generally used for this purpose but helium is an alternative depending on gas cost and availability. Nitrogen has been used as a purge gas but is unsuitable for some stainless steels.

Fig 1



Back purging is the act of removing all undesirable gasses and vapours from the backside of your welding surface by replacing the atmosphere with argon, leaving your weld contaminant - free making it clean, smooth & looking like the front side of the weld.

Back purging is used most when welding tube, tanks, cylinders and numerous other hollow objects. All though important for all metals it is most detrimental if you are not back purging when working with stainless steel, duplex steels, nickle, titanium and zirconium.

Back purging is Necessary

Stainless steel provides corrosion resistance and strength, making it a commonly used process in pipe applications across many industries. But when open - root pipe welding is completed with the TIG process, it typically requires a back purge with argon gas to protect the back side of the weld. Otherwise , heavy oxides can form a defect that can lead to work.

The back purge helps prevent surgaring by introducing gas to remocve contaminants, but can be time - consuming and costly --- sometimes thousands of dollars per project--- especially on larger - bore pipe welds.

Types of tubular structures used on structural fabrication

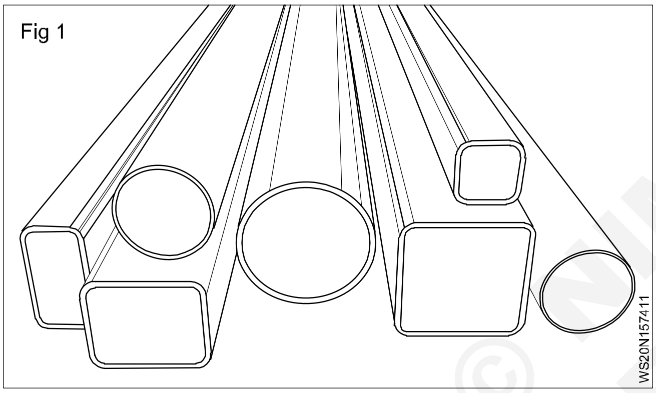
Objectives: At the end of this lesson you shall be able to
- **to know about types of tubular structures used on structural fabrication's**
- **to know about types of steel tube's**
- **to know about steel tube application's.**

Introduction

Production of tubular components was introduced in the early 1800s, and since then these components have found their applications in several industries.

Tubes can come in different shapes such a square , rectangular and cylindrical, whereas piping is always round. The circular shape of the pipe makes the pressure force evenly distributed. pipes accommodate large applications with size that range from a ½ inch to several feet.

Fig 1



Types:

The three main three types of steel tubing that are available include

1 Carbon steel tubing

2 Alloy steel tubing

3 And stainless steel tubing

Each of these types of steel tubing offers its own advantages and disadvantages

TIG welding is most commonly used to weld thin sections of alloy steel, stainless steel and nonferrous metals such as aluminium magnesium and copper alloys.

Application's:

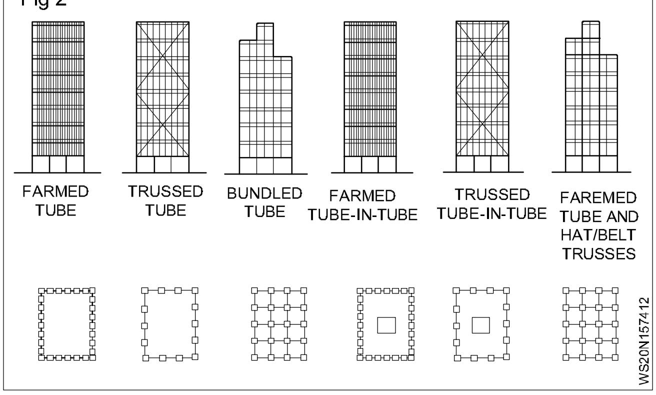
Automobile, aerospace, nuclear, oil and gas and food processing, either as a structural component or for conveying fluids in aerospace and aviation industries, tubular structure forms the core part of the aircraft which can operate flawlessly underhigh pressure and temperature. The rocket fuel tanks, webbed fuselage structures, steering columns, landing gears for an aircraft, etc., are some of the tubular components which are being used by these industries different techniques involving casting, forming and welding are used to fabricate tubes; among all, welding is the most utilized manufacturing route because of its versatility and cost - effectiveness.

Types of tubular structural system

The main types of tubular structural systems are:

1. Framed tube system
2. Trussed tube system
3. Tube in tube system
4. Bundled pipe system
5. Hybrid tube system

Fig 2



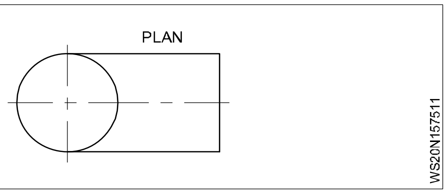
Development of templates for marking and preparation of pipe elbow, T, Y and K joints (Similar and dissimilar diameter pipe connections)

Objectives: At the end of this lesson you shall be able to
- **development of templates**
- **preparation of pipe elbow T,Y and K joint.**

Develop the pattern for a 90° elbow of equal diameter pipes by parallel line method:

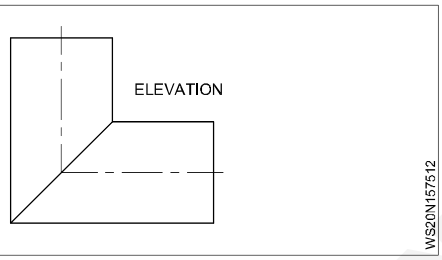
Draw plan as shown in Fig 1.

Fig 1



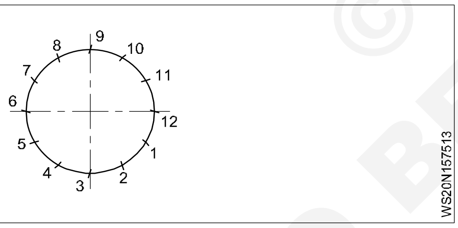
Below this, draw the front elevation as shown in Fig 2.

Fig 2



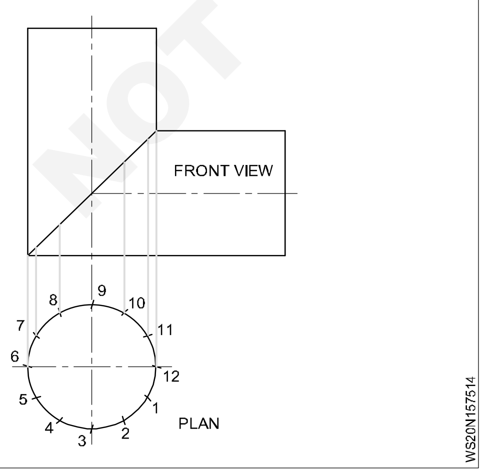
Divide the circle in the plan into twelve equal parts and number the points 0 to 12 as shown in Fig 3.

Fig 3



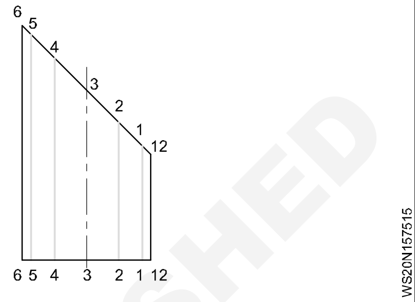
Draw the perpendicular line from these points towards the front view and number 1 to 12 as shown in Fig 4.

Fig 4



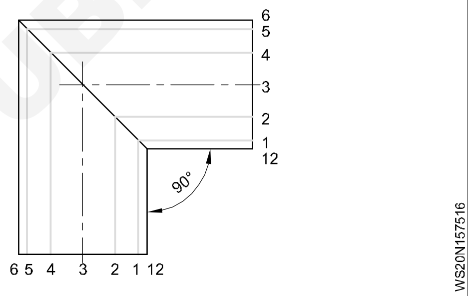
Now you find that the vertical lines are cutting at six different points top and bottom in the elevation line. Number them as shown in Fig 5.

Fig 5



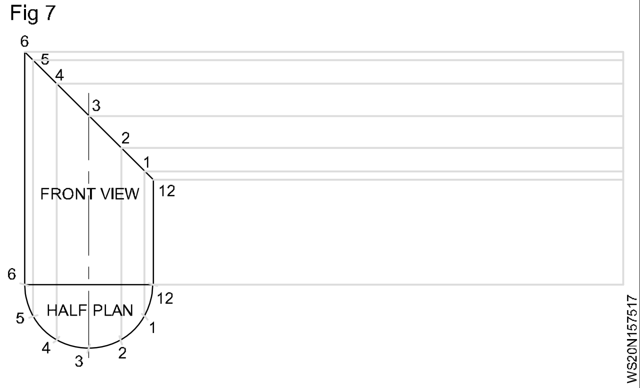
Draw horizontal parallel lines from each point and number them as shown in Fig 6.

Fig 6



Extend the front elevation base line as shown in Fig 7.

Fig 7



Take the distance equal to one division of plan and mark twelve times on base line by a compass and draw perpendicular lines from each point as shown in Fig 8.

Now you find that each horizontal line and corresponding vertical line meet at a point. Number the points as 1 to 12 as shown in Fig 9.

Fig 8

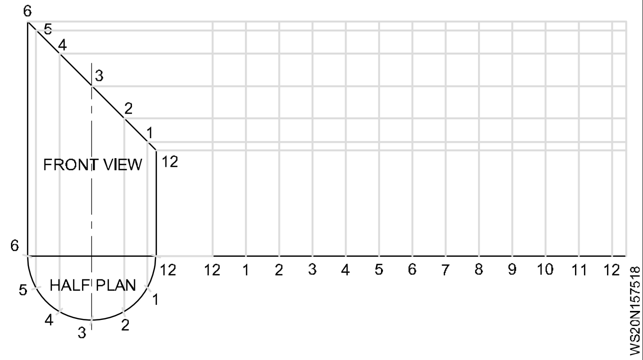
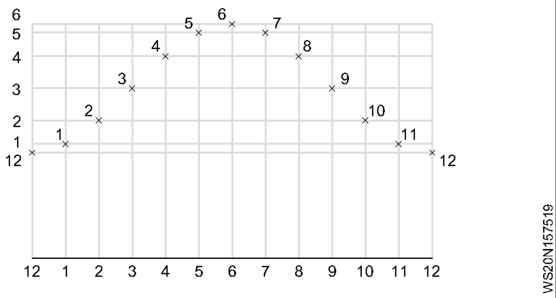
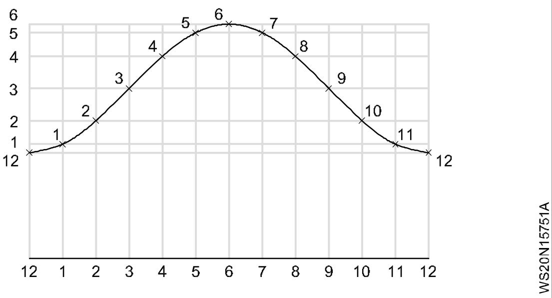


Fig 9



Join these points by free hand curve as shown in Fig 10.

Fig 10



Development of a pipe "T" joint

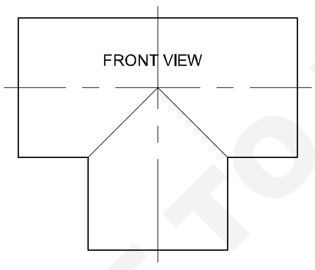
Objective: At the end of this lesson you shall be able to

- **develop and layout the pattern for 90° "T" pipe of equal diameter by parallel line method.**

Develop the pattern for a 90° "T" pipe of equal diameter by parallel line method:

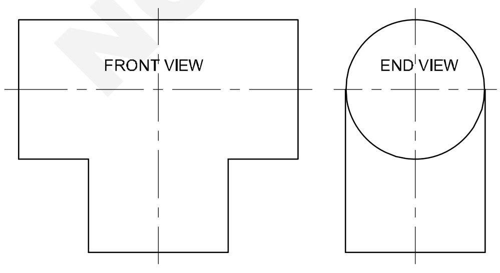
Draw the front view as shown in Fig 1.

Fig 1



Draw the side view as shown in Fig 2.

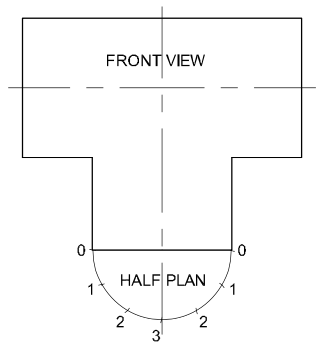
Fig 2



Draw a semi-circle on the base line of the front elevation. (Fig 3)

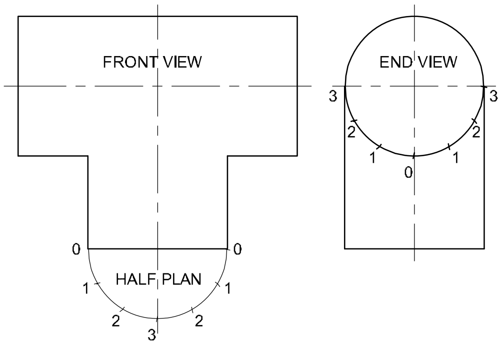
Divide the semi-circle into six equal parts and number them as 0, 1, 2, 3, 2, 1, 0. (Fig 3)

Fig 3



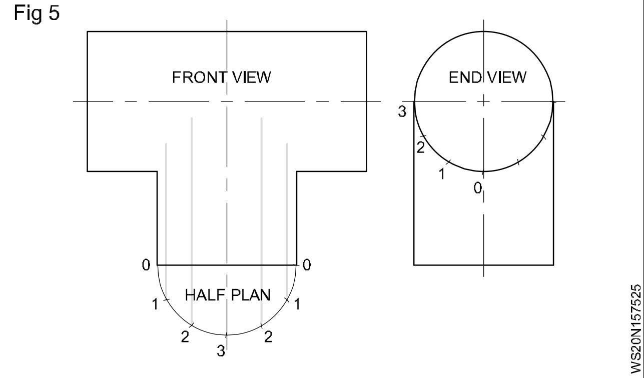
Divide a semi-circle in side view into six equal parts and number as 3, 2, 1, 0, 1, 2, 3 as shown in Fig 4.

Fig 4



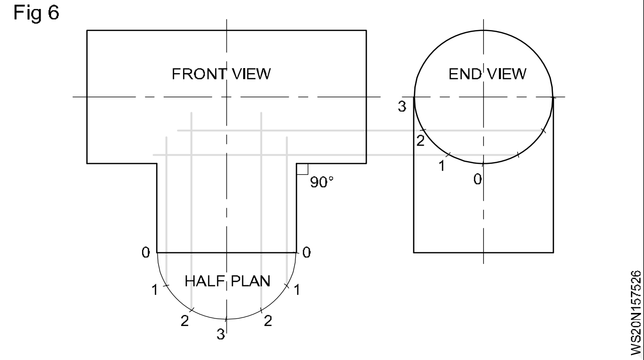
Draw the perpendicular lines from each point of the semi-circle of the view as shown in Fig 5.

Fig 5



Draw horizontal lines from the side view towards the front view as shown in Fig 6.

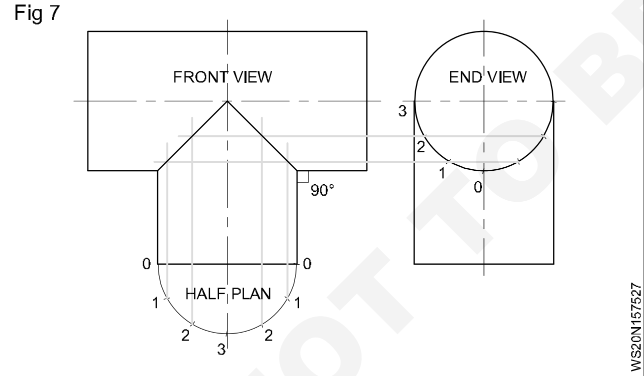
Fig 6



Now the vertical lines of the front view and the horizontal lines of side meet at their respective points.

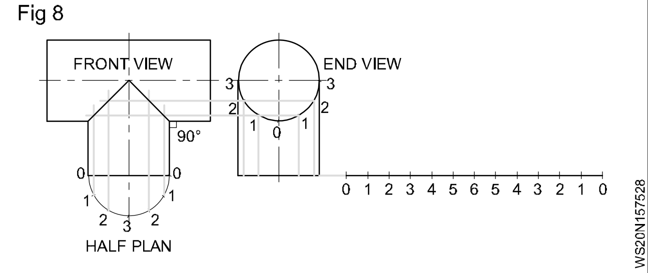
Join these points to get the line of intersection of "T" pipe as shown in Fig 7.

Fig 7



Extend the base line of the side view and mark the end point as 0. (Fig 8)

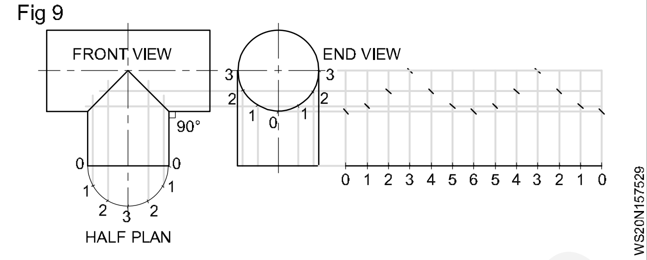
Fig 8



Take one division of the semi-circle in side view and transfer it 12 times on the base line starting from: 0: and number as 0, 1, 2, 3, 2, 1, 0, 1, 2, 3, 2, 1, 0 as shown in Fig 9.

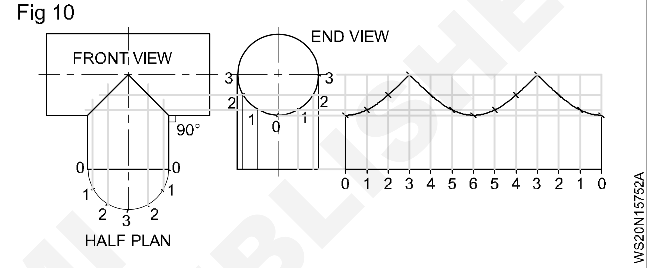
Draw perpendicular lines from these points and draw horizontal lines from the points on the line of intersection of "T". These line meet at their respective points. (Fig 9)

Fig 9



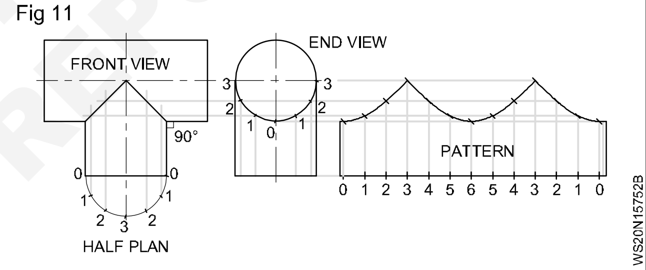
Join these points by free hand curve. (Fig 10)

Fig 10



Provide locked grooved joint allowance as shown in Fig 11.

Fig 11

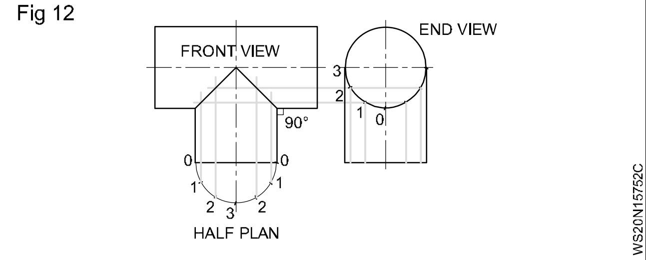


Check the pattern once again and cut. Thus you get the pattern for branch pipe.

For main pipe, develop and layout the pattern as follows:

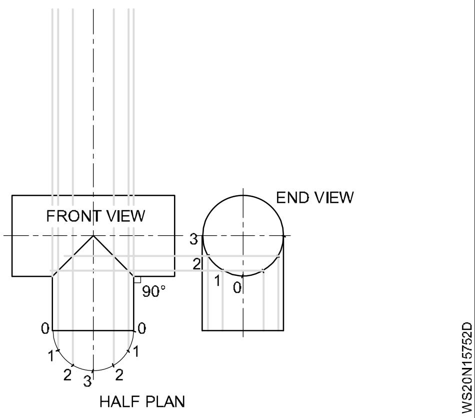
Draw the front view and end view. (Fig 12)

Fig 12



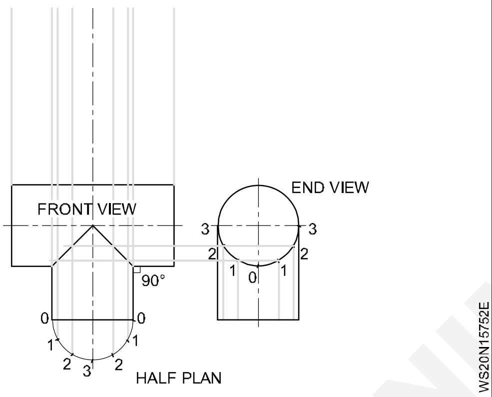
Extend the vertical lines 0, 1, 2, 3, 1, 0 of branch pipe from the front view as shown in Fig 13.

Fig 13



Extend the two extreme end vertical lines of the main pipe from the front view as shown in Fig 14.

Fig 14



On one of these lines, take point "0" as starting point and mark points 0, 1, 2, 3, 2, 1, 0, 1, 2, 3, 2, 1, 0 at equal distances equal to one division of the semi-circle and draw horizontal lines from these points. (Fig 15)

Now these horizontal lines meet the vertical lines at their respective points as shown in Fig 16.

Join these points by free hand curve and get the pattern for the main pipe. (Fig 17)

Provide the locked grooved joint allowances as shown in Fig 17.

Fig 15

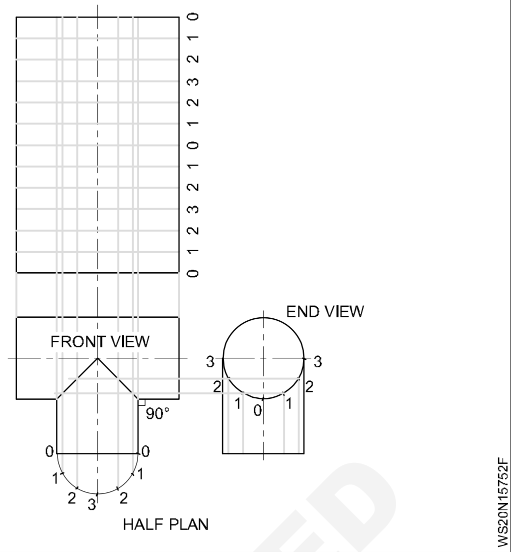


Fig 16

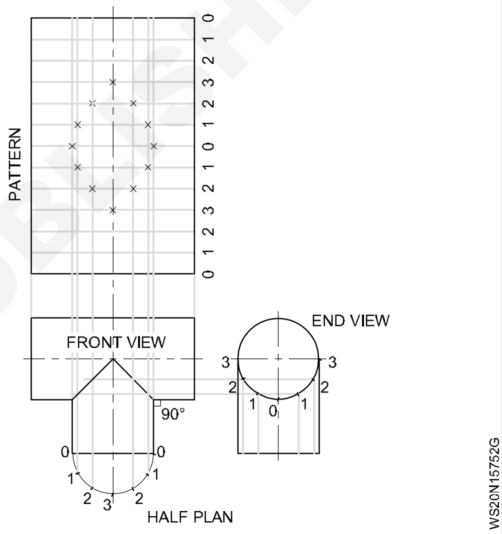
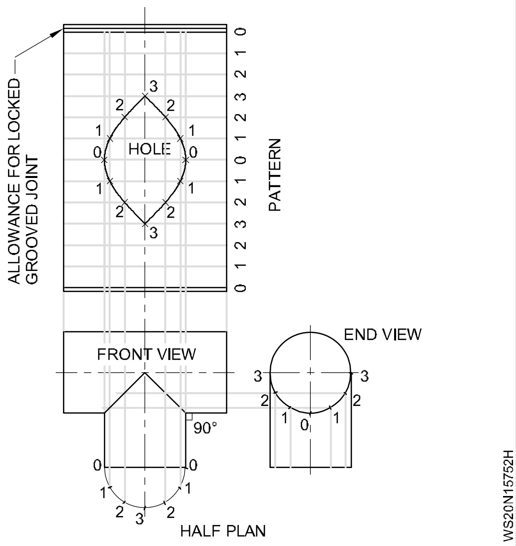


Fig 17



Pipe development for "Y" joint

Objectives: At the end of this lesson you shall be able to
- **develop and able to layout the pattern for "Y" joint pipes intersecting at 120°**
- **develop and layout the pattern for "Y" joint pipes branching at 90°.**

Development of "Y" joint pipes intersecting at 120°: Draw the development of intersecting cylinders of dia. 30 mm at 120°. (Fig 1)

All the cylindrical pipes are of same diameter and intersecting each at equal angles. Hence in this case the development of all the pipes are same and so the development of one pipe will represent other pipes.

- Draw the plan and elevation of the pipe 'A' and mark the division on the plan. (Fig 1b)
- Draw the vertical projectors from the plan to front view to meet the line of intersection.
- Draw horizontal projectors from these points on to the development.
- Mark the intersecting points and join with a smooth curve to complete the required development.

Development of 'Y' joint branching at 90°: Three cylindrical pipes of X, Y, Z form a 'Y' piece. (Fig 2) Draw the lateral surface development of each pipe.

In the three pipes XYZ, Y & Z are similar in size and shape, hence their developments are also similar.

- Draw the development of pipe 'X' as in the previous exercise.
- Draw the elevation and plan of pipe 'Y' as shown.
- Divide the plan circle into 16 equal parts.
- Project the points to the elevation.
- Draw the rectangle ABCD in which AB is equal to D.
- Draw the development of pipe Y as shown in Fig 2.

Fig 1

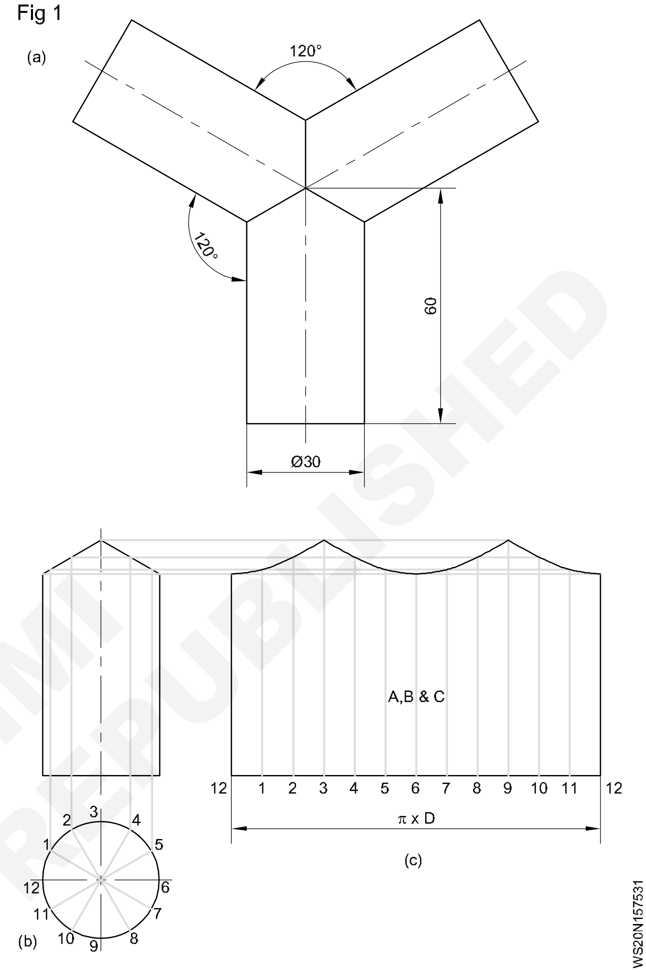
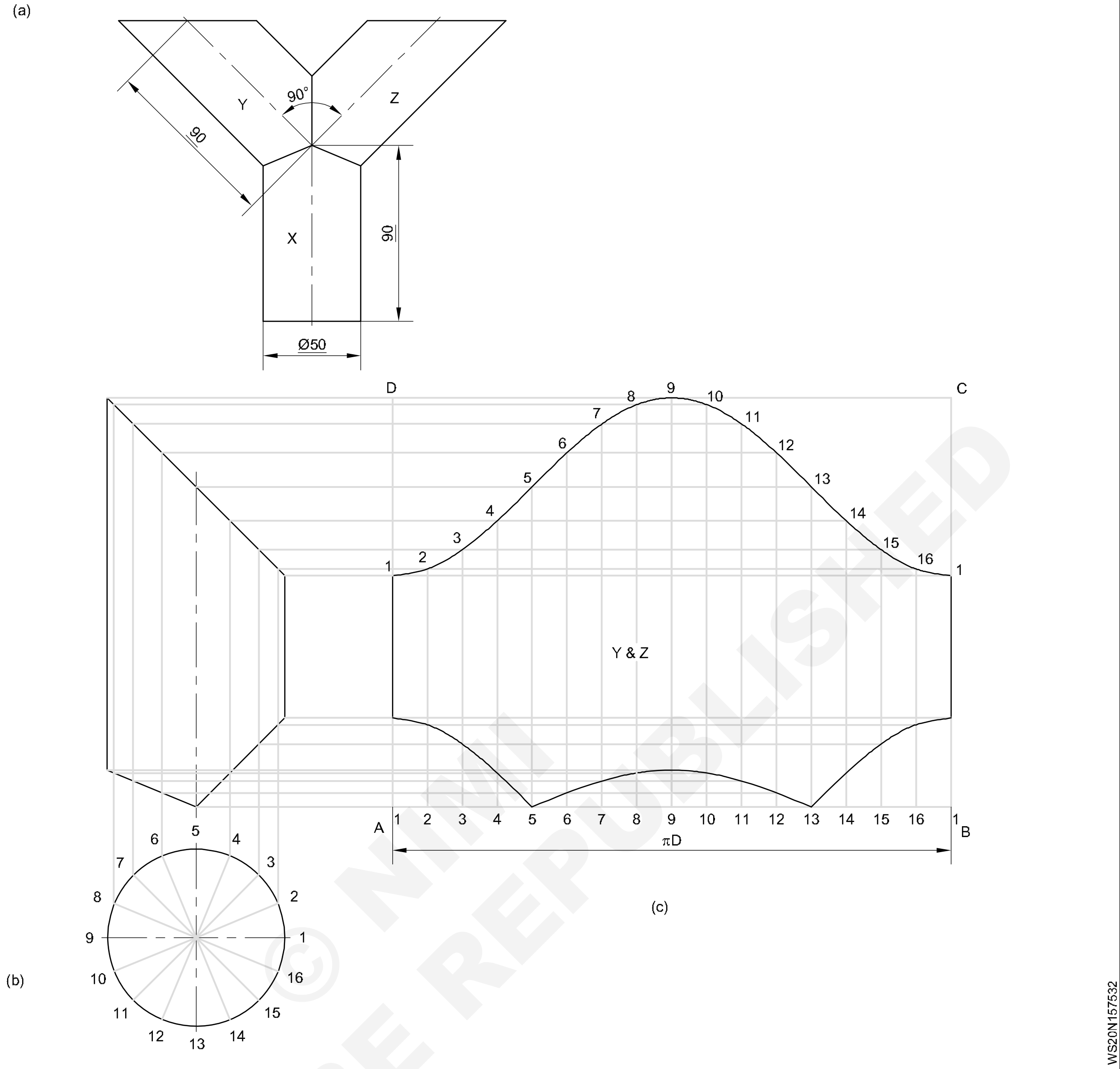


Fig 2



Development of K joint pipe

Objective: At the end of this lesson you shall be able to

- **prepare the development of pipe for k joint pipe.**

Procedure for development of 45° branch pipe: Refer Fig 1. Draw a center line AB.

Mark the points C, D, E and F taking the radius and the length of the given pipe with the center line AB as reference line.

On the line "CD" locate the position of the 45° branch pipe. This will be "G".

Draw a 45° angle at the point "G".

Choose a suitable height and mark the height of the branch pipe (GI) in 45° line from point G.

From I, draw a horizontal line on both sides (XX'). This XX' will be the base line for drawing development.

From I, plot the outside diameter of the branch pipe IJ on the line XX'.

Draw a center line for the branch pipe. This line will cut the main pipe's center line AB at K.

Join GK. Draw a perpendicular line to GK at K which meets CD at H. Join KH. Now IHKHJ will be the shape (outline) of the branch pipe.

Draw a semi-circle equal to the branch pipe outside diameter.

Divide the semi-circle into 6 equal parts as 0-1; 1-2; 2-3; 3-4; 4-5 & 5-6.

Draw vertical lines from these points 1, 2, 3, 4, 5. Already there will be two vertical lines IG from the points 6 and JH from point 0. These vertical lines will cut the branch pipe lines 'GK' and 'KH' at points 6', 5', 4', 3', 2', 1', & 0'. Note that points 6' and G as points 0' and H are the same points. In the base line XX' plot 12 points equal to the distance of '0-1' as 0, 1, 2, 3, 4, 5, 6, 5, 4, 3, 2, 1, 0.

Draw vertical lines to XX' from these 13 points.

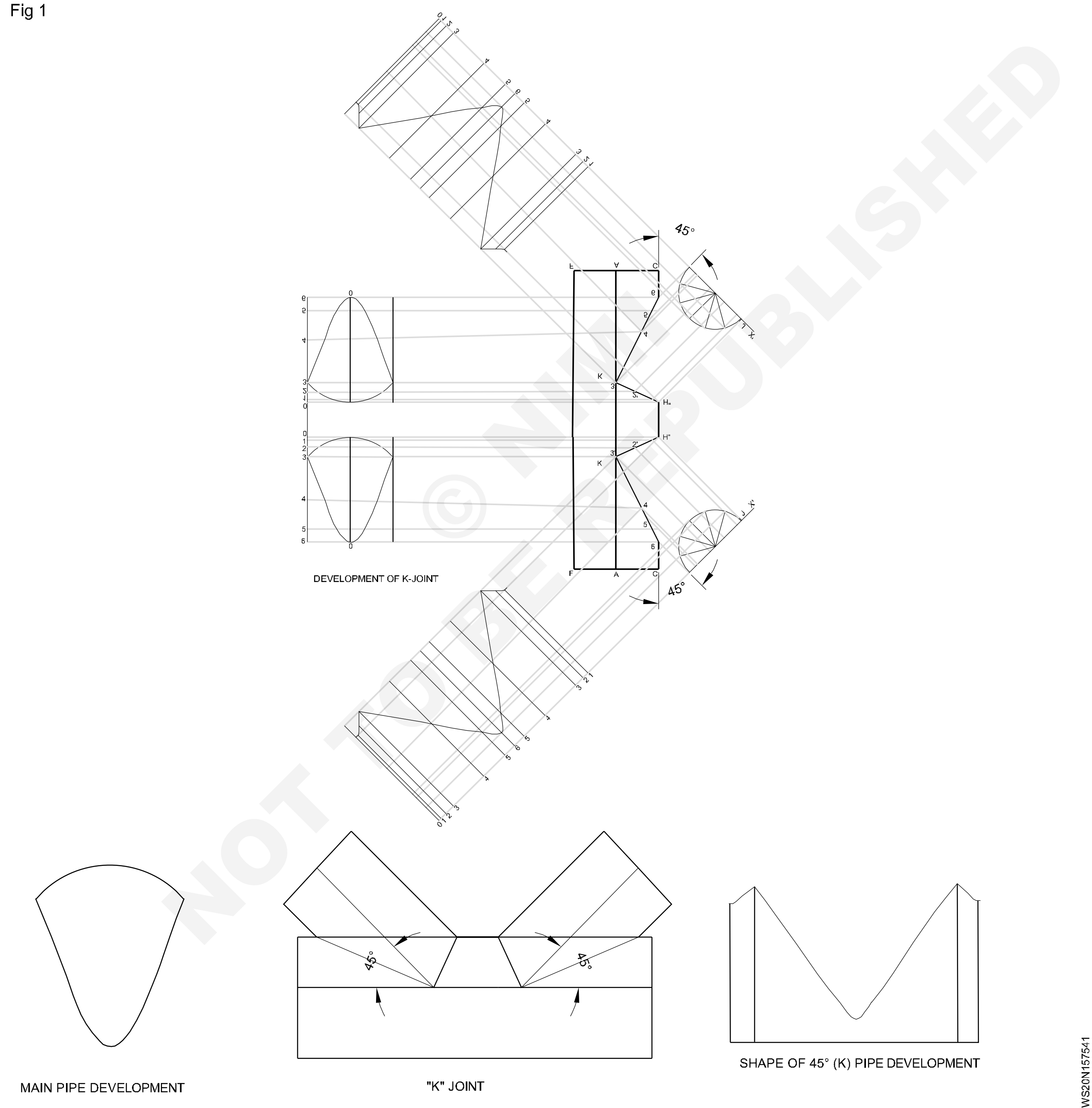
Draw horizontal lines parallel to XX' from points 6', 5', 4', 3', 2', 1', 0'. These 7 horizontal lines will cut the 13 vertical lines from the base line at 13 points.

Join the 13 cutting points with a regular smooth curve. Now the required development for the 45° branch pipe will be ready. Give allowance of 3 to 5 mm at the edges of the development. (Fig 1)

For developing a hole in the base pipe: Above the main pipe, draw 7 lines parallel to AB namely 3, 2, 1, 0, 1, 2, 3 equal to the distance of 0-1 on the semi circle.

Draw vertical lines from 0', 1', 2', 3', 4', 5', 6'. These vertical lines will intercept the 7 horizontal lines. Join the intercepting points with a smooth curve. The required development for hole is now ready.

Fig 1



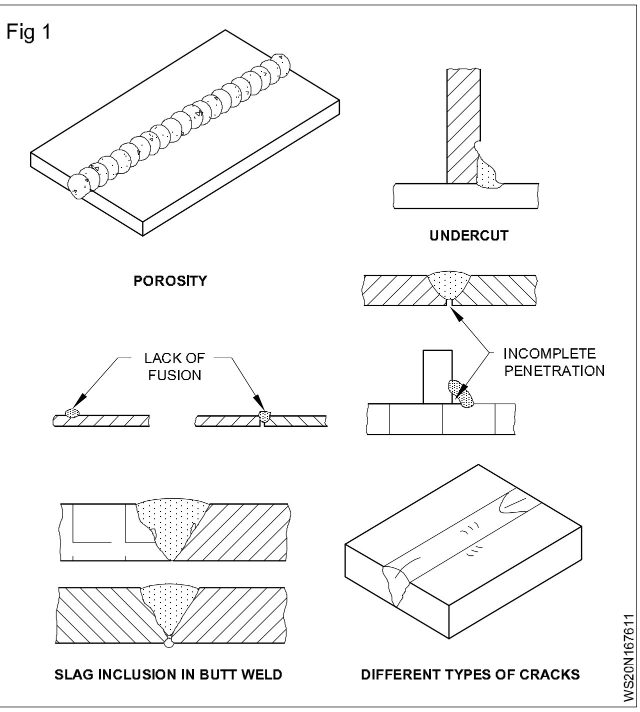
Defects causes and remedy

Objectives: At the end of this lesson you shall be able to
- **state the different type of defects in GTAW**
- **state the causes and remedies of GTAW defects.**

The following table relates to the cause and prevention of the more common defects encountered in welds made by the TIG welding process. (Fig. 1)

Defect	Appearance	Cause	Remedy
Porosity	Pin holes in the weld.	Insufficient shielding gas. Bore of gas nozzle too small arc length too long. Surplus degreasing agent.	Satisfactory supply gas. Correct ceramic shield. Remove all degreasing agents and dry. Shorten arc length.
Undercut	Irregular grooves or channels	Incorrect welding technique. Current too high. Incorrect welding speed.	Correct current. Correct rod manipulation. Clear weld surface. at the toes of the weld.
Lack on fusion. (side root or inter run)	Surface on to which weld is deposited has not been melted. Not always visible. Usually	Incorrect current level. Incorrect filler rod manipulation. Unclean plates surfaces. detected by bend test or by non-destructive techniques (e.g.ultrasonic flaw detection).	Correct current. Use correct rod manipulation. Clean plate surfaces.
Lack of Penetration	Notch or gap at the root of a weld.	Incorrect preparation and set up. Incorrect current level. Welding speed too fast.	Use the correct preparation and set up. Correct current. Correct weld speed.
Inclusions	Usually internally and only detected by suitable testing techniques. Normally oxide or tungsten inclusions.	Oxide inclusions. Inadequate cleaning of parent material before welding. Contamination onsurface of filler rod. Inadequate protection of underside of a weld.Loss of gas shield.	Clean all metal surfaces. Ensure a satisfactory supply of shielding gas. Excluide draughts.
Cracking	Cracks can occur in the weld metals and in the parent metal alongside the weld. They may not be visible on the surface and may only be detected by the use of suitable testing techniques.	The type of crack and therefore its cause will depend on the material being welded. The correct diagnosis of the cause of a crack frequently calls for expert knowledge.	Use correct welding procedure. Pre-heating and post heat treatm-ent. Use correct preparation Set up current. Use correct filler rod. Always adhere strictly to the procedure specified when welding materials that are susceptible to cracking. Always ensure the correct type of filler is used and the correct amount of filler metal is added.

Fig 1



UNDERCUT
POROSITY
LACK OF FUSION
INCOMPLETE PENETRATION
SLAG INCLUSION IN BUTT WELD
DIFFERENT TYPES OF CRACKS
WS20N167611

Procedure of rectifying, weld defects - Gouging methods , grinding, testingwith die penetrant, preheating and re welding

Objectives: At the end of this lesson you shall be able to
- **name different weld defects in arc welded joints**
- **define weld defect**
- **state the effect of defects on the welded joints**
- **differentiate between external and internal defects.**

Introduction: The strength of a welded joint should be more than or equal to the strength of the base metal. If any weld defect is in a welded joint, then the joint becomes weaker than the base metal. This is not acceptable.

So a strong or good weld should have uniformly rippled surface, even contour, bead width, good penetration and should not have defect.

Definition of a weld defect/fault: A defect or fault is one which does not allow the finished joint to withstand or carry the required load.

Effects of weld defect/fault: Always a defective welded joint will have the following bad effects.

- The effective thickness of the base metal is reduced.
- The strength of the weld is reduced
- The effective throat thickness is reduced
- The joint will break, when loaded, causing accident.
- The properties of base metal will change.
- More electrodes are required which will also increase the cost of welding.
- Waste of labour and materials.
- The weld appearance will be poor.

Since the weld defects will give bad effects on the joint, always proper care and action has to be taken before and during welding to avoid/prevent the defects. If the defects have already taken place then proper action has to be taken to correct/rectify the defect after welding.

The action/measure taken to avoid/prevent and correct/rectify a weld defect is also called as a remedy.

So some remedies may help to avoid/prevent a weld defect and some remedies may help to correct/rectify a weld defect which has already taken place.

Weld defect may be considered under two heads.

- External defects
- Internal defects

The defects which can be seen with bare eyes or with a lens on the top of the weld bed, or on the base metal surface or on the root side of the joint are called external defects.

Those defects, which are hidden inside the weld bead or inside the base metal surface and which cannot be seen with bare eyes or lens are called internal defects.

Some of the weld defects are external defects, some are internal defects and some defects like crack, blow hole and porosity, slag inclusion, lack of root penetration in fillet joints, etc. will occur both as external and internal defects.

External defects

1 Undercut
2 Cracks
3 Blow hole and porosity
4 Slag inclusions
5 Edge plate melted off
6 Excessive convexity/Oversized weld/Excessive reinforcement
7 Excessive concavity/insufficient throat thickness/ insufficient fill
8 Incomplete root penetration/lack of penetration
9 Excessive root penetration
10 Overlap
11 Mismatch
12 Uneven/irregular bead appearance
13 Spatters

Internal defects

1 Cracks
2 Blow hole and porosity
3 Slag inclusions
4 Lack of fusion
5 Lack of root penetration
6 Internal stresses or locked-up stresses or restrained joint.

Defects in arc Welding - Definition, Causes and Remedies

Objectives: At the end of this lesson you shall be able to
- **define common weld defects in arc welded joints**
- **describe the causes, remedies and corrections of weld defects.**

A sound or good weld will have uniformly rippled surface, even contour, bead width, good penetration and no defects.

Definition of a defect: A defect is one which does not allow the finished joint to withstand the required strength (load).

Causes for weld defects means wrong actions taken which creates the defect.

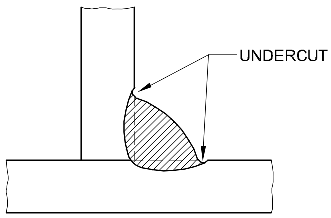
A remedy can be

a Preventing the defect by taking proper actions before and during welding.

b Taking some corrective actions after welding to rectify a defect which has already taken place.

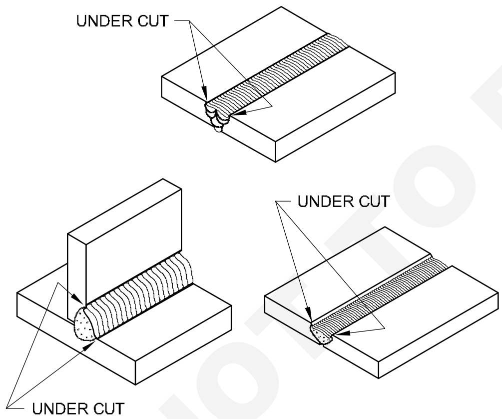
Undercut: A grooved or channel formed in the parent metal at the toe of the weld. (Figs 1, 2 & 3)

Fig 1



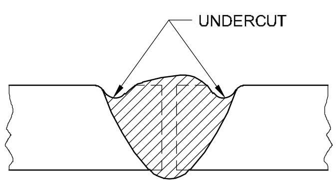
TEE-JOINT FILLET WELD

Fig 2



A SCHEMATIC DIAGRAM OF UNDERCUTS IN FILLET AND BUTT WELDS.

Fig 3



SQUARE-BUTT WELD

Causes

- Current too high
- Use of a very short arc length
- Welding speed too fast
- Overheating of job due continuous welding
- Faulty electrode manipulation
- Wrong electrode angle

Remedies

a Preventive action

Ensure

- proper current is set
- correct welding speed is used
- correct arc length is used
- correct manipulation of electrode is followed

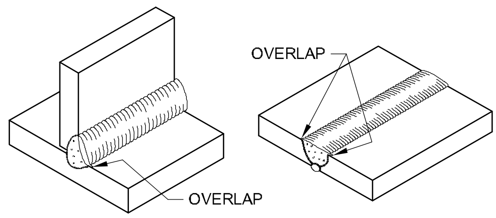
b Corrective action

- deposit a thin stringer bead at the top of the weld using a 2mm ø electrode to fill up the undercut.

Overlap

An overlap occurs when the molten metal from the electrode flows over the parent metal surface without fusing into it. (Fig 4)

Fig 4



SCHEMATIC DIAGRAM OF OVERLAP IN FILLET AND BUTT WELDS

Causes

- Low current.
- Slow arc travel speed.
- Long arc.
- Too large a diameter electrode.
- Use of wrist movement for electrode weaving instead of arm movement.

Remedies

a Preventive actions

- Correct current setting.
- Correct arc travel speed.

- Correct arc length.
- Correct diameter electrode as per metal thickness.
- Proper manipulation of electrode.

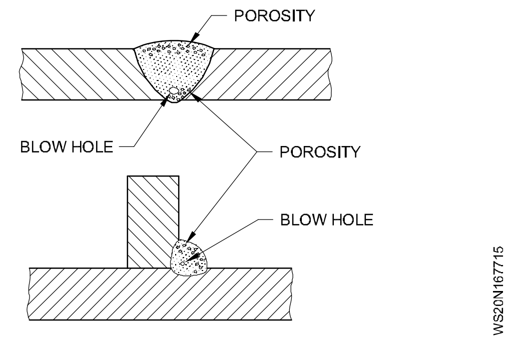
b Corrective actions

- Remove the overlap by grinding without an undercut.

Blowhole and porosity

Blow hole or gas pocket is a large diameter hole inside a bead or on the surface of the weld caused by gas entrapment. Porosity is a group of fine holes on the surface of the weld caused by gas entrapment. (Fig 5)

Fig 5



Causes

Presence of contaminants/impurities on the job surface or on electrode flux, presence of high sulphur in the job or electrode materials. Trapped moisture between joining surfaces. Fast freezing of weld metal. Improper cleaning of the edges.

Remedies

a Preventive actions

- Remove oil, grease, rust, paint, moisture, etc. from the surface. Use fresh and dried electrodes. Use good flux-coated electrodes. Avoid long arcs.

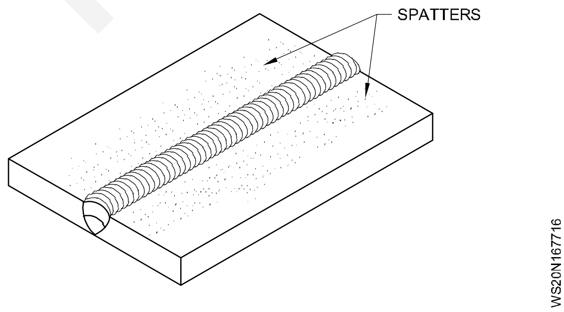
b Corrective action

- If the blowhole or porosity is inside the weld then gouge the area and re-weld. If it is on the surface then grind it and re-weld.

Spatter

Small metal particles which are thrown out of the arc during welding along the weld and adhering to the base metal surface. (Fig 6)

Fig 6



Causes

Welding current too high. Wrong polarity (in DC). Use of long arc. Arc blow. Uneven flux coated electrode.

Remedies

a Preventive actions

- Use correct current.
- Use correct polarity (DC).
- Use correct arc length.
- Use good flux-coated electrode.

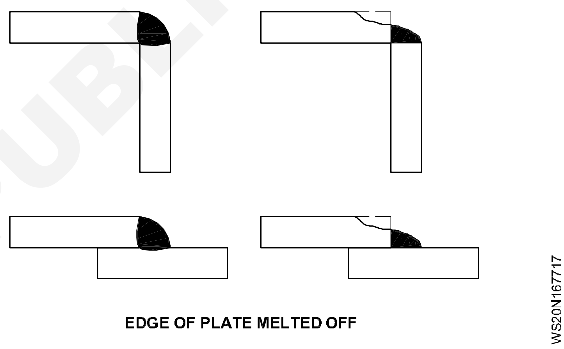
b Corrective actions

- Remove the spatters using a chipping hammer and wire brush.

Edge of plate melted off

Edge of plate melted off defect takes place in lap and corner joints only. If there is excess melting of one of the plate edges resulting in insufficient throat thickness then it is called edge of plate melted off defect. (Fig 7)

Fig 7



Causes

- Use of oversize electrode.
- Use of excessive current.
- Wrong manipulation of the electrode i.e. excessive weaving of electrode.

Remedies

a Preventive action

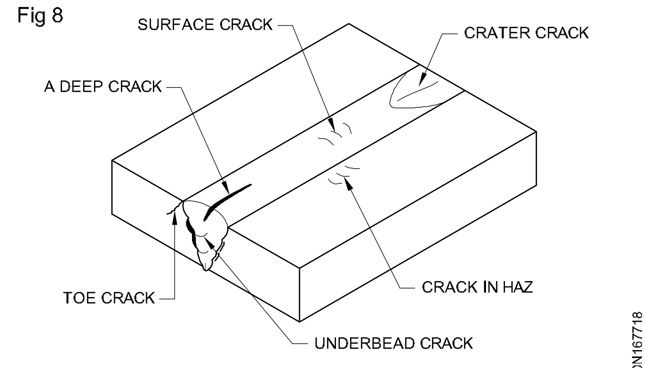
- Select correct size electrode.
- Set correct current.
- Ensure correct manipulation of electrode.

b Corrective action

- Deposit additional weld metal to increase throat thickness.

Crack

A hairline separation exhibits in the root or middle or surface and inside of the weld metal or parent metal. (Fig 8)



DIFFERENT TYPES OF CRACKS

Causes

- Wrong selection of electrode.
- Presence of localized stress.
- A restrained joint.
- Fast cooling.
- Improper welding techniques/sequence.
- Poor ductility.
- Absence of preheating and post-heating of the joint.
- Excessive sulphur in base metal.

Remedies

a Preventive actions

- Preheating and post-heating to be done on copper, cast iron, medium and high carbon steels.
- Select low hydrogen electrode.
- Cool slowly.
- Use fewer passes.
- Use proper welding technique/sequence.

Cracks

b Corrective actions

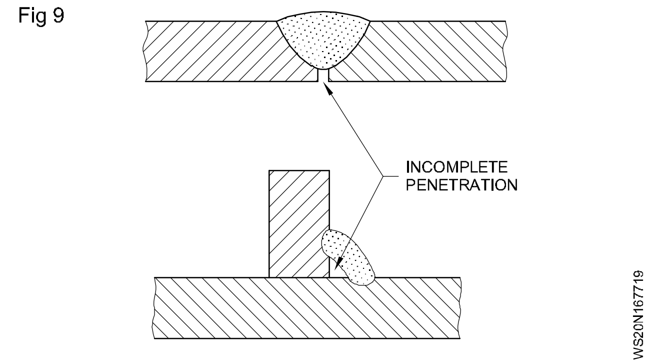
- For all external cracks to a smaller depth, take a V groove using a diamond point chisel upto the depth of the crack and re-weld (with preheating if necessary) using low hydrogen electrode. Cool the job slowly.
- For internal/hidden cracks gouge upto the depth of the cracks and re-weld (with preheating if necessary) using low hydrogen electrode. Cool the job slowly.

Incomplete penetration

Failure of weld metal to reach and fuse the root of the joint. (Fig 9)

Causes

- Edge preparation too narrow - less bevel angle.
- Welding speed too much.



- Key-hole not maintained during welding the root run of a grooved joint.
- Less current.
- Use of larger dia. electrode.
- Inadequate cleaning or gouging before depositing sealing run.
- Wrong angle of electrode.
- Insufficient root gap.

Remedies

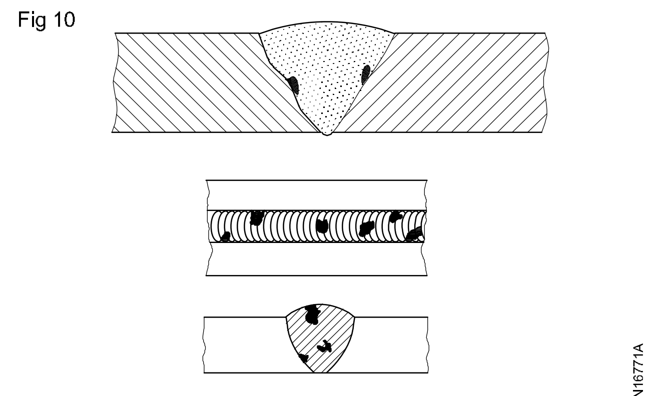
a Preventive actions

- Correct edge preparation is required.
- Ensure correct angle of bevel and required root gap.
- Use correct size of electrode.
- Correct welding speed is required.
- Maintain a keyhole throughout the root run.
- Correct current setting is required.

b Corrective actions

- For butt welds and open corner welds gouge the root of the joint and deposit the root run from the bottom side of the joint. For a Tee & lap fillet welds blow off the full weld deposit and reweld the joint.

Slag inclusion: Slag or other non-metallic foreign materials entrapped in a weld. (Fig 10)



SLAG INCLUSION IN BUTT WELD

Causes

- Incorrect edge preparation.
- Use of damaged flux coated electrode due to long storage.
- Excessive current.
- Long arc length.
- Improper welding technique.
- Inadequate cleaning of each run in multi-run welding.

Remedies

a Preventive actions

- Use correct joint preparation.
- Use correct type of flux coated electrode.
- Use correct arc length.
- Use correct welding technique.
- Ensure thorough cleaning of each run in multi-run welding.

b Corrective actions

- For external/surface slag inclusion remove them using a diamond point chisel or by grinding and re-weld that area. For internal slag inclusions use gouging upto the depth of the defect and re-weld.

Excessive convexity (Fig 11)

This defect is also called as oversize weld or excessive reinforcement. It is the extra weld metal deposited in the final layer/covering run.

Excessive concavity/insufficient throat thickness

If the weld metal deposited into a butt or fillet weld is below the line joining the toes of the weld then this defect is called excessive concavity or insufficient throat thickness. (Fig 12)

Causes

- Incorrect bead profile due to improper weaving of electrode.

Fig 11

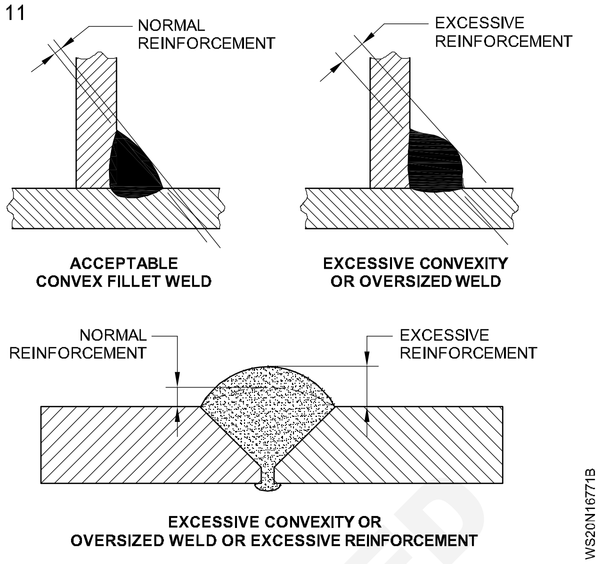
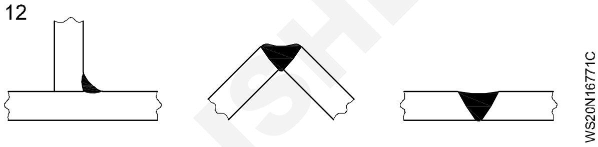


Fig 12



- Use of small dia. electrode.
- Excessive speed of welding.
- Wrong welding sequence when using stringer beads to fill the groove.
- Sagging of weld metal is not controlled in horizontal position.
- Electrode movement is not uniform.
- Improper electrode angle between the plate surfaces.

Remedies

- Lack of fusion.
- Mismatch.
- Uneven/irregular bead appearance.
- Excessive root penetration.

Introduction to GMAW

Objectives: At the end of this lesson you shall be able to
- **priciple of GMAW welding**
- **other names of GMAW welding.**

Introduction to CO_2 welding: Fusion welding of metal plates and sheets is the best method of joining metals because in this process the welded joint will possess the same properties and strength as the base metal.

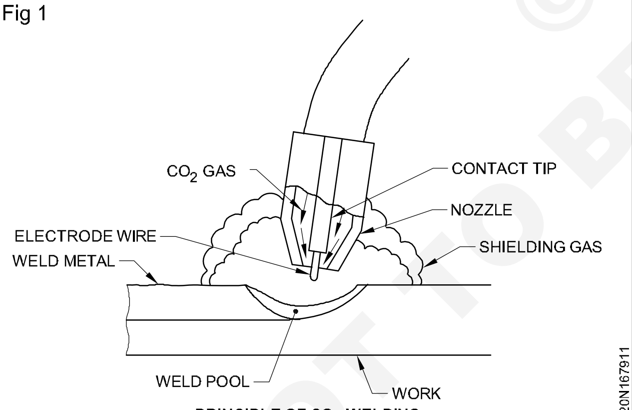
Without a perfectly shielded arc and molten puddle, the atmospheric oxygen and nitrogen will get absorbed by the molten metal. This will result in weak and porous welds.

In shielded metal arc welding (SMAW) the arc and molten metal are protected/shielded by the gases produced by the burning of the flux coated on the electrode.

The above mentioned shielding action can be done by passing an inert gas such as argon, helium, carbon-di-oxide through the welding torch/gun. The arc is produced between the base metal and a bare wire consumable electrode fed continously through the torch.

Principle of GMA welding: In this welding process, an arc is struck between a continuously fed consumable bare wire electrode and the base metal. The heated base metal, the molten filler metal and the arc are shielded by the flow of inert/noninert gas passing through the welding torch/gun. (Fig 1)

Fig 1



PRINCIPLE OF CO_2 WELDING

If an inert gas is used to protect the arc produced by a consumable metal electrode, this process is called Metal Inert Gas Welding (MIG).

When carbon-dioxide is used for shielding purposes, it is not fully inert and it partly becomes an active gas. So CO_2 welding is also called as Metal Active Gas (MAG) welding.

MIG/MAG welding is a name with respect to gas used for shields purpose

On the other hand Gas Metal Arc Welding is the common name.

Basic equipment for a typical GMAW semiautomatic setup: (Fig 2)

- Welding Power Source - provides welding power.
- Wire Feeders - controls supply of wire to welding gun.
- Supply of Electrode Wire.
- Welding Gun - delivers electrode wire and shielding gas to the weld puddle.
- Shielding Gas Cylinder - provides a supply of shielding gas to the arc.

Other names

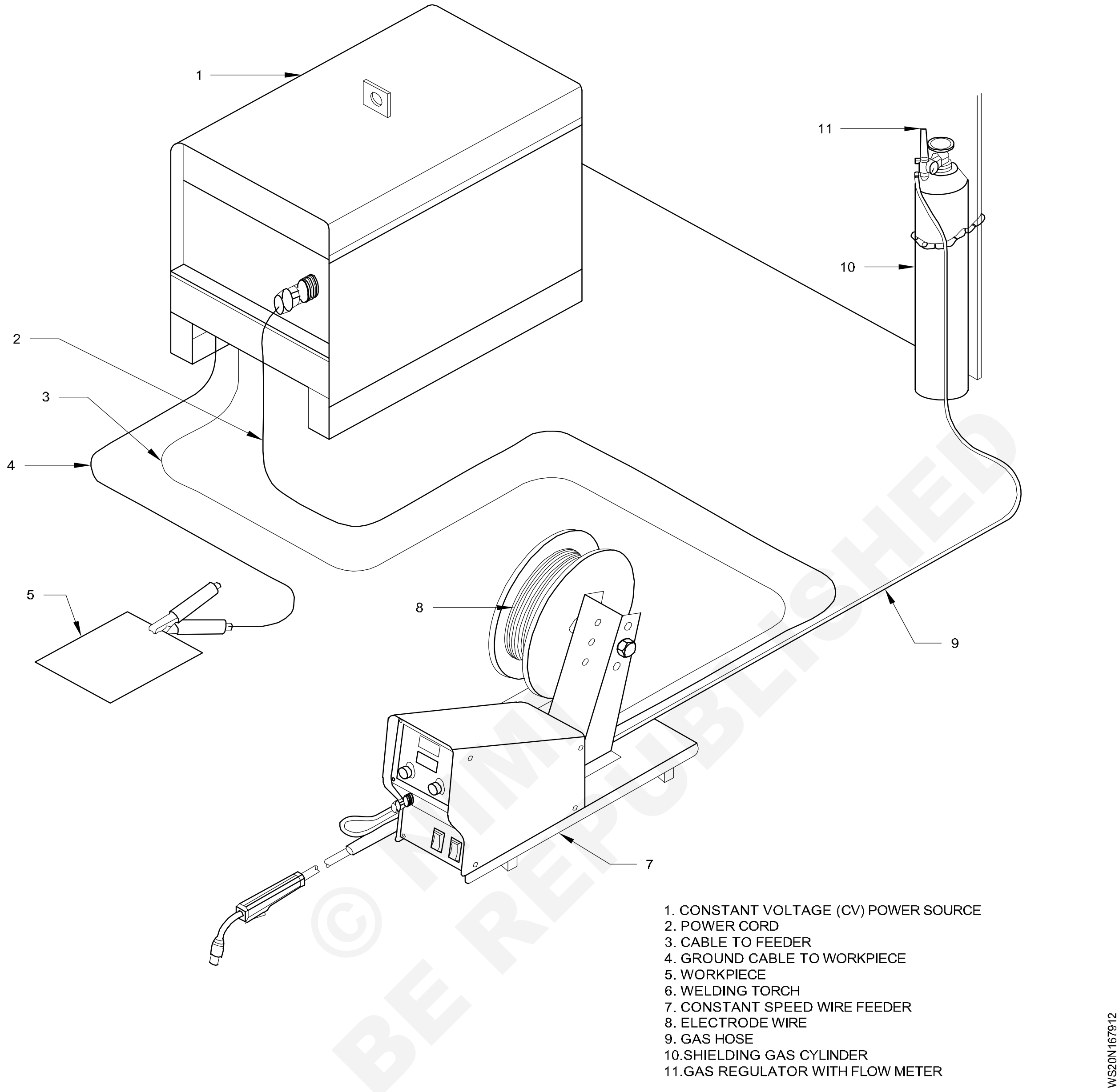
- MIG (Metal Insert Gas) welding,
- MAG (Metal Active Gas)/CO_2 Welding
- GMAW (Gas Metal Arc Welding)

GMAW can be done in three different ways:

- **Semiautomatic welding** - equipment controls only the electrode wire feeding. Movement of welding gun is controlled by hand. This may be called hand-held welding.
- **Machine welding -** uses a gun that is connected to a manipulator of some kind (not hand-held). An operator has to constantly set and adjust controls that move the manipulator.
- **Automatic welding -** uses equipment which welds without the constant adjusting of controls by a welder or operator.

  On some equipment, automatic sensing devices control the correct gun alignment in a weld joint.

Fig 2



Flux Cored Arc Welding (FCAW)

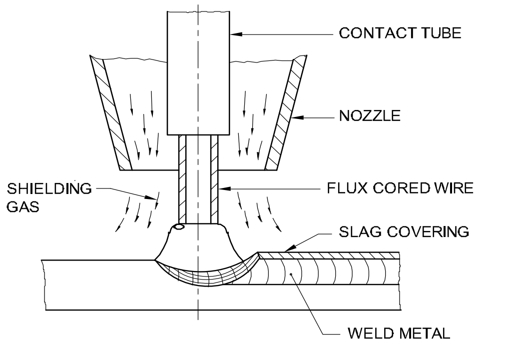
Objectives: At the end of this lesson you shall be able to
- **explain the flux cored arc welding and narrow gap welding process**
- **explain the type of metal transfer in flux cord Arc welding**
- **classification of flux cored wires**

Flux Cored Arc Welding (FCAW) Fig.1 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.

There are two major versions of the process, namely self shielded type (in which the flux performs all the functions of shielding) and the 'gas shielded type', which requires additional gas shielding.

The gas shielded type FCAW is widely employed for welding of carbon steel, low alloy steel and stainless steel in flat, horizontal and overhead positions.

Fig 1



FLUX CORED ARC WELDING

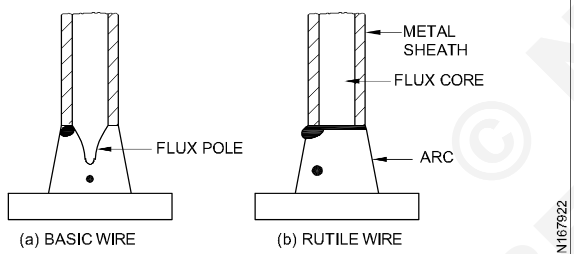
However, the self shielded type FCAW is mainly used for carbon steel welding and the quality of weld produced by this type is generally inferior to that of welds made with gas shielded type.

Equipment: The noticeable differences in the equipment used for GMAW and FCAW, are in the construction of welding torch and feed rollers.

The welding torch used for self shielded wire is very simple in construction as there is no need for the gas nozzle. Similarly the feed rollers used for flux cored wires have to ensure positive feeding of the wire without applying too much pressure on the soft tubular wire.

Metal transfer in FCAW: The metal transfer in FCAW differs significantly from GMAW process. FCAW process exhibits two distinctly different modes of metal transfer, namely large droplet transfer and small droplet transfer. However, both are classified as free flight transfer. The FCAW process does not produce a stable dip transfer as that of solid wire GMAW. The large droplet transfer occurs at the lower current voltage ranges. At higher current voltage ranges, the transfer mode changes to smaller droplet transfer. An important aspect to be observed during FCAW metal transfer is the presence of the 'flux pole' at the core of the arc column, protruding into the arc. The 'flux pole' appears only during welding with basic type flux cored wire. Fig.2(a) However, with rutile wire 'flux pole' does not occur and the metal transfer is of spray type. Fig.2(b)

Fig 2



APPEARANCE OF FLUX POLE

Classification of flux cored wires: The basic functions of the flux contained within the tubular wire include providing protective slag on the weld bead, introducing the required alloying elements and deoxygenerators into the weld pool and providing stability to the arc, besides producing the required shielding medium to protect the arc and weld pool.

Flux cored wires are now available for welding of plain carbon steel, low alloy steel and stainless steel and also for hard facing applications. These wires based on the nature of flux, may be classified as rutile gas shielded, basic gas shielded, metal cored and self shielded.

Rutile gas shielded wires have extremely good arc running characteristics, excellent positional welding capabilities and good slag removal and mechanical properties.

Basic gas shielded wires give reasonable arc characteristics, excellent tolerance to operating parameters and very good mechanical properties.

Metal cored wires contain very little mineral flux, the major constituent being iron powder and ferro alloys. These wires give smooth spray transfer in Argon/CO_2 gas mixtures. They generate minimum slag and are suitable for mechanised welding applications. Self shielded wires are available for general purpose down hand welding.

The flux cored wires are available in both seamless and folded types. The seamless type is generally coated with copper, whereas the folded type wires (i.e. close butt and overlapped type) are treated with special compounds.

Deposition rate and efficiency: Deposition rate is defined as the weight of metal deposited per unit time. The deposition efficiency is defined as the ratio of weight of weld metal effectively deposited to the weight of wire consumed.

In GMAW welding the deposition efficiency is generally between 93% to 97% and in FCAW the corresponding figure is between 80% to 86%. These values are determined by the spatter losses and slag formation. The low deposition efficiency in the case FCAW is due to the slag formation.

Generally the spatter loss can be minimised by using Argon/CO_2 mixed gas instead of CO_2 gas.

Advantages, disadvantages of GMAW over SMAW process and applications

Objectives: At the end of this lesson you shall be able to
- **state the advantages and disadvantages of Co_2 welding over shielded metal arc welding process**
- **state the applications of Co_2 welding.**

Advantages: Welding is economical due to less edge preparation and no stub loss.

Produces joints with deep penetration.

Thin and thick materials can be welded.

It can be used for welding of carbon steels, alloy steel, stainless steel, copper and its alloys, aluminium and its alloys.

Welding in all positions can be done.

Deposition rate is more.

No solid flux is used. So needs no cleaning of slag after each run.

Reduced distortion.

Disadvantages

Welding equipment is costly, more complex and less portable.

Since air drifts may disturb free flow of the shielding gas, GMAW may not work well in outdoor welding.

Applications: This process can be used for welding carbon, steel alloy steels, stainless steel, aluminium, copper, nickel and their alloys, titanium etc.

Light and heavy fabrication work.

This process is successfully used in ship building fabrication of pressure vessels and automobile industries.

GMAW power sources

Objective: At the end of this lesson you shall be able to
- **state the power sources for GMAW.**

MIG welding power sources have come a long way from the basic transformer type power source to the highly electronic and sophisticated types we see around today.

Even though the technology of MIG welding has changed, the principles of the MIG power source have, in most cases, not. The MIG power sources use mains power and converts that mains power into CV (constant voltage), DC (direct current) power suitable for the MIG welding process.

MIG welding power sources control voltage – this is done by either voltage stepped switches, wind handles, or electronically. The amperage that the power source produces is controlled by the cross sectional area of the wire electrode and the wire speed, ie the higher the wire speed for each wire size, the higher the amperage the power source will produce.

Because the output of the MIG power source is DC (direct current) the terminals on the front will have + positive and negative on the output side. The principles of electric circuits states that 70% of the heat is always on the positive side.

This means that the lead that is connected to the positive side of the welder, will carry 70% of the total energy (heat) output.

The characteristics volt, ampere curves (A & B) are shown in Fig.1.

Curve A (For SMAW): On the output slope or voltampere curve A, a change from 20 volts to 25 volts will result in a decrease in amperage from 135 amps to 126 amps. With a change of 25 percent in voltage, only a 6.7 percent change occurs in the welding current in curve A. Thus if the welder varies the length of the arc, causing a change in voltage, there will be very little change in the current and the weld quality will be maintained. The current in this machine, even though it varies slightly is considered constant.

This is called drooping characteristic power source. Also called constant current (CC)power source.

This type of power source is used in SMAW & GTAW process.

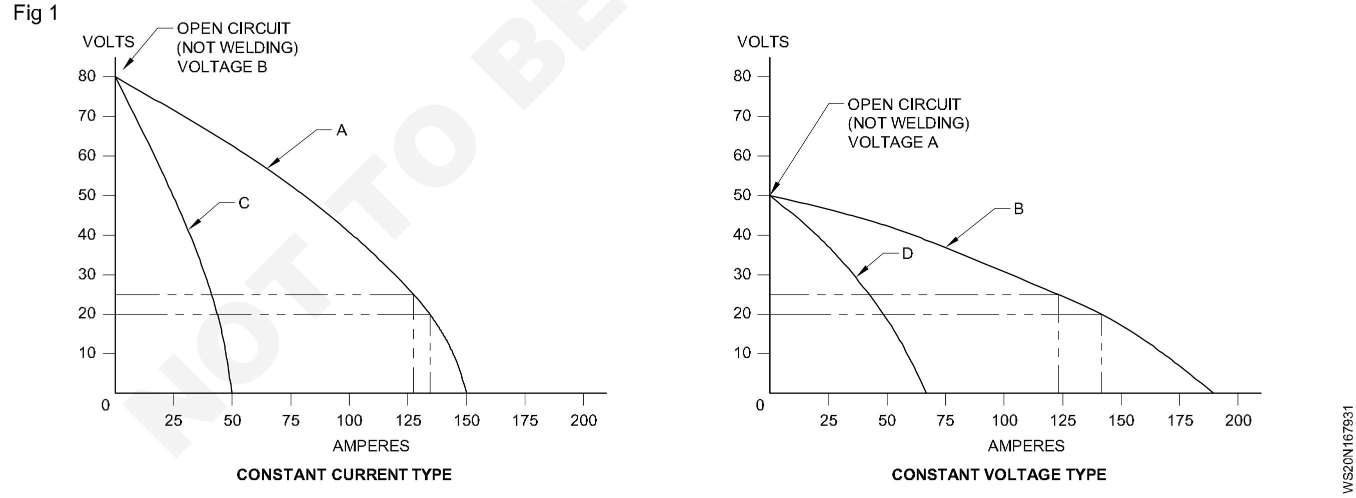
Curve B (For GMAW): The open circuit voltage curve for a setting of 50 volts on the machine is shown as curve B in the Fig.1. The same 20 volt to 25 volt (25 percent) change in the welding voltage will result in a drop in current from 142 amps to 124 amps or 13.3 percent. This slower sloping volt ampere curve output causes a large change in amperage with the same small change in voltage. A welder may wish to have this slower sloping (flatter) volt-ampere output curve.

This is called flat characteristic power source. Also called constant Voltage(CV)power source.

This type of power source is used in **GMAW & SAW** process.

With a flatter output slope the welder can control the molten pool and electrode melt rate by making small changes in the arc length. Control of the molten pool and electrode melt rate are most important when welding in the horizontal, vertical and overhead positions.

Fig 1



Wire feed system

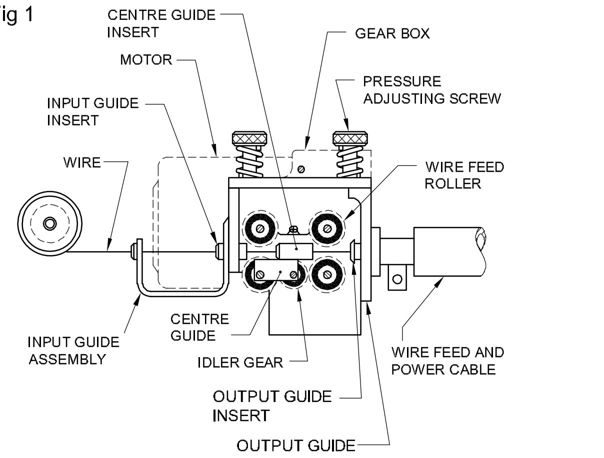
Objective: At the end of this lesson you shall be able to
- **state the functions of wire feeder and different types of drive rollers.**

Wire feeder (Fig 1)

The wire feeder is the part of the MIG/MAG welding set up that:

i) Controls the speed of the wire electrode and pushes this wire from the feeder through the welding torch to the workpiece.

Fig 1



A SIMPLIFIED WIRE FEED MECHANISM FOR GMAW

ii) Provides the path for welding current to be passed from the welding power source through the interconnecting lead to the feeder and then to the welding torch.

iii) Provides gas flow control through a solenoid valve. The gas is fed down from the gas regulator to the weld area via the feeder and then the MIG welding torch.

Wire feeders come in many different shapes and sizes, but they all do the same basic job roles. Feeders can be separated from the power source or built into the power source itself. Feeders are made up of different parts, each having a different job role.

Wire spool holder. This is designed to hold the spool of the correct wire size in place on the feeder to ensure the wire electrode is on the correct input angle for the drive roller to be able to do its job properly.

Drive motor MIG/MAG welding relies on smooth and constant wire feed. The wire drive motor has the job of turning the drive rollers (this can be one or more sets of rollers). Undersize drive motors can result in poor feeding of the wire electrode down the MIG welding torch . This will have the effect of making the overall performance of the MIG machine sub-standard as compared to a machine with a quality drive system.

Drive rollers: The drive rollers grasp the wire electrode and continuously feed the wire down the MIG torch into the welding arc (Fig 2 & 3). The rollers need to be selected by :

i) the wire size

ii) the type of wire to be fed. Each type of wire may need a different style of roller groove – eg

V rollers for steel and other hard wires

V-Knurled for Fluxcored wire

U-Grooved for aluminium and other soft wires

The idea of using the correct roller is to have a good wire drive without crushing the wire. The pressure roller is also used to set the wire tension. This must be set with enough pressure to feed the wire electrode, but not too much tension as to crush the wire.

Fig 2

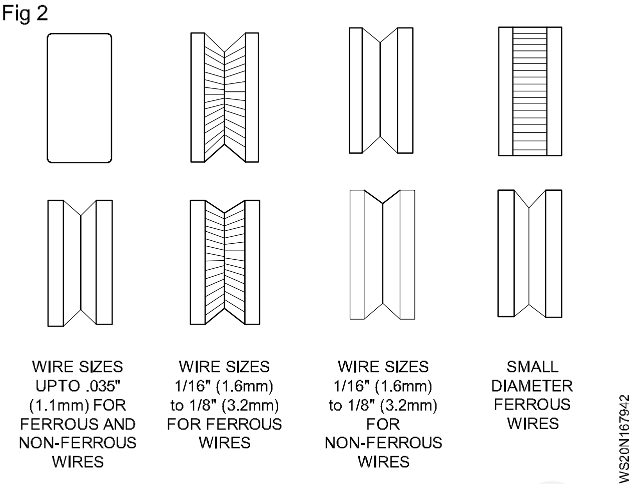
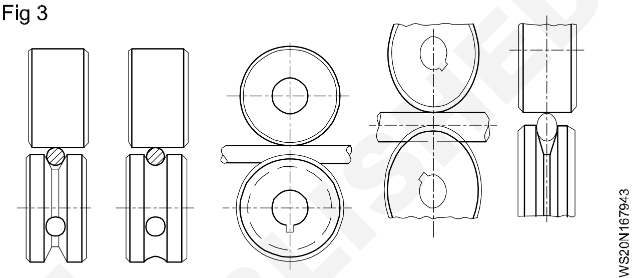


Fig 3



iii) all guides must be as close as possible to the drive roller to prevent the possibility of the wire bunching up.

Wire feed controls

The wire feeder will have its own built-in control system. The number of controls that will be built into the feeder will depend on the type of feeder but the most common are

i Wire speed - this control is the adjustment for how fast the drive rollers will turn and as stated earlier, the faster the wire speed for each wire size the more amperage the power source will produce. The wire speed controls can be labelled as wire speed, eg ipm (inches per minute) or mpm(metre per minute), or as a percentage from the slowest speed being zero to the highest speed being 100%. Usually mpm will be the range of 1 m/min to 25 m/min.

The amperage being set by the wire speed setting will also have an effect on the speed of travel and the deposition rate of the wire (how fast the weld metal is being put onto the weldpiece); with the advantage of, the higher the amperage the thicker the material that can be welded.

ii Purge switch - Some feeders have a purge switch. This is to allow the gas flow setting to be set on the gas regulator without turning of the wire feed roller or without any welding power being turned on.

iii Burnback - Burnback is the setting of the degree that the wire electrode will melt back towards the contact tip at the completion of the weld. If there is too much burnback the wire electrode will melt back onto the contact tip, possibly damaging it. If there is not enough burnback set, the wire electrode will not melt away from the weldpool and can be left stuck to the weld metal.

iv **Spot timers or stitch modes** are to be found on some feeders. These controls normally control the time the drive roller will turn for after the trigger contactor has been activated.

Welding wires used for GMAW, standard diameter and codification as per AWS

Objective: At the end of this lesson you shall be able to
- **state the chemical composition of different electrode wires.**

Electrode wire - consumable wire for GMAW: Performance & metal transfer characteristics are largely governed by the diameter of the wire and the machine settings such as arc voltage and amperage and chemical properties of the filler wire employed.

Machine settings: Diameter of the wire and ampere/ current employed for welding decide the type of metal transfer. The various recommended diameter, voltage and current ranges are tabulated in tables below for welding mild steel, low alloy steel and stainless steel.

Approx. machine settings for short circuit metal transfer on mild and low alloy steel

Electrode diameter(mm)	Arc voltage	Amperage range
0.8	16-22	80-190
1.2	17-22	100-225

Approx. machine settings for spray arc transfer on mild and low alloy steel

Electrode diameter(mm)	Arc voltage	Amperage range
0.8	24-28	150-265
1.2	24-30	200-315
1.6	24-32	275-500

Approx. machine settings for short circuit transfer on series 300 stainless steel

Electrode diameter(mm)	Arc voltage	Amperage range
0.8	17-22	50-180
1.2	17-22	100-210

Approx. machine settings for spray transfer on series 300 stainless steel

Electrode diameter(mm)	Arc voltage	Amperage range
0.8	24-28	160-210
1.2	24-30	200-300
1.6	24-32	215-325

Chemical properties: Chemical compositions of the filler wire play a very important role. The main composition, apart from the major elements, in the case of mild steel welding, will contain deoxidisers like Si, Mn to take of care of porosity due to oxidation of carbon in the steel. Typical composition of mild steel filler wires are listed in the table. We are using ER70S-6 for most of our carbon steel fabrication.

Specification of electrode wires

The GMAW electrode specification as per AWS is as given below.

Eg: E 70S-2 or ER70S-2 or E70T-2

E — Electrode

ER — Electrode can also be used as a filled Rod in GTAW.

70 — 70 x 1000 PSI — Tensile strength of the weld metal in pounds per square inch.

S — Solid wire / Rod

T — Tubular wire used in FCAW.

2 — Chemical composition of the wire.

Chemical composition, Weight percent

AWS classification	c	Mn	Si	P	S	Cu	Ti	Zr	Al
70S-2	0.07	0.90 to 1.40	0.40 to 1.40	0.025	0.035	0.5	0.05 to 0.15	0.02 to 0.12	0.05 to 0.15
70S-3	0.06 to 0.15	0.90 to 1.4	0.45 to 0.7						
70S-6	0.07 to 0.15	1.4 to 1.85	0.8 to 1.15						

Types of shielding gases for GMAW

Objectives: At the end of this lesson you shall be able to
- **state the different types of shielding gases used in Gas Metal Arc Welding (GMAW) process**
- **state the effects of different shielded gases and gas mixtures on ferrous and non-ferrous metals**
- **select the inert gas or gas mixtures for welding different metals using different modes of metal transfer**
- **explain why a gas heater is used in CO_2 welding plant.**

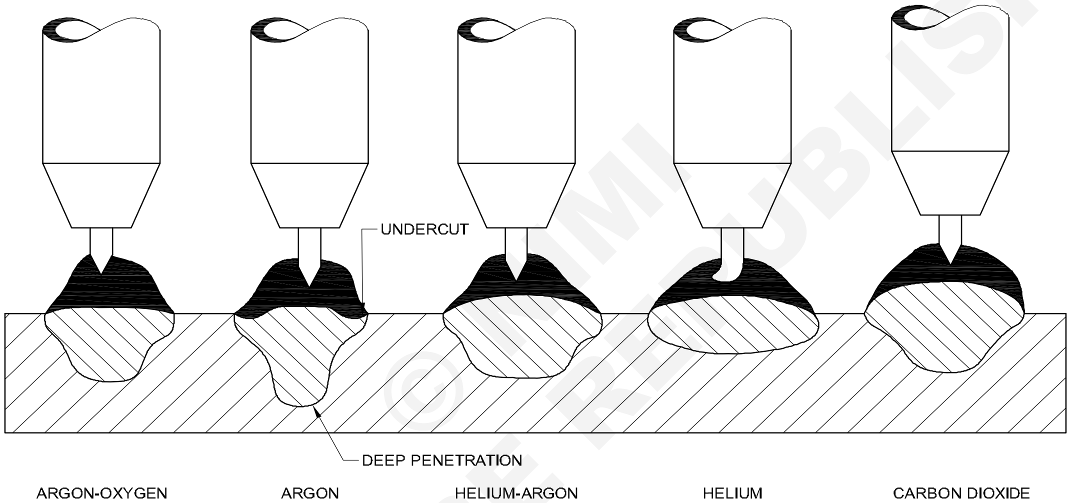
There are three types of shielding gases used for GMAW. They are inert gases, reactive gases and gas mixtures.

Inert gases: Pure argon and helium gas are excellent for protecting the arc, metal electrode and weld metal from contamination. Argon and helium are generally used for GMAW of non ferrous metals. Helium has very good conductivity and conducts heat better than argon. Therefore helium is choosen for welding thicker metals as well as high conductivity metals like copper and aluminium.

For thinner metal welding, lower conductivity argon is the better choice. Also argon is often used for welding out of position because of its lower thermal conductivity. Argon gas is 10 times heavier than helium gas, hence less argon gas is required to provide a good shield as compared to helium gas.

The weld bead contour and penetration are also affected by the gas used. Welds made with argon generally have deeper penetration. They also have a tendency to under cut at the edges. Welds made with helium have wider and thicker beads. Fig.1 shows the shape of welds made with various gases and gas mixtures.

Fig 1



GMAW BEAD SHAPES AND DEPTH OF PENETRATION FOR VARIOUS GASES AND GAS COMBINATIONS.
THESE SHAPES ARE TYPICAL FOR DCEP (DCRP).

WS20N167951

Argon used with the gas metal arc spray transfer process tends to produce deeper penetration through the center line of the bead. Spray transfer occurs more easily in argon than in helium.

Reactive gases and gas mixtures used in GMAW

Carbondioxide: Carbondioxide (CO_2) has a higher thermal heat conductivity than argon. This gas requires a higher voltage than argon. Since it is heavy, it covers the weld well. Therefore less gas is needed.

CO_2 gas is cheaper than argon. This price difference will vary in various locations. Beads made with CO_2 have a very good contour. The beads are wide and have deep penetration and no undercutting.

The arc in a CO_2 atmosphere is unstable and a great deal of spattering occurs. This is reduced by holding a short arc. Deoxidizers like aluminium, manganese or silicon are often used. The deoxidizers remove the oxygen from the weld metal. Good ventilation is required when using pure CO_2. About 7-12 percent of the CO_2 becomes CO (carbon monoxide) in the arc. The amount increases with the arc length.

A 25% higher current is used with CO_2 than with argon or helium. This causes more agitation of the weld puddle, hence entrapped gases raises to the surface of the weld, so low weld porosity.

Argon carbondioxide: CO_2 in argon gas makes the molten metal in the arc crater more fluid. This helps to eliminate undercutting when GMA welding carbon steels.

CO_2 also stabilizes the arc, reduces spatter and promotes a straight line (axial) metal transfer through the arc.

Argon-Oxygen: Argon-oxygen gas mixtures are used on low alloy carbon and stainless steels. A 1-5 percent oxygen mixture will produce beads with wider, less finger shaped, penetration. Oxygen also improves the weld contour, makes the weld pool more fluid and eliminates undercutting.

Oxygen seems to stabilize the arc and reduce spatter. The use of oxygen will cause the metal surface to oxidise slightly. This oxidization will generally not reduce the strength or appearance of the weld to an unacceptable level. If more than 2% oxygen is used with low alloy steel, a more expensive electrode wire with additional deoxidisers must be used.

The desirable rate of gas flow will depend on the type of electrode wire, speed and current being used and the metal transfer mode.

As a rule small weld pools 10 L/min

medium weld pools 15 L/min

and large spray weld pools 20-25 L/min

Too much gas flow can be just as bad as not having enough. The reason being that if the gas flow is too high it will come out of the MIG Torch.

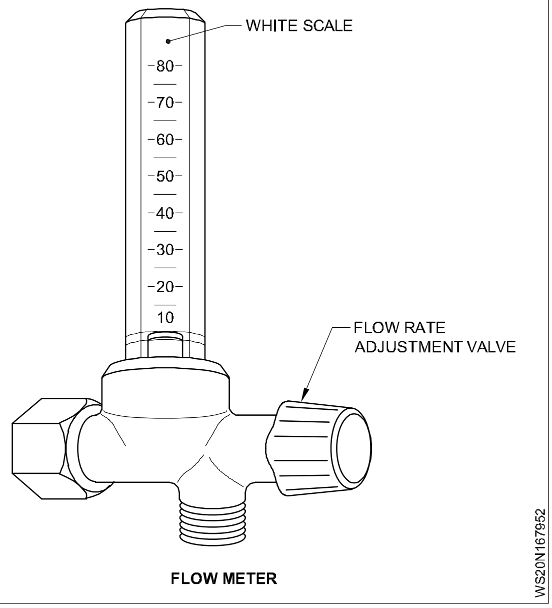
Suggested gases and gas mixtures for use in GMAW spray transfer

Metal	Shielding gas	Advantages
Aluminium	Argon	0.1 in.(2.5mm) thick; best metal transfer and arc stability; least spatter
	75% Helium 25% argon	1-3 in.(25-76mm) thick; higher heat input than argon
Copper, nickel and alloys	Argon	Provide good wetting;good control of weld pool for thickness up to 1/8 in.(3.2mm)
Magnesium	Argon	Excellent cleaning action
Carbon Steel,	Argon 5-8% CO_2	Good arc stability; produces a more fluid and controllable weld pool; good coalescence and bead contour, minimizes undercutting ; permits higher speeds compared with argon.
Low alloy Steel	Argon 2% oxygen	Minimizes undercutting; provides good toughness
Stainless Steel	Argon 1% oxygen	Good arc stability; produces a more fluid and controllable weld pool, good coalescence and bead contour, minimizes under cutting on heavier stainless steels
	Argon 2% oxygen	Provides better arc stability, coalescence and welding speed than 1% oxygen mixture for thinner stainless steel materials
Aluminium copper, magnesium, nickel and their alloys	Argon and argon helium	Argon satisfactory on sheet metal argon-helium preferred on thicker sheet metal
Carbon steel	Argon 20-25% CO_2	Less than 1/8 in.(3.2mm) thick; high welding speeds without melt through; minimum distortion and spatter; good penetration
	CO_2	Deeper penetration; faster welding speeds;minimum cost
Stainless Steel	90% helium 7.5% argon 2.5% CO_2	No effect on corrosion resistance small heat affected zone; no undercutting; minimum distortion; good arc stability

CO_2 gas cylinder and regulator: The shielding gas required for GMAW/CO_2 welding is supplied from a gas cylinder through an outlet valve and regulator.

Gas flow meter: It is a unit which has graduations marked on the glass tube. A flow rate adjustment valve fixed to the flow meter controls the rate of flow of inert gas/CO_2 gas to the welding gun in litre per minute. Fig. 2.

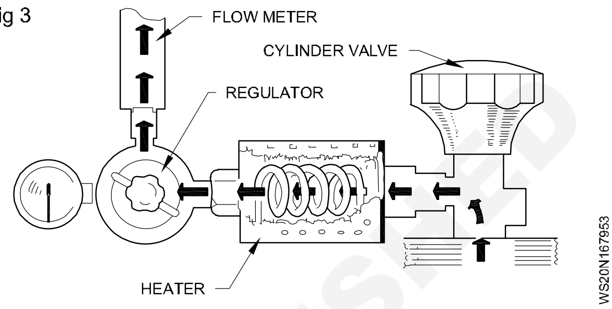
Fig 2



FLOW METER

Gas Preheater for CO_2 welding (Fig 3): Carbondioxide is filled in cylinders in liquid form. i.e., the CO_2 at room temperature and high pressure condenses into liquid form. Therefore while welding the liquid CO_2 has to be in gaseous form as they enter into the welding torch. CO_2 liquid boils and expands into gas as it passes through the regulator. This causes the gas to cool. If moisture is present in the regulator inlet, it will condense and freeze in the regulator, causing blocking of the gas passage. Therefore to avoid cooling a gas heater is connected to the cylinder to increase the temperature of the gas leaving the cylinder. Hence a uniform gas flow is maintained during welding.

Fig 3



Modes of metal transfer in GMAW

Objective: At the end of this lesson you shall be able to
- **state and explain the different types of metal transfer in CO_2 welding.**

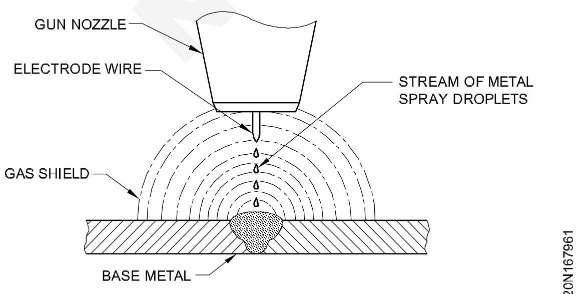
Types of metal transfer: In GMAW/CO_2 welding process, the weld metal is transferred from the electrode wire to the base metal in different methods/modes. Though there are many methods, only the following four methods are used popularly used in industries.

- Spray transfer (Free flight)
- Globular transfer (Intermediate)
- Short circuit or Dip transfer
- Pulsed transfer

The type of metal transfer that occurs will depend on the electrode wire size, shielding gas, **arc voltage** and welding current.

Spray transfer: In spray transfer very fine droplets of the electrode wire are rapidly projected through the arc from the end of the electrode to the workpiece. (Fig.1) Spray transfer requires high current density (28 to 32V).

Fig 1



SPRAY TRANSFER OF METAL.

To obtain a good spray mode of welding shielding gases containing a blend of argon is used. The spray method of metal transfer can be used with most of the common welding wire electrodes (eg mild steel, aluminium, stainless steel).

The advantages of metal spray transfer are

i high deposition rates
ii good travel speeds
iii good looking weld appearance
iv little weld spatter
v good weld fusion
vi very good on heavy sections

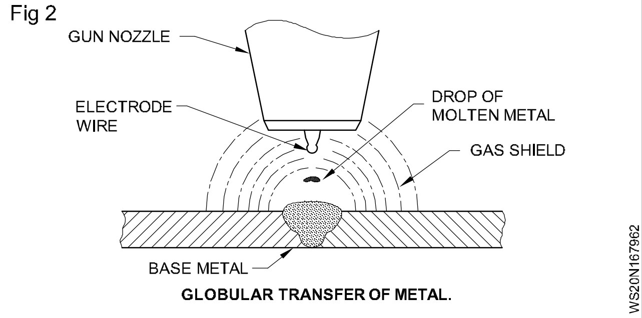
The disadvantages of the spray mode are

i higher capacity power source needed
ii weld position is limited to flat and horizontal fillet
iii the cost of using a more expensive mixed gas
iv higher radiated heat is produced so extra protection is needed

Globular transfer: In globular transfer, only a few drops are transferred per second at low current values, while many drops are transferred at high current values. This transfer occurs when the welding current is low. (Fig. 2). The voltage range is 23 to 27V.

The spatter produced in this transfer is more and hence it is less preferred. But this is a good transfer method for using CO_2 gas as a shielding gas.

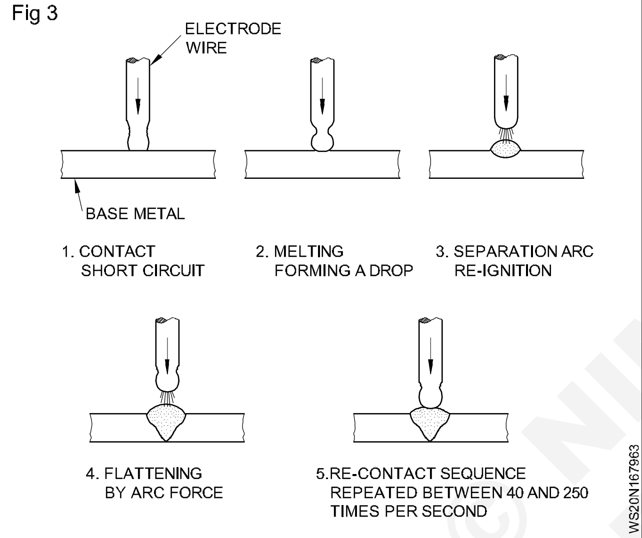
Fig 2



GLOBULAR TRANSFER OF METAL.

Short circuit transfer (DIP transfer): In short circuit transfer, as the molten wire is transferred to the weld, each drop touches the weld puddle before it breaks away from the advancing electrode wire. The circuit is shorted and the arc is extinguished. (Fig 3). The voltage range is 16 to 22V.

Fig 3



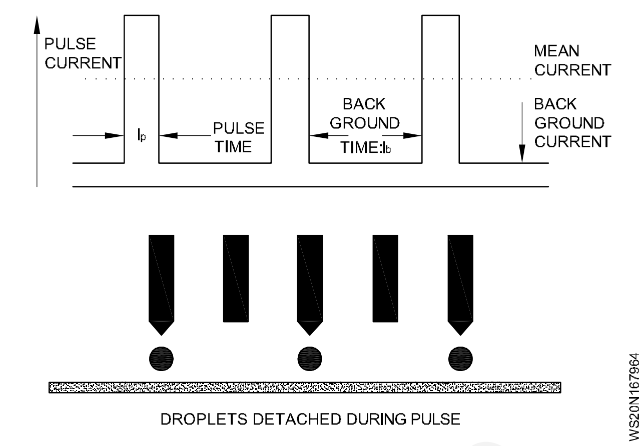
It permits welding thinner sections with greater ease, and is extremely practical for welding in all positions.

Pulsed spray transfer (Fig 4)

Pulsed spray transfer has a steady stream of metal droplets crossing the welding arc. The pulsed power source supplies the welding arc with two types of welding current.

1 **Peak current -** this current allows the formation of metal droplets which then cross the welding arc.

Fig 4



2 **Background current -** the background current will keep the arc alive, but doesn't allow for any weld metal transfer.

Pulsed spray transfer allows time for the weld puddle to freeze a little on the background current cycle, which allows for

i more control of the weld puddle.

ii more time for impurities to float to the top of the weld pool resulting in cleaner and stronger welds.

Advantages

i able to spray thinner metals

ii less heat input

iii stronger welds

iv more weld control

v out-of-position welding

vi Little spatters

Disadvantages

i higher set up costs

ii needs operator training

iii lower deposition rate

Welding parameters in GAMW

Objectives: At the end of this lesson you shall be able to
- **state and explain different welding parameters to be set for GMAW welding**
- **explain the welding procedure while using GMAW welding process.**

GMA welding process parameters/variables

The following parameters must be considered in the welding procedure of GMAW/CO_2 welding.

Electrode size

Rate of wire feed (Welding current)

Arc voltage

Stick out

welding position

Shielding gas

Travel speed

electrode position

Electrode: Best results are obtained by using the proper size wire for the thickness of the metal to be welded and the position in which the welding is to be done.

Electrode wires should be of the same composition as that of the material being welded.

Basic wire diameters are 0.8 mm, 1.0 mm, 1.2 mm, 1.6 mm and 2.4 mm.

Welding current: The wire feed speed will control the current. A wide range of current values can be used with each wire diameter. This permits welding metal of various thicknesses without having to change the wire diameter. The current selected should be high enough to secure the desired penetration and low enough to avoid under-cutting or burn through.

The success of GMA welding is due to the concentration of high current density at the electrode tip.

General data on current selection is given in the table given below.

The current varies as the wire feed varies.

Ranges of wire feed rate in CO_2 welding (Current is shown in brackets)
Wire feed speed, m/min]

Wire dia. (mm)	Spray type arcs (28 - 32 V)	Short circuiting arcs (16-22 V)
0.8	5.0-15 (150-250 amps)	2.5-7.5 (60-160 amps)
1.2	5.0-15 (200-350 amps)	2.0-3.8 (100-175 amps)
1.6	5.0-8.8 (350-500 amps)	1.5-2.0 (120-180 amps)

Arc voltage: This is a very important variable in GMAW/ CO_2 welding process, mainly because it determines the type of metal transfer by influencing the rate of droplet transfer across the arc. The arc voltage to be used depends on the base metal thickness, type of joint, electrode composition and size, shielding gas composition, welding position, type of weld and other factors.

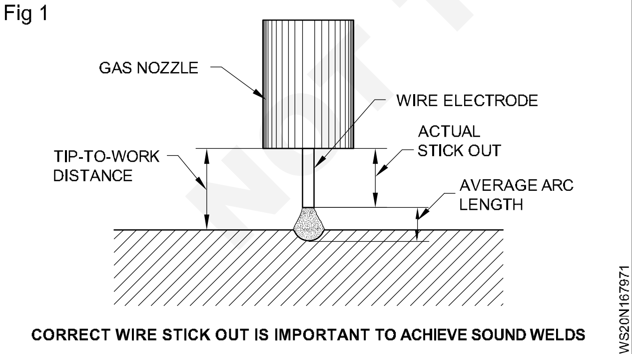
For details refer to the table of General guide to welding conditions.

Arc travel speed: The linear rate at which the arc moves along the joint, termed arc travel speed, affects the weld bead size and penetration.

If the arc travel speed is lowered, the weld pool becomes larger and shallower. As the travel speed is increased, the heat input rate of the arc is decreased; consequently there is decreased penetration and narrower weld bead. When the travel speed is excessive, undercutting occurs along the weld bead, because the deposition of the filler metal is not sufficient to fill the paths melted by the arc.

Stick out: It is the distance between the end of the contact tube and the tip of the electrode. (Fig 1)

Fig 1



CORRECT WIRE STICK OUT IS IMPORTANT TO ACHIEVE SOUND WELDS

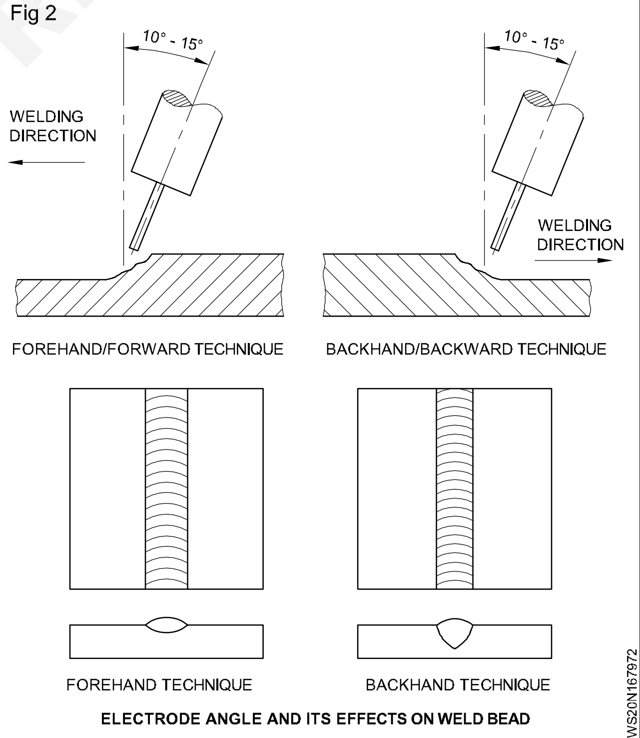
Too long a stick out results in excess weld metal being deposited at low arc heat, giving rise to badly shaped weld and shallow penetration.

When the stick out is too short, excessive spatter gets deposited on the nozzle, which can restrict the shielding gas flow and cause porosity in the weld.

Recommended stick out is 6 to 13 mm for a short circuiting arc, and 13 to 25 mm for the spray transfer arc.

Electrode position: In all welding processes, the position of the gun and electrode with respect to the joint affects the weld bead shape and penetration. The welding can be done either by using Forehand/Forward technique or by using Backhand/ Backward technique. The gun angles are usually maintained within 10 to 15° as shown in Fig 2.

Fig 2



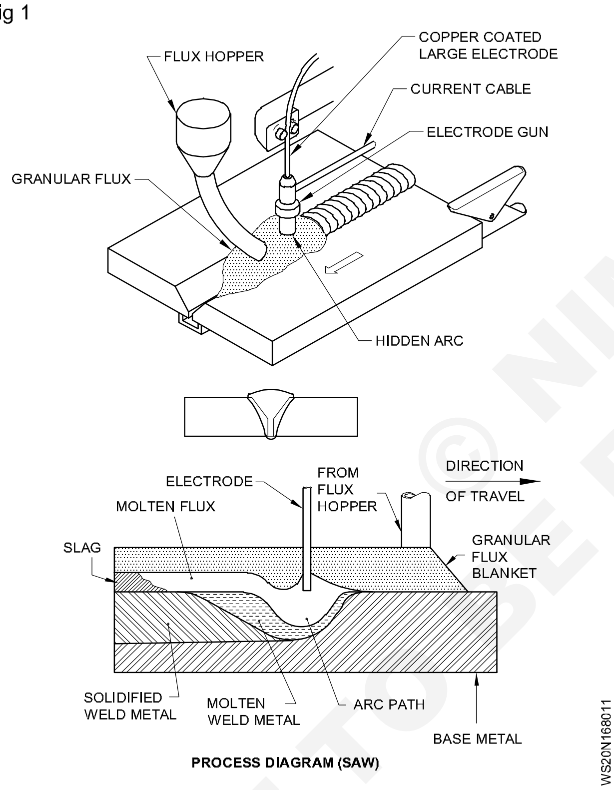
ELECTRODE ANGLE AND ITS EFFECTS ON WELD BEAD

Introduction to Submerged arcwelding (SAW). Advantage,limitation, equipment and operating conditions

Objectives: At the end of this lesson you shall be able to
- **explain the principles and applications of submerged arc welding**
- **explain the SAW**
- **describe the welding procedure of the above processes**
- **state the advantages and limitations of the above processes.**

Principles of submerged arc welding: Submerged arc welding is an arc welding process that uses an arc between a bare metal electrode and the weld pool. The arc and the molten metal are hidden by a blanket of granular flux on the workpieces. (Fig 1)

Fig 1



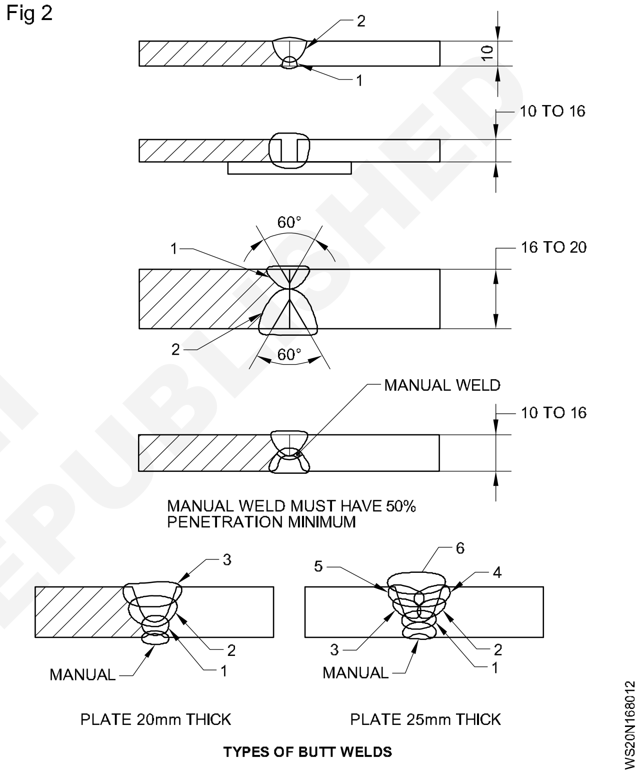
PROCESS DIAGRAM (SAW)

Metals which can be welded by SAW: In submerged arc welding, low and medium carbon steels, low alloy steels, high strength steels, quenched and tempered steel and stainless steel can be welded.

Metals weldable by saw

Base metal	Weldability
Wrought iron	Weldable
Low carbon steel	Weldable
Low alloy steel	Weldable
High and medium carbon	Possible but not popular
High alloy steel	Possible but not popular
Stainless steel	Weldable

Fig 2



TYPES OF BUTT WELDS

Edge preparation in SAW process: The edge preparation for Butt welds are as shown in Fig.2.

For plate thicknesses higher than 25mm a double Vee or single U or double "U" edge preparation is done Fig.3 shows fillet welds done by submerged arc welding.

The "T" and Lap joints shown in Fig.3 are tilted to 45^0 to weld them in flat position. If the thickness of plates are more than 16mm in T fillet joint then the edge of the vertical plate is bevelled by 45^0 and the joint is welded without a root gap.

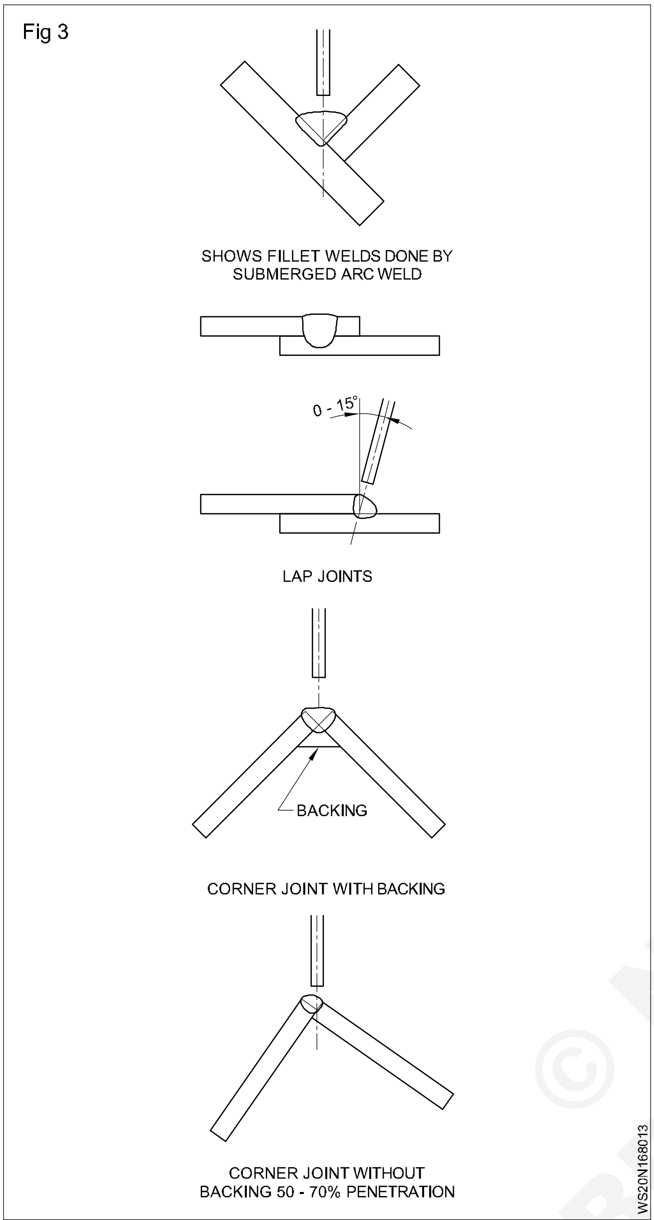
Types of submerged arc welding process

There are two types of SAW.

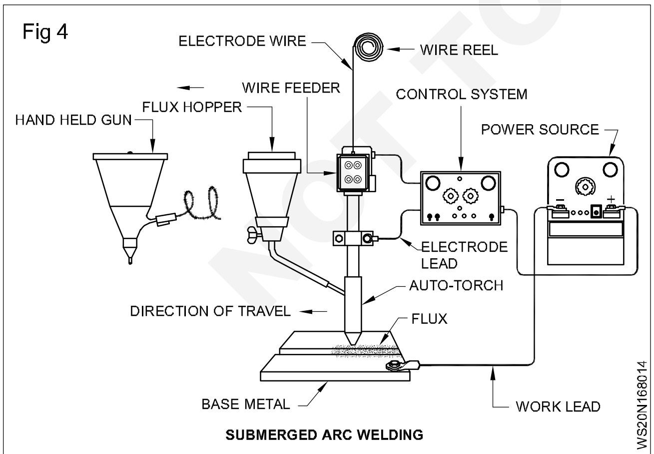
- Automatic
- Semi-automatic

Automatic SAW: In this type the arc voltage, arc length, speed of travel and electrode feed are automatically controlled.

Semi-automatic SAW: The arc length, flux feeding and electrode feed are automatic but the speed of travel is controlled by the operator.



Parts of a SAW machine and their functions (Fig 4)



A wire feeder to drive the electrode to the work through the contact tube of the welding gun or welding head.

A welding power source to supply welding current to the electrode at the contact tube.

Arrangement for holding the flux and feeding it on the head of the arc.

A means of traversing the joint.

Fluxes: Fluxes used with submerged arc welding are granulated fusible mineral materials which are free from substances capable of producing large amount of gas during welding.

Flux when cool is non-conductive, but when molten it is highly conductive and allows high current.

The flux protects the weld pool from atmospheric contamination and influences deep penetration.

Electrode: Bare or lightly copper coated rods or wires are used as electrodes in SAW. These electrodes are available in coil or reel form.

Standard reels with diameters 2 to 8 mm are available.

Welding procedure (for striking the arc): The electrode momentarily contacts the work and is withdrawn slightly.

Arc start: Arc starting is difficult in submerged arc welding because of the flux cover. It is important to start the weld at a specific point on the joint.

Method of starting arc by using steel wool or iron powder: A rolled ball of steel wool 10 mm in dia. is placed at the required spot on the joint and the electrode wire is lowered on to it till it is lightly compressed. The flux is then applied and when the welding is commenced the steel wool or iron powder conducts the current from the wire to the workpiece, while at the same time it melts away rapidly as the arc is formed.

Clean the prepared workpiece and place it in position with provision for backing up. Fill the hopper with flux and insert the electrode ends into the welding head.

Adjust the voltage, the current and the welding speed as indicated in Table 1 and 2.

Start welding by striking an arc beneath the flux on the work.

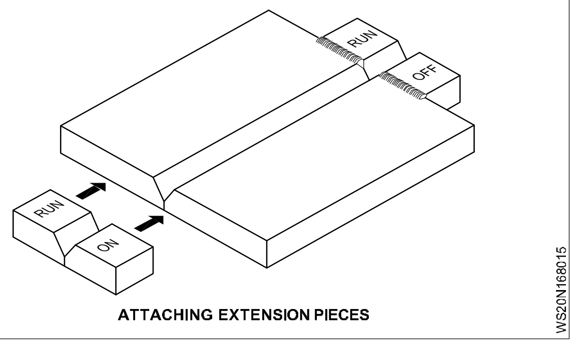
The entire welding zone is buried under a blanket of flux and longitudinaly it travels along the seam.

Use 'run on' and ' run off ' pieces for starting and ending to avoid formation of crater and beginning and ending faults. (Fig 5)

Advantages of SAW

- High quality weld metal
- High deposition rate and speed
- Smooth, uniform finished weld
- No spatter
- Little or no smoke
- No arc flash
- High utilization of electrode wire
- No need for protective clothing

Fig 5



ATTACHING EXTENSION PIECES

Limitations: The submerged arc welding process is limited to flat position and horizontal fillet position.

Table 1
Submerged arc welding parameters for single electrode
(For fillet welds by automatic welding)

Weld size (mm)	5	6	8	10	12	16	20
Plate thickness (mm)	6	8	10	12	16	20	25
Electrode size (mm)	3.2	4	5	5	5	5	5
Current (amp) DC	520	620	720	800	870	920	970
Volts	30	32	34	36	38	39	40
Welding speed (m/min.)	1.4	1	0.7	0.56	0.36	0.25	0.20
Electrode req'd (Kg/m)	0.10	0.18	0.28	0.40	0.70	1.1	1.6
Flux req'd (Kg/m)	0.05 - 0.09	0.75 - 0.12	0.14 - 0.18	0.18 - 0.27	0.33 - 0.45	0.53 - 0.75	0.83 - 1.2
Total time (hr/m of weld)	0.012	0.016	0.0024	0.03	0.047	0.67	0.09

Table 2
Submerged arc welding parameters for single electrode
(For Butt welds by Automatic welding)

Plate thickness (mm)	6		10		12		16		20	
Pass	1	2	1	2	1	2	1	2	1	2
Electrode size (mm)	5		5		5		5		5	
Current (amp) DC+	600	750	650	800	750	850	750	850	800	900
Volts	31	33	33	35	35	36	35	36	36	37
Welding speed (m/min)	1.8	1.8	1.2	1.2	0.9	0.9	0.6	0.6	0.5	0.5
Electrode consumed (Kg/m)	0.13		0.23		0.35		0.56		0.63	
Flux consumed (Kg/m)	0.14 – 0.16		0.19 – 0.25		0.3 – 0.4		0.5 – 0.65		0.55 – 0.72	
Total time (hr/m of weld)	0.019		0.028		0.038		0.059		0.06	

Procedure of Structural Fabrication

Objectives: At the end of this lesson you shall be able to
- **procedure of Structural Fabrication.**

Structural Steel Fabrication

structural is a multifaceted process that requires specialized knowledge, skills, and resources to complete successfully. To create structural steel beams, components, or equipment, a good metal fabricator follows a specific process:

Step 2: Blueprint/Drawing Creation

During ideation, your vendor will listen to you and draw up blueprints using specialized engineering software You can come prepared with your own blueprints or drawings for this stage. Review your vendor's blueprints to verify correct requirements, code compliance, and specifications.

Step 4: Cut and Drill Steel Beams

The vendor will have special tools, such as saws, shears, lasers, punches, notches, and plasmas to cut and drill the steel beams according to project blueprints. At Swanton Welding, Inc, we use the Ficep 1003 DDVD VanGuard Drill Line for this stage of the process. This advanced equipment produces higher quality results, faster.

Step 5: Piece Etching

Your vendor will etch each piece with a unique part number and plate location. This makes final assembly on site fast, easy, and accurate, eliminating costly mix-ups and project delays.

Step 6: Component Assembly

Once your vendor finishes cutting and forming the components of your project, the team will weld and assemble the pieces. At this stage, the fabrication team will check to make sure all pieces assemble correctly and match order specifications.

Step 7: Custom Part Machination

If you request any custom metal fabrication, your vendor will create custom parts at this stage. Custom parts are ideal when you need components to fit a specific structure or product. You may need custom part machination if standard looks or sizes aren't right for your project, either in function or aesthetics.

Step 8: Complete Assembly

Your vendor will complete a full assembly of your project, if possible. In some cases, partial assembly may apply. Complete assembly ensures all parts of the order are present and functioning. Changes at this stage are rare and only occur if there has been a mistake in a previous step.

Edge preparation

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of edge preparation**
- **describe the edge preparation for butt and fillet welds.**

Necessity of edge preparation: Joints are prepared to weld metals at less cost. The preparation of edges are also necessary prior to welding in order to obtain the required strength to the joint. The following factors are to be taken into consideration for the edge preparation.

- The welding process like SMAW, oxy-acetylene welds, $Co_{2,}$ electro-slag etc.
- The type of metal to be joined, (i.e) mild steel, stainless steel, alumininum, cast iron etc.
- The thickness of metal to be joined.
- The type of weld (groove and fillet weld)
- Economic factors

The square butt weld is the most economical to use, since this weld requires no chamfering, provided satisfactory strength is attained. The joints have to be beveled when the parts to be welded are thick so that the root of the joints have to be made accessible for welding in order to obtain the required strength.

In the interest of economy, bevel butt welds should be selected with minimum root opening and groove angles such that the amount of weld metal to be deposited is the smallest. “J” and “U” butt joints may be used to further minimise weld metal when the savings are sufficient to justify the more difficult and costly chamfering operations. The “J” joint is usually used in fillet welds.

A root gap is recommended since the spacing allows the shrinking weld to draw the plates freely together in the butt joint. Thus, it is possible to reduce weld cracking and minimise distortion and increase penetration, by providing a root gap for some welded joints.

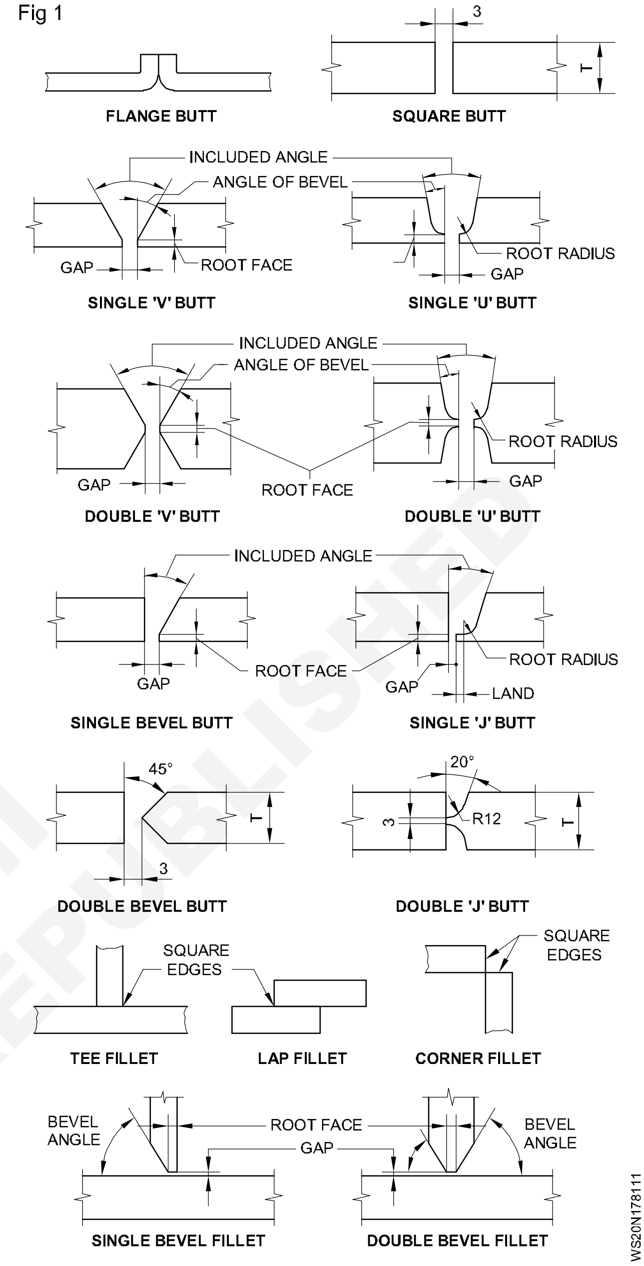
Method of edge preparation: The joining edges may be prepared for welding by any one of the methods mentioned below.

- Flame cutting
- Machine tool cutting
- Machine grinding or hand grinding
- Filing, chipping

Types of edge preparation and setup

Different preparation generally used in arc welding are shown in Fig 1 below.

Fig 1



Planning for Structural member, marking and edge preparation. Assembling, tack welding, measurement of weldment size, root pass welding making cover pass and inspection and testing etc,.

Objectives: At the end of this lesson you shall be able to

- **statethe structural members Marking, Edge preparation, assembly and root pass, and cover pass inspection and Testing.**

MEASUREMENT OF WELDMENT SIZE

The strength of a fillet weld is based, in the design, on the product (effective area of the weld: 1 x W of the theoretical throat (design throat thickness) and effective weld length as shown in Fig. 1. Filler weld legs determine filler weld sizes. Fillet weld sizes are measured by the length of the legs of the largest night triangle that may be inscribed within the filler weld cross section.

Fig.1 Fillet weld measurements: L: Leg length, S: Fillet weld Size, T: Theoretical throat, V: Convexity, C: Concavity, W: Effective weld length.

Fillet weld sizes determine theoretical throat. The product of the size and cos45° in ease where an isosceles right triangle may inscribe within the fillet weld cross section: Sx Cos 45°=0.7S, as shown in Fig. 2.

Fig 1

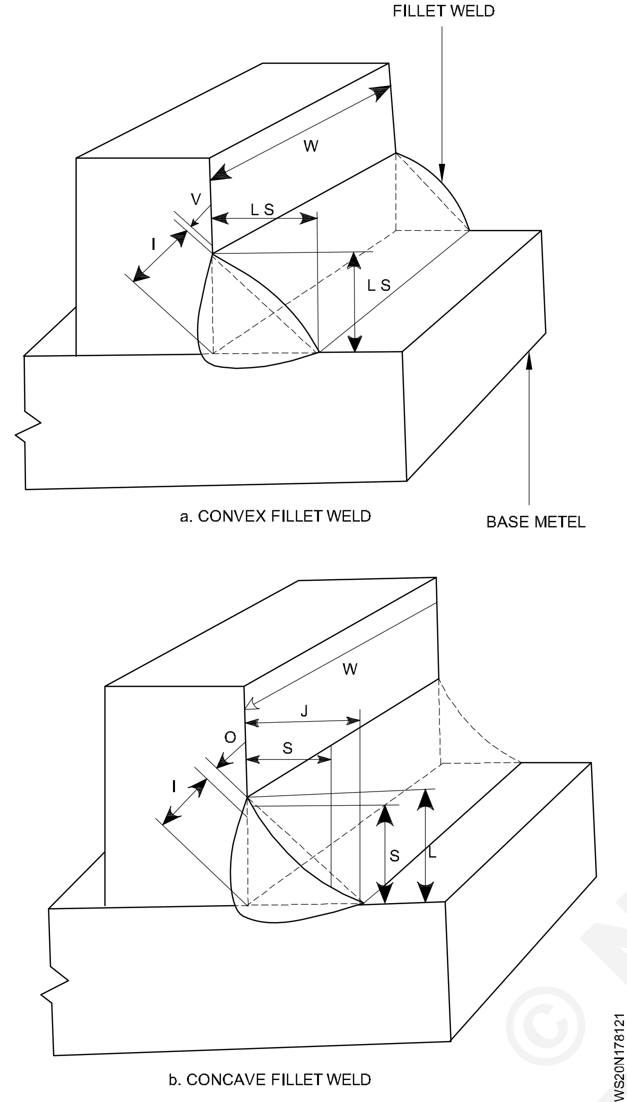
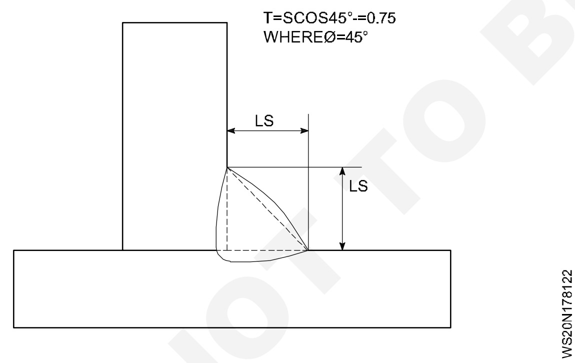


Fig 2



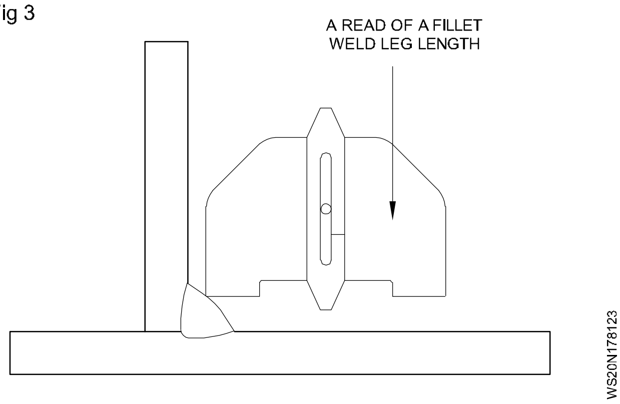
size throat convexity, and convexity are inspected by using several types of welding gages. Fig 3 shows a multipurpose gage measuring fillet weld leg.

Tack welding

Tack welds are Small and temporary welds that hold parts together ready for final welding.

Tack welds maintain the desired alignment. and gap between the piece of metal being joined.

Fig 3



Root pass welding: -

The first weld bead placed in the weld joint is known as root run welding.

The root pass fuses the two parts together and Stablishes the depth of weld metal

Penetration. A good root pass is needed to obtain a Sound weld.

Cover pass welding:

The second (or) intermediate weld pass is called a filler pass. The final weld pass is the cover pass is the cover pass.

The weld last bead on a multipass weld is known as the coverpass. The cover pass may use a different electrode weave, or It may be the same as the filler beads. Keeping the cover pass uniform and neat looking is important. Most welds are not tested, and often the inspection program is only visual. Thus, the appearance might be the only factor used for accepting or rejecting welds. The Cover pass should be free of any defects such as undercut, overlap,porosity.orslaginclusions.It should be uniform in width and reinforcement. A cover pass should not be more than 1/8 in. (3 mm) wider than the groove opening. Cover passes that are too wide do not add to the weld strength

1 Structural Planning

After getting an architechtural plan of the buildings, the structural planning of the building frame is done. This involves determination of the following.

- position and orientation of columns
- positioning of beams
- spanning of slabs
- layouts of stairs
- seleeting proper type of footing

process of marking edge preparation and assembly

Before designing the structure member, marking and cutting and then take the necessary members. Then assemble it and Complete the tag weld, root pass welding, cover pass welding as Follow.

- prepare "'L' Channels and clean their Surfaces as shown in (Fig 1, 2)

Fig 1

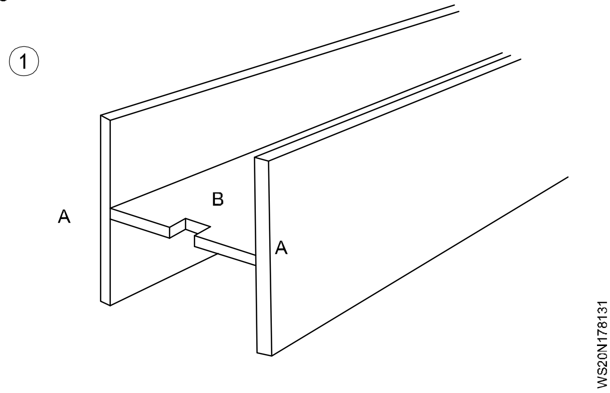
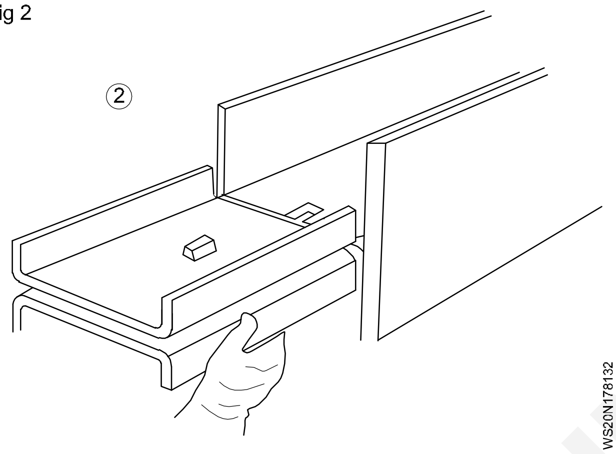


Fig 2



- prepare T L Channel pieces Should be placed in Flat position and tack weld at both ends
- Place the tack weld outward before welding. This defects in weld initiation can be avoided. (Tack weld, length 20mm)
- All safety equipment must be worn.

Preparation of Pieces:

- Cut the 'I' 'L' channels using an oxy acetylene cutting (Fig 2)
- Cut slope at 20° angle for section only Fig 2
- Set the prepared I channels parts & set stiffener on both sides place the tack weld outward of before welding.
- Set 0 current of 130 Amps a 3.15mm diameter electrode suitable for I and L channels.
- IF dc current electrode should DCEP
- Use a 3.15mm electrode to deposit a root run bead, and then remove slag.
- Finally second run and third run using 4mm electrode.
- Clean weld deposite and inspect for surface defects.

- 3.15mm dia electrodes should be used to deposite the root run by applying a current of (120 - 130) Amps. (Fig 3 & 4)

Fig 3

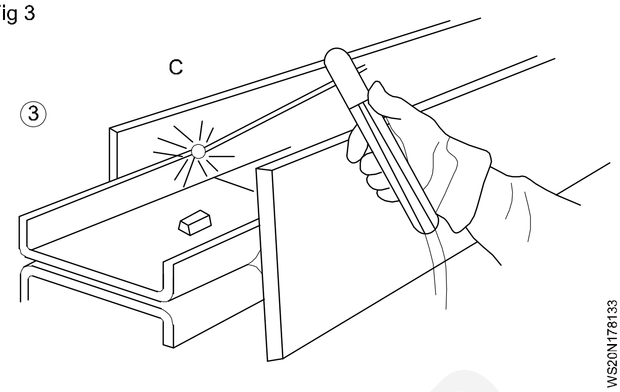
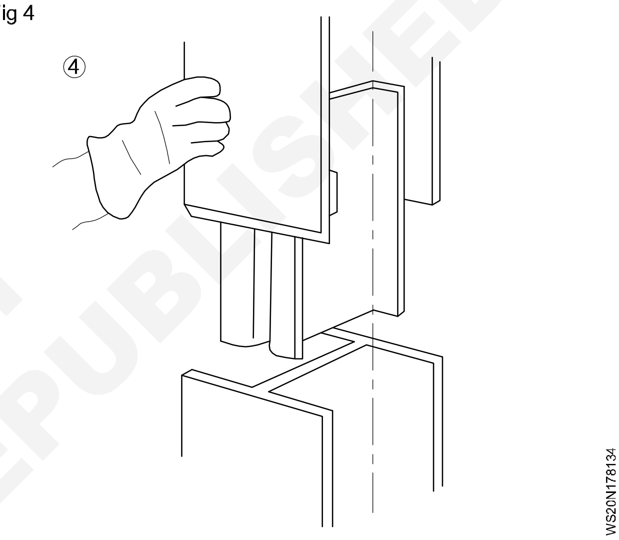


Fig 4



- Apply a current of 170 Amps with electrode of 4mm dia and deposite the second run & third run layer.

Inspection of root pass and cover pass welding:

- Preparation of welds for weld testing
- Root pass and cover pass testing should be done after welding.
- Root and cover pass testing in a variety of ways.
- (They are LPI/ RT, VT)
- Determine whether proper electrode angle current, type of electrode I and techniques are used durin root and cover pass welding.
- Check the surface of cover pass for defects. If there are (undercut, low penetration & high penetration) etc. They should be detected and corrected.

Cleaning and inspection.

- Clean both sides of the welded joint thoroughly
- It should be checked for weld width and full penetration of surface & distortion.

Fig 5

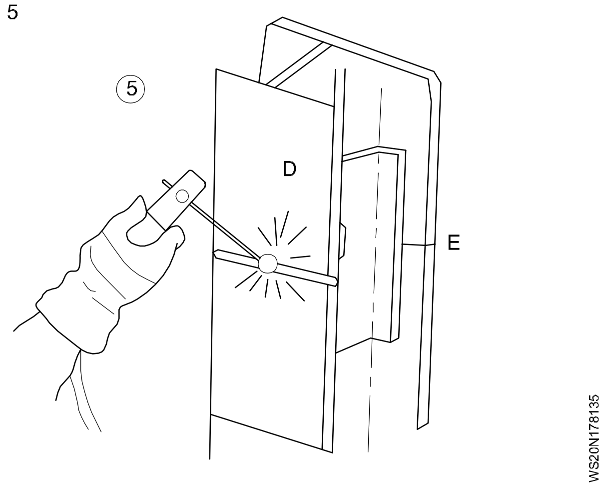

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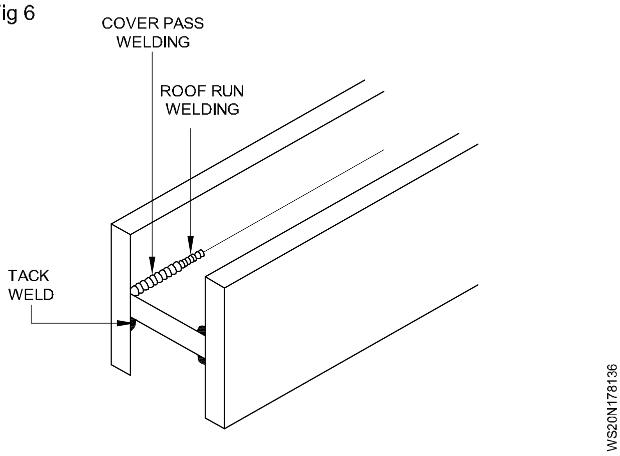
Fig 6


COVER PASS
WELDING
ROOF RUN
WELDING
TACK
WELD
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Inspection of weld (NDT) - Visual inspection

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of inspection and testing of weld**
- **describe the different stages of visual inspection**
- **explain the check points of visual inspection**
- **state types of testing of welds.**

Necessity of inspection: The purpose of inspection is to locate and determine the type of weld fault, strength and quality of joint and quality of workmanship.

Types of tests

– Non-destructive test (NDT)

– Destructive test

– Semi destructive test

Determining the quality of the weld without destroying the weld is called a non-destructive test (NDT). The job can be used after the test. The test to be carried out on welded specimens by cutting the job and destroying it is called destructive test. The job cannot be used after the test.

Sometimes the quality of a welded joint is tested by grinding, drilling, etching, filing etc. for finding machinability, microstructure etc. These tests are called semi-destructive tests. The tested job can be used after the test by rewelding the small area damaged during the test.

Visual inspection (non-destructive test): Visual inspection is observing the weld externally using simple hand tools and gauges to know whether there is any external weld defects. This is one of the important inspection methods without much expense. This method of inspection needs a magnifying glass, a steel rule, try square and weld gauges. Visual inspection is made in three stages namely:

– before welding

– during welding

– after welding

Visual inspection before welding

(The operator must be familiar with the type of work, electrode and welding machine)

The following factors are to be ensured.

The material to be welded is of weldable quality.

The edges have been properly prepared for welding as per thickness of the plate.

Proper cleaning of the base metal.

Setting of proper root gap.

Proper procedure to be followed to control distortion.

Proper selection of blow pipe nozzle and filler rod, flux and flame.

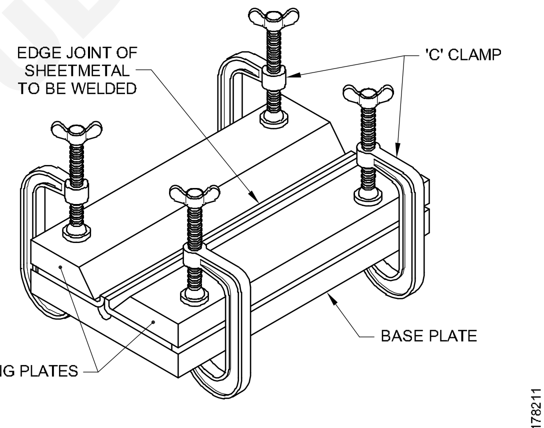
Polarity of the electrodes in the case of DC welding current.

Whether the cable connections are tight.

Current setting according to the size of the electrode and position of welding.

Whether any jigs and fixtures are necessary to ensure proper alignment. (Fig 1)

Fig 1



CLAMPING PIECES BETWEEN HEAVY BLOCKS WILL KEEP THEM STRAIGHT.

Proper facilities should exist for storing and drying of the electrodes.

Visual inspection during welding

The following points are to be checked.

Studying the sequence of weld deposit.

Examining whether each weld is cleaned adequately before making the next run in multi-run welding.

Measuring gauges

Objectives: At the end of this lesson you shall be able to
- **describe the surface defects on weld**
- **explain the measuring gauges**
- **states the types of gauges.**

Inspection after welding: Surface defects in and around the welds, such as cracks, (longitudinal and transverse) (Fig.1), undercut (Fig.2), overlap (Fig.3), excessive convexity of contour, the weld surface smoothness of the run and penetration, control of distortion, unfilled crater are to be inspected.

Fig 1

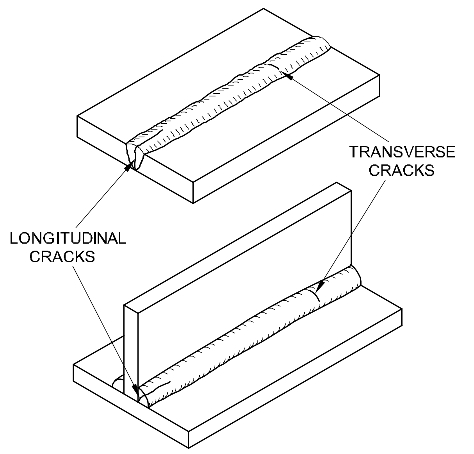


Fig 2

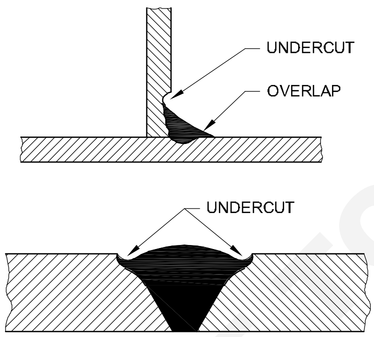
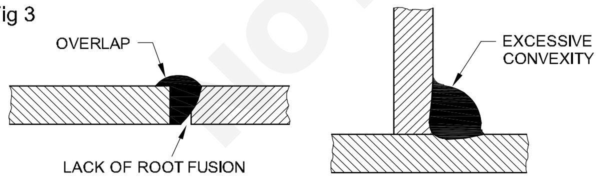


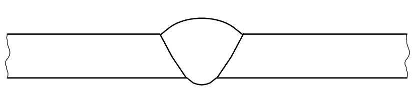
Fig 3



Freedom from surface cavities and slag inclusions. (Fig 4).
Deposition of runs, single or multiple.

Penetration bead in butt weld.

Fig 4



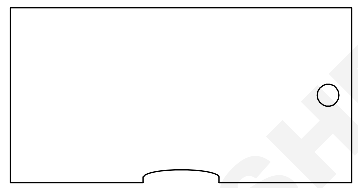
FREE FROM SURFACE CAVITIES AND SLAG INCLUSIONS

Quality of the weld metal.

Measuring gauges used for inspection

A template may be used to check the contour. (Fig.5)

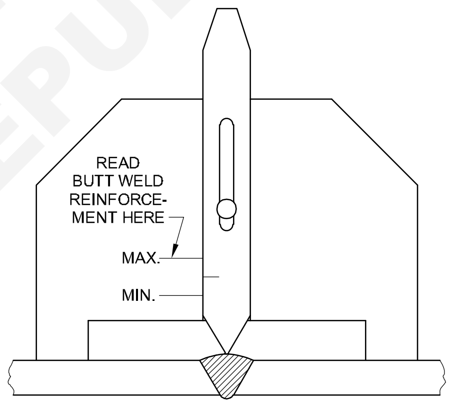
Fig 5



TEMPLATE FOR TESTING THE BEAD CONTOUR OF WELDS

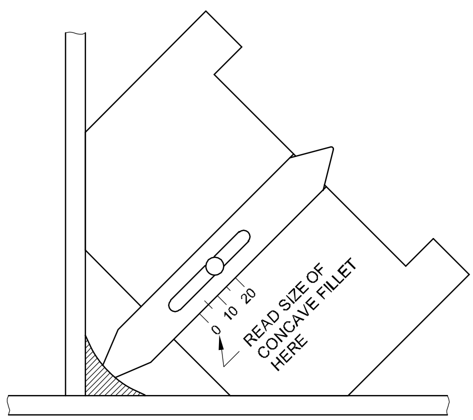
Use gauges for measuring both convex and concave in fillet weld and to check contour of weld. (Figs 6 to 12)

Fig 6



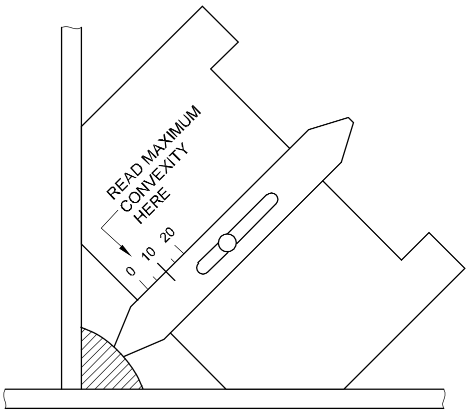
CHECKING BUTT WELD FOR MAXIMUM AND MINIMUM CONVEXITY

Fig 7



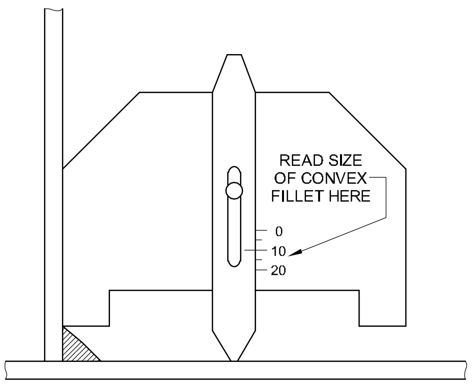
TO DETERMINE THE SIZE OF A CONCAVE FILLET

Fig 8



TO CHECK THE MAXIMUM PERMISSIBLE CONVEXITY

Fig 9



TO MEASURE THE SIZE OF A FILLET WELD

Fig 10

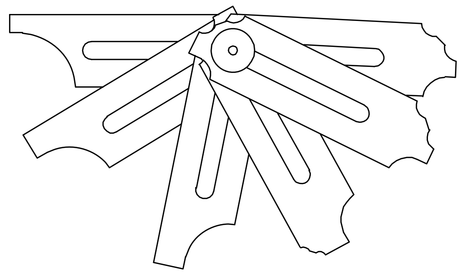


Fig 11

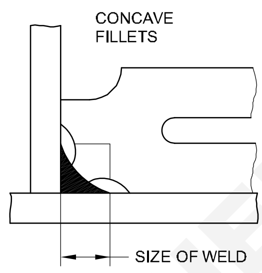
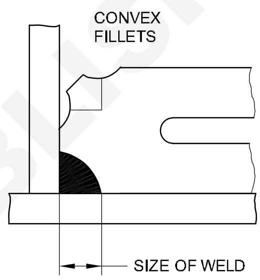


Fig 12



Methods of non-destructive tests

Objectives: At the end of this lesson you shall be able to
- **explain the non-destructive testing methods**
- **explain the uses of the common non-destructive methods**
- **explain the uses of special non-destructive testing.**

Non-destructive testing methods are classified as common testing and special testing methods.

Common non-destructive testing

– Visual inspection

– Leak or pressure test

– Stethoscopic test (Sound)

Special non-destructive tests

– Magnetic particle test

– Liquid penetrant test

– Radiography (X-ray) test

– Gamma ray test

– Ultrasonic test

Visual inspection: Visual inspection is the simplest, fastest, economical and most commonly used test for detecting defects on the surface of the welded job. The weld surface and joint are examined visually with naked eyes preferably with the help of a magnifying lens. Visual examination can help in detecting the following defects on the surface of the weld.

– Porosity

– Surface defects like surface cracks, external slag inclusions, overlap, spatters, unfilled crater, misalignment, distortion etc.

– Undercut

– Improper profile and dimensional accuracy

– Poor weld appearance

– Incomplete penetration.

Leak or pressure test: This test is used to test welded pressure vessels, tanks and pipelines to determine if leaks are present. The welded vessel, after closing all its outlets, is subjected to internal pressure using water, air or kerosene. The internal pressure depends upon the working pressure which the welded joint has to withstand. The internal pressure may be raised to two times the working pressure of the vessel. The weld may be tested as follows.

1 The pressure on the gauge may be noted immediately after applying the internal pressure and again after, say, 12 to 24 hours. Any drop in pressure reading indicates a leak.

2 After generating air pressure in the vessel, soap solution may be applied on the weld seam and carefully inspected for bubbles which would indicate leak.

Stethoscopic (sound) test: The principle of this test is that defect-free weld metal gives a good ringing sound when struck with a hammer whereas a weld metal containing defects gives a flat sound.

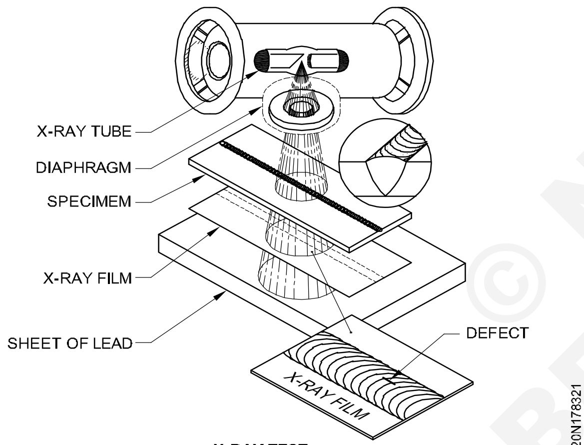
An ordinary physician's stethoscope and a hammer may be used to magnify and identify the sound.

Structural welds and welds in pressure vessels have been successfully tested using this method.

Radiographic test: This test is also called X-ray or gamma ray test.

X-ray test: In this test internal photographs of the welds are taken. The test specimen is placed in between the X-ray unit and film. (Fig 1) Then the X-ray is passed. If there is any hidden defect, that will be seen in the film after developing it. Defects appear in the same manner as bone fractures of human beings appear in X-ray films. Below the X-ray film a lead sheet is kept to arrest the flow of X-ray further from the X-ray testing machine.

Fig 1



X-RAY TEST

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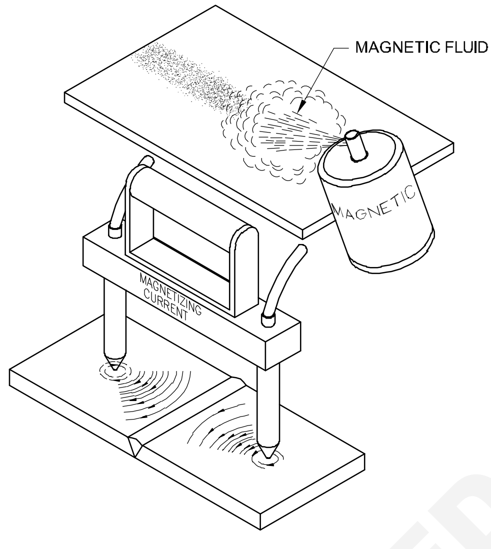
Gamma ray test: The short invisible rays given off by radium and radium compounds like cobalt 60 etc. are known as gamma rays. These rays penertrate greater thickness of steel than x-rays and the chief advantage of this process is portability. This test can be done at places where electricity is not available. These tests are used on high quality jobs like boilers and high pressure vessels and penstock pipes and nuclear vessels.

Magnetic particle test: This test is used to detect surface defects as well as sub-surface (up to 6 mm depth) defects in ferrous materials.

A liquid containing iron powder is first sprayed over the joint to be tested. When this test piece is magnetised, the iron particles will gather at the edges of the defect (crack or flaw) and can be seen as dark hair line marks with naked eyes. (Figs 2 & 3)

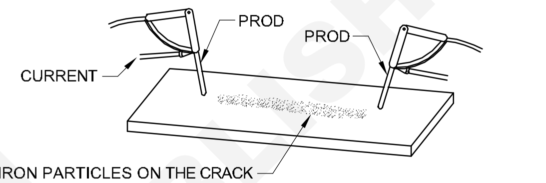
Fig 2



MAGNETIC PARTICLE TEST

WS20N178322

Fig 3



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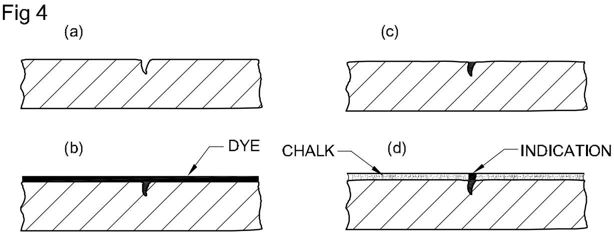
Liquid penetrant test; This test is based on the principle that coloured liquid dyes and fluorescent liquid penetrate into the cracks and are used to check for surface defects in metals, plastics, ceramics and glass. A solution of the coloured dye is sprayed on the clean welded joint and allowed to soak. Then the dye is washed off using a cleaner, and the surface dried with soft cloth.

A liquid developer (white in colour) is then sprayed on the weld. The coloured dye comes out in the shape of surface defects into the white developer coating. The defect can be seen in normal light with naked eyes. (Fig 4)

Fig 4



LIQUID PENETRANT TEST

WS20N178324

Ultrasonic test: Sound waves of high frequency are used in this test. This test is used to find out the discontinuities in the weldment. The sound waves can penetrate from a very small thickness of plate to 6 to 10 metres of steel.

A sound wave producing transmitter is placed on the job. The echo of the sound waves is directly shown on the calibrated screen attached with the ultrasonic testing unit. (Fig 5)

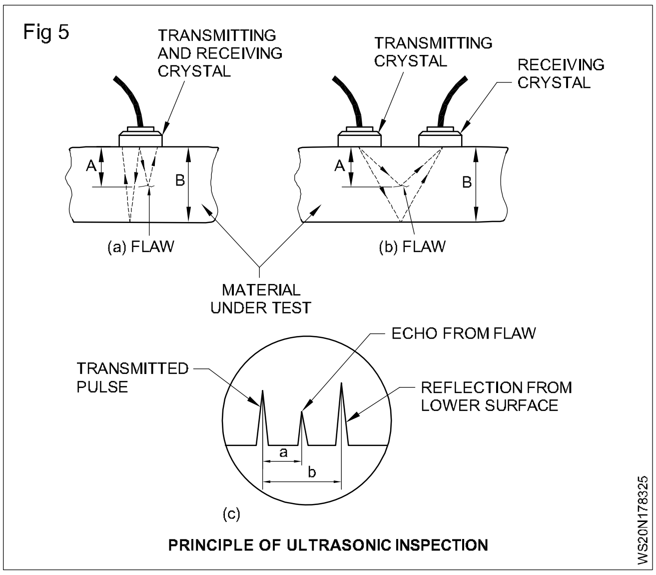


Fig 5 PRINCIPLE OF ULTRASONIC INSPECTION

Structural welding codes and standards

Objectives: At the end of this lesson you shall be able to
- **describe the welding codes and standards**
- **explain about WPS & PQR.**

Welding procedure, Performance, Qualification and codes

Introduction

'Code' is any set of standards set forth and enforced by a local government for the protection of public safety, health etc.. as in the structural safety of building, (building code) health requirements for plumbing, ventilation etc.... (Sanitary or health code) and the specifications for fire escapes or exits (Fire code)

'Standard' is defined as 'something considered by an authority or by general consent as a basis of comparison, an approved model'.

As a practical matter, codes tell the user what to do and when and under what circumstances to do it. Codes often legal requirements that are adopted by local jurisdictions that then enforce their provisions.

Standards tell the user how to do it and are usually regarded only as recommendations that do not have the force of law.

The uses of welding in Engineering Industries are Boilers, Heat Exchangers, Pressure Vessels, Bridges, Ships, Pipelines, Reactors, Storage tanks, Construction Structures and Equipment etc. When a design engineers designs a welding structure, the function of production & Quality control personnel is to translate that design in to a real component.

From a design point of view properties of the weld joint are designed as

1 Physical soundness (free from discontinuities)

2 Related Theory for Related Theory Exercise 2.6.06 Metallurgical compatibility (Chemistry of weldment, base metal, gas etc.)

3 Mechanical Properties

The welding Procedure Specification (WPS) is written exactly to translate these property requirements on to relevant welding variables.

The procedure has to be testified on a test piece for its intented performance by a qualified welder. To draw a correct weld procedure, performance methods and qualification criteria, there are popular codes and standards are available.

All the codes specifies the rules for the preparation of welding procedures specification and the qualification of welding procedures, welders and welding operators. This code specifies the rules for all manual and machine welding processes.

Reading of Welding Procedure specifications (WPS) & Reading of Procedure Qualification Record (PQR)

Government as well as private organizations develop and issue standards that apply to a particular area of interest. Many standards with regard to the welding industry are prepared by the American Welding Society (AWS). Many countries have their own national standards on the subject of welding.

The following are examples of the various standards, and the bodies responsible for them.

Standard codes	Country	Responsible bodies
IS	India	Bureau of Indian Standards (BIS)
BS	U.K	British Standard issued by British Standard Association
ANSI	U.S.A	The American National Standards Institute (ANSI)
AWS	U.S.A	American Welding Society
ASME	U.S.A	American Society of Mechanical Engineers
API	U.S.A	American Petroleum Institute
DIN	Germany	German standard issued by the Deutsches Institute fuer Normung
JIS	Japan	Japanese industrial standard issued by the Japanese standards Association

There is also the International Organization for Standardisation (ISO). The main goal of ISO is to establish uniform standards for use in international trade.

The American Welding Society publishes numerous documents on welding and some of them are listed below:

Welding procedure qualification

A welding procedure qualification is the test to prove that the properties of a weld to withstand the service conditions as designed for particular/specific purpose.

Welder performance qualification

A welder's performance qualification is the test to certify a welder's or a welding operator's ability to deliver consistently quality welds. This performance qualification is always done in accordance with a qualified weld procedure specification.

Weld procedure specification

A WPS is deemed to have been qualified if through tests that are conducted on the weld test coupon meeting the requirements or the acceptance criteria. Acceptance criteria and the specification format may vary depending on the code of design and manufacture. The tests that are carried out on the weld test coupon are destructive tests, and they help to evaluate the mechanical properties of the weldment carried out in accordance with WPS.

The results of this qualification are generally recorded in a format and these are generally recorded in a particular format and this is usually referred to as an Procedure Qualification Record (PQR). Thus for every WPS there has to be at least ONE PQR and vice versa.

A performance qualification is generally done to evaluate the performance of a welder on a welding operator. It is done to evaluate the ability of a welder or operator to perform consistently and deliver sound and good quality welds. As this is done to a WPS which has already been qualified most codes of practice generally permit the evaluation to be done by the use of non destructive tests viz, radiography. Welders and operators who fulfill the requirements are deemed to be certified for welding to the specific WPS/ WPSs.

ASME sections IX, AWS B2.1, API 1104 are some of the popular American codes specifying welding procedures and welder performance qualification.

BS 2633, BS 4870/4871, BS 4872, DIN 8560, AD Merkblatt HP 2 and HP 3, eN 288-2 and EN 287-1 are some of the European standards for welding procedures and performance qualification.

IBR chapter 13, IS 2825, IS 7307, IS 7310, IS 7318 are the major Indian codes on welding qualifications.

Weld procedure specifications, variables and logic for requalification

A WPS (Weld Procedure Specification) is a document which lists out all the essential characteristics for performing a weld. For purposes of qualifying for the WPS, a test coupon is welded adhering to all parameters as stated/ listed in the WPS. A WPS is valid only when supported by a relevant PQR.

The characteristics listed in the WPS, those in this chapter, are otherwise known as variable. As the term signifies, these characteristics may be changed or varied. When these "variables" are changed we have a new WPS. Whenever a change in a particular "variable" is bound to influence the mechanical properties of the weld, then that "variable" is termed as an ESSENTIAL variable. The variable which do not have any impact on the mechanical properties of the weld are generally termed as NON-ESSENTIAL variables. However, under certain conditions, some of the variables could influence the mechanical properties of the weld. Such variables are termed as supplementary essential variables. A more detailed treatment of these is made in the code of manufacture and the same could be referred to.

Similarly those variable that have an influence on the welder's ability to produce sound welds are referred to as essential variables for purposes of Welder Performance Qualification. An example that comes to one's mind right way would be the position in which a weld is made.

Introduction to ASME Sec.IX

Welding procedure and performance qualification

Section IX of the ASME code specifies the rules for the preparation of welding procedure specification and the qualification of welding procedures, welders and welding operators.

This code specifies the rules for all manual and machine welding processes.

Materials

All the materials that can be used for pressure vessel manufacture have been grouped (Table 1) under different 'P' numbers. The object of grouping the base materials is to reduce the number of qualifications required. The 'P' numbers grouping of materials is based essentially on comparable metal characteristics such as composition, weldability and mechanical properties.

Table 1

'P' Number grouping

P1 to P11	Steel and steel alloy
P21 to P30	Aluminium and aluminium based alloys
P31 to P35	Copper and copper based alloys
P43 to P47	Nickel and nickel based alloys
P51 to P52	Titanium and titanium based alloys.

Filler metals

The filler metals are grouped as both "F" numbers and "A" numbers.

Qualification procedure under various code

Objectives: At the end of this lesson you shall be able to
- **various codes of qualification procedure**
- **welding procedure qualification**
- **different types of number grouping.**

Introduction

Qualification tests are not intended to be used as a guide for welding during actual construction, but rather to assess whether an individual has a certain minimum level of skill. The test does not determine what an individual normally will or can do in production. For this reason, complete reliance should not be placed on qualification testing of welders. The quality of all production welds should be determined by inspection during and following completion of the actual welding.

Various codes (such as American Welding Society (AWS) D1.1 Structural Welding Code and ASME Boiler and Pressure Vessel rode Section IX), specifications, and governing rules generally prescribe similar though frequently somewhat different methods or details for qualifying, welders, welding operators, and tackers. The applicable or required standard should be consulted for specific details and requirements.

Typical codes for welder certification include

AWS Codes

D1.1 Structural welding steel

D1.2 Structural welding aluminium

D1.3 Structural welding sheet steel

D1.4 Structural welding reinforcing steel

D1.5 Bridge welding

D1.6 Structural welding stainles steel

D1.8 Structural welding seismic supplement

D17.1 Aerospace fusion welding

B2.1 specifi cation for welding procedure and performence qualification

ASME codes

B 31.1 power piping

B 31.3 process piping

AWS code I

AWS D1.1 structural welding (Steel)

AWS D1.2 structural welding (aluminum)

AWS D1.3 structural welding (Sheet steel)

AWS D1.4 structural welding (Reinforcing Steel)

AWS D1.5 Bridge welding

AWS D1.6 structural welding (Stainless Steel)

AWS D1.7 structural welding (Seimic supplement)

AWS D1.8

AWS D1.9 structural welding (titanium)

AWS D1 7.1 Aerosoace fusion welding

AWS B21 specification for welding procedure and performance qualification

Asme codes: Section II

AWS B31 Power piping

ASME B31.1 process piping

Different tests and inspection involved in qualification

Objectives: At the end of this lesson you shall be able to
- **different test and inspection**
- **welders qualification.**

Welding Procedures Qualification

The codes stipulate that all the details of the welding procedure should be listed in the 'Welding procedure specification' (WPS).

Each of these welding procedure specifications shall be qualified by the welding of test coupons, and the mechanical testing of the specimens cut from these coupons are required by this code. The welding date for these coupons and the results of these tests shall be recorded in a document known as 'procedure qualification record (PQR)'.

A WPS may require the support of more than one PQR, while alternatively, one PQR may support a number of WPSs. A WPS will be applicable equally for a plate, pipe and tube joints. The WPS should contain the following nine points in detail.

1 **Joints : Details**

The groove design, the type of backing used etc. are to be specified in this. If a change in the type of edge preparation (Single Vee, Single 'U' or double Vee etc.) is made or if the joint backing is removed, a new WPS has to written but need not be qualified by a test.

2 **Base Metals**

The base metal (P) number and the thickness ranges for which the procedure is applicable etc. have to be mentioned here. If the range of thickness has to be increased or a change of base metal from one 'P' number to another 'P' number is required, a new WPS should be prepared and supported by a PQR after due tests.

3 **Filler Metals**

The details of the electrodes, and filler wires such as the 'F' number, 'A' number and the type of the filler metals have to be specified here. The electrodes, flux compositions, (basic, rutile, etc.) are also to be mentioned. A change in 'F' number or 'A' number shall require a new WPS and PQR. A change in the diameter of the electrode also requires a new WPS but need not be qualified by a test. The addition or deletion of filler metals requires a new WPS and PQR after re-tests.

4 **Position**

The positions in which the welding should be done shall be mentioned here. The qualification test can be done in any position but still the same procedure is applicable to all positions.

5 **Preheating**

The preheating temperature, interpass temperature etc. shall be clearly specified. If the preheat is to be decreased by more than 550C, then a new WPS has to be prepared and qualified by a test.