WELDER

NSQF LEVEL - 3

TRADE THEORY

SECTOR : CAPITAL GOODS AND 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

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

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

Sector : Capital Goods and Manufacturing

Duration : 1 Year

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

Developed & Published by

National Instructional Media Institute
Post Box No.3142
Guindy, Chennai - 600 032
INDIA
Email: chennai-nimi@nic.in
Website: www.nimi.gov.in

First Edition : October 2022 Copies : 1000

First Reprint : December 2022 Copies : 1000

Rs.270/-

FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by 2020 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 Mentor Councils comprising various stakeholder's 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 -Trade Theory - NSQF Level - 3 (Revised 2022) in CG & M Sector.** 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 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

Addl.Secretary / Director General (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 Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of the Federal Republic of Germany. The prime objective of this institute is to develop and provide instructional materials for various trades as per the prescribed syllabi (NSQF LEVEL - 3) 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 organisations to bring out this Instructional Material **(Trade Theory)** for the trade of **Welder** (NSQF Level - 3) (Revised 2022) under **CG & M** Sector for ITIs.

MEDIA DEVELOPMENT COMMITTEE MEMBERS

Shri. K. Rajasekaran	_	Assistant Training Officer Govt. ITI, Chennai - 81
Shri. B. Subith	_	Senior Instructor, Govt. ITI, Chengannur.
Smt. G. Sangareeswari	_	Junior Training Officer Govt. ITI, Guindy.

NIMI CO-ORDINATORS

Shri. Nirmalya Nath	_	Deputy Director of Training NIMI- Chennai - 32.
Shri. G. Micheal Johny	_	Manager, NMI, Chennai - 32
Shri. V. Gopalakrishnan	_	Manager, NMI, Chennai - 32

NIMI records its appreciation for 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 NIMI staff who have contributed towards the development of this Instructional Material.

NIMI is also grateful to everyone who has directly or indirectly helped in developing this Instructional Material.

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 course of the **Welder** 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

Module 1	-	**Induction Training & Welding Process**
Module 2	-	**Welding Techniques**
Module 3	-	**Weldability of Steels (OAW, SMAW)**
Module 4	-	**Inspection and Testing**
Module 5	-	**Gas Metal Arc Welding**
Module 6	-	**Gas Tungstan Arc Welding**
Module 7	-	**Repair and Maintenance**

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 course of the **Welder** Trade. The contents are sequenced according to the practical exercise contained in the manual on Trade practical. Attempt has been made to relate the theortical 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 indicating about the corresponding practical exercise are given in every sheet of this manual.

It will be preferable to teach/learn the trade theory connected to each exercise atleast 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 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

Sl.No	Learning Outcome	Exercise No
1	Set the gas welding plant and join MS sheet in different position following safety precautions. [Different position: - 1F, 2F, 3F, 1G, 2G, 3G.]	1.1.01 - 1.1.04
2	Set the SMAW machine and perform different type of joints on MS in different position observing standard procedure. [different types of joints Fillet (T-joint, lap & Corner), Butt (Square & V); different position - 1F, 2F, 3F,4F, 1G, 2G, 3G, 4G]	1.1.05 - 1.1.08
3	Set the gas welding plant and join MS sheet in different position following safety precautions. [Different position: - 1F, 2F, 3F, 1G, 2G, 3G.]	1.1.09 - 1.1.10
4	Set the SMAW machine and perform different type of joints on MS in different position observing standard procedure. [different types of joints Fillet (T-joint, lap & Corner), Butt (Square & V); different position - 1F, 2F, 3F,4F, 1G, 2G, 3G, 4G]	1.1.11 - 1.1.12
5	Set the oxy- acetylene cutting plant and perform different cutting operations on MS plate. [Different cutting operation - Straight, Bevel, circular]	1.1.13-1.1.17
6	Set the gas welding plant and join MS sheet in different position following safety precautions. [Different position: - 1F, 2F, 3F, 1G, 2G, 3G.]	1.1.18-1.2.20
7	Set the SMAW machine and perform different type of joints on MS in different position observing standard procedure. [different types of joints Fillet (T-joint, lap & Corner), Butt (Square & V); different position - 1F, 2F, 3F,4F, 1G, 2G, 3G, 4G]	1.2.21-1.3.37

8	Set the SMAW machine and perform different type of joints on MS in different position observing standard procedure. [different types of joints Fillet (T-joint, lap & Corner), Butt (Square & V); different position - 1F, 2F, 3F,4F, 1G, 2G, 3G, 4G]	1.3.38 - 1.3.41
9	Perform welding in different types of MS pipe joints by Gas welding (OAW). [Different types of MS pipe joints - Butt, Elbow, T-joint, angle (45) joint, flange joint]	1.3.42-1.3.45
10	Set the SMAW machine and perform different type of joints on MS in different position observing standard procedure. [different types of joints Fillet (T-joint, lap & Corner), Butt (Square & V); different position - 1F, 2F, 3F, 4F, 1G, 2G, 3G, 4G]	1.3.46 - 1.3.49
11	Set the SMAW machine and perform welding in different types of MS pipe joints by SMAW. [Different types of MS pipe joints - Butt, Elbow, T-joint, angle (45) joint, flange joint]	1.3.50 - 1.3.51
12	Choose appropriate welding process and perform joining of different types of metals and check its correctness. [appropriate welding process - OAW, SMAW; Different metal - SS, CI, Brass, Aluminium]	1.3.52 - 1.3.54
13	Choose appropriate welding process and perform joining of different types of metals and check its correctness. [appropriate welding process - OAW, SMAW; Different metal - SS, CI, Brass, Aluminium] Demonstrate arc gauging operation to rectify the weld joints.	1.3.55 - 1.3.57
14	Choose appropriate welding process and perform joining of different types of metals and check its correctness. [appropriate welding process - OAW, SMAW; Different metal - SS, CI, Brass, Aluminium]	1.3.58 - 1.3.59
15	Test welded joints by different methods of testing. [different methods of testing- Dye penetration test, Magnetic particle test, Nick break test, Free band test, Fillet fracture test]	1.3.60 - 1.4.64
16	Set GMAW machine and perform welding in different types of joints on MS sheet/plate by GMAW in various positions by dip mode of metal transfer. [different types of joints- Fillet (T-joint, lap, Corner), Butt (Square & V); various positions- 1F, 2F, 3F,4F, 1G, 2G, 3G]	1.5.65 - 1.6.85
17	Set the GTAW machine and perform welding by GTAW in different types of joints on different metals in different position and check correctness of the weld. [different types of joints- Fillet (T-joint, lap, Corner), Butt (Square & V) ; different metals- Aluminium, Stainless Steel; different position- 1F & 1G]	1.6.86 - 1.6.91
18	Perform Aluminium & MS pipe joint by GTAW in flat position.	1.6.92
19	Perform Aluminium & MS pipe joint by GTAW in flat position. Set the Plasma Arc cutting machine and cut ferrous & non-ferrous metals.	1.6.93 - 1.6.94
20	Set the resistance spot welding machine and join MS & SS sheet	1.6.95 - 161.96
21	Perform joining of different similar and dissimilar metals by brazing operation as per standard procedure. [different similar and dissimilar metals- Copper, MS, SS]	1.6.97 - 1.7.100
22	Repair Cast Iron machine parts by selecting appropriate welding process. [Appropriate welding process- OAW, SMAW]	
	Hard facing of alloy steel components / MS rod by using hard facing electrode.	1.7.101 - 1.7.104

SYLLABUS

Duration	Ref. Learning Outcome	Process Code	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 47Hrs; Professional Knowledge 11Hrs	Set the gas welding plant and join MS sheet in different position [Different position:1F, 2F, 3F, 1G, 2G, 3G] Set the SMAW machine and perform different type of joints on MS in different position observing standard procedure [different types of joints- Fillet (T-joint, lap & Corner), Butt (Square & V); different position - 1F, 2F, 3F,4F, 1G, 2G, 3G, 4G]		1 Demonstration of Machinery used in the trade 2 Identification to safety equipment and their use etc. 3 Hack sawing, filing square to dimensions 4 Marking out on MS plate and punching	- Importance of Trade Training - 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.
		OAW-01 SMAW-01	5 Setting of oxy-acetylene welding equipment, Lighting and setting of flame. 6 Perform fusion run without filler rod on MS sheet 2mm thick in flat position. 7 Setting up of Arc welding machine & accessories and striking an arc. 8 Deposit straight line bead on MS plate in flat position.	- 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 21Hrs; Professional Knowledge 05Hrs	Set the gas welding plant and join MS sheet in different position following safety precautions. [Different position: - 1F, 2F, 3F, 1G, 2G, 3G.]	OAW-02 OAW-03	9 Depositing bead 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.	- Different process of metal joining methods: Bolting, riveting, soldering, brazing, seaming etc. - Types of welding joints and its applications. Edge preparation and fit up for different thickness. - Surface Cleaning
Professional Skill 23Hrs; Professional Knowledge 05Hrs	Set the SMAW machine and perform different type of joints on MS in different position observing standard procedure. [different types of joints- Fillet (T-joint, lap & Corner), Butt (Square & V); different position - 1F, 2F, 3F,4F, 1G, 2G, 3G, 4G]	SMAW-02 SMAW-03	11 Straight line beads on M.S. plate 10 mm thick in flat position. 12 Weaved bead on M. S plate 10mm 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.
Professional Skill 23Hrs; Professional Knowledge 05Hrs	Set the oxy- acetylene cutting plant and perform different cutting operations on MS plate. [Different cutting operation - Straight, Bevel, circular]	OAGC-01 OAGC-02 OAGC-03	13 Setting up of oxy-acetylene and make straight cuts (freehand) 14 Perform marking and straight line cutting of MS plate 10 mm thick by gas. Accuracy within ±2mm. 15 Beveling of MS plates 10 mm thick, cutting regular geometrical shapes and irregular shapes, cutting chamfers by gas cutting.	- 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.

		OAGC-04 OAGC-05 OAGC-06	16 Marking and perform radial cuts, cutting out holes using oxy-acetylene gas cutting. 17 Identify cutting defects viz., distortion, grooved, fluted or ragged cuts; poor draglines; rounded edges; tightly adhering slag.	
Professional Skill 126Hrs; Professional Knowledge 31Hrs	Set the gas welding plant and join MS sheet in different position following safety precautions. [Different position: - 1F, 2F, 3F, 1G, 2G, 3G.] Set the SMAW machine and perform different type of joints on MS in different position observing standard procedure. [different types of joints- Fillet (T-joint, lap & Corner), Butt (Square & V); different position - 1F, 2F, 3F,4F, 1G, 2G, 3G, 4G]	OAW-04 SMAW-04 OAW-05	18 Square butt joint on M.S. sheet 2 mm thick in flat Position. **(1G)** 19. Fillet "T" joint on M.S. Plate 10 mm thick in flat position. **(1F)** 20. Open corner joint on MS sheet 2 mm thick in flat Position **(1F)**	- 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
		SMAW-05 OAW-06 SMAW-06	21 Fillet lap joint on M.S. plate 10 mm thick in flat position. **(1F)** 22 Fillet "T" joint on MS sheet 2 mm thick in flat position. **(1F)** 23 Open Corner joint on MS plate 10 mm thick in flat position. **(1F)**	- Welding positions as per EN &ASME: flat, horizontal, vertical and over head position. - Weld slope and rotation. - Welding symbols as per BIS & AWS.
		OAW-07 SMAW-07 I&T-01	24 Fillet Lap joint on MS sheet 2 mm thick in flat position. **(1F)** 25 Single "V" Butt joint on MS plate 12 mm thick in flat position **(1G).** 26 Testing of weld joints by visual inspection. 27 Inspection of welds by using weld gauges.	- Arc length - types - effects of arc length. - Polarity: Types and applications. - Weld quality inspection, common welding mistakes and appearance of good and defective welds - Weld gauges & its uses.
		OAW-08 SMAW-08 SMAW-09	28 Square Butt joint on M.S. sheet. 2 mm thick in Horizontal position. (2G) 29 Straight line beads and multi layer practice on M.S. Plate 10 mm thick in Horizontal position. 30 Fillet "T" joint on M.S. plate 10 mm thick in Horizontal position. (2F)	- Calcium carbide uses and hazard. - Acetylene gas properties and flash back arrestor.
		OAW-09	31 Fillet Lap joint on M.S. sheet 2 mm thick in horizontal position **(2F)**	- Oxygen gas and its properties, uses in welding. - Charging process of oxygen and acetylene gases
		SMAW-10	32 Fillet Lap joint on M.S. plate 10 mm thick in horizontal position. **(2F)**	- Oxygen and Dissolved Acetylene gas cylinders and Color coding for different gas cylinders. - Uses of single and double stage Gas regulators.

		OAW-10 OAW-11 SMAW-11	33 Fusion run with filler rod in vertical position on 2mm thick M.S sheet. 34 Square Butt joint on M.S. sheet. 2 mm thick in vertical position **(3G)** 35 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.
		SMAW-12 OAW-12 SMAW-13	36 Fillet "T" joint on M.S sheet 2 mm thick in vertical position. **(3F)** 37 Fillet "T" joint on M.S. plate 10 mm thick in vertical position. **(3F)**	- 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 80 Hrs; Professional Knowledge 17Hrs	Set the SMAW machine and perform different type of joints on MS in different position observing standard procedure. [different types of joints- Fillet (T-joint, lap & Corner), Butt (Square & V); different position - 1F, 2F, 3F,4F, 1G, 2G, 3G, 4G] Perform welding in different types of MS pipe joints by Gas welding (OAW). [Different types of MS pipe joints - Butt, Elbow, T-joint, angle (45°) joint, flange joint]	OAW-13 SMAW-14	38 Structural pipe welding butt joint on MS pipe Ø 50 and 3mm WT in 1G position. 39 Fillet Lap joint on M.S. Plate 10 mm in vertical position. **(3G)**	- Specification of pipes, various types of pipe joints, pipe welding all positions, and procedure. - Difference between pipe welding and plate welding.
		SMAW-15 OAW-14	40 Open Corner joint on MS plate 10 mm thick in vertical position. **(2F)** 41 Pipe welding - Elbow joint on MS pipe Ø 50 and 3mm WT. **(1G)**	- Pipe development for Elbow joint, "T" joint, Y joint and branch joint - Brief use of Manifold system
		OAW-15 SMAW-16	42 Pipe welding "T" joint on MS pipe Ø 50 and 3mm WT. **(1G)**	- Gas welding filler rods, specifications and sizes. - Gas welding fluxes - types and functions.
			43 Single "V" Butt joint on MS plate12 mm thick in vertical position (3G).	- Gas Brazing & Soldering : principles, types fluxes & uses - Gas welding defects, causes and remedies
		OAW-16 SMAW-17	44 Pipe welding 45 ° angle joint on MS pipe Ø 50 and 3mm WT. **(1G)** 45 Straight line beads on M.S. plate 10mm thick in over head position.	- Electrode : types, functions of flux, coating factor, sizespecifications of electrode, Coding of electrode as per BIS, AWS, - Effects of moisture pick up. - Storage and baking of electrodes.
Professional Skill 61Hrs; Professional Knowledge 06Hrs	Set the SMAW machine and perform different type of joints on MS in different position observing standard procedure. [different types of joints- Fillet	SMAW-18 SMAW-19	46 Pipe Flange joint on M.S plate with MS pipe Ø 50 mm X 3mm WT **(1F)** 47 Fillet "T" joint on M.S. plate 10 mm thick in over head position. **(4F)**	- Weldability of metals, importance of pre heating, post heating and maintenance of inter pass temperature.

	(T-joint, lap & Corner), Butt (Square & V); different position - 1F, 2F, 3F,4F, 1G, 2G, 3G, 4G] Set the SMAW machine and perform welding in different types of MS pipe joints by SMAW. [Different types of MS pipe joints - Butt, Elbow, T-joint, angle (45) joint, flange joint]	SMAW-20 SMAW-21	48 Pipe welding butt joint on MS pipe Ø 50 and 5 mm WT. in 1G position. 49 Fillet Lap joint on M.S. plate 10 mm thick in over head position. **(4G).**	- Welding of low, medium and high carbon steel and alloy steels.
		SMAW-22 SMAW-23	50 Single "V" Butt joint on MS plate 10mm thick inover head position**(4G)** 51 Pipe butt joint on M. S. pipe Ø 50mm WT 6mm (**1G** Rolled).	- Stainless steel types- weld decay and weldability.
Professional Skill 25 Hrs; Professional Knowledge 04Hrs	Choose appropriate welding process and perform joining of different types of metals and check its correctness. [appropriate welding process - OAW, SMAW; Different metal - SS, CI, Brass, Aluminium]	OAW-17 SMAW-24 OAW-18	52 Butt joint of copper pipe ½ inch by brazing process by induction welding machine 53 Square Butt joint on S.S. Sheet 2 mm thick in flat position. **(1G)** 54 Corner/T joint of copper pipe of ½ inch and of length 75 mm	- Induction welding, brazing of copper tubes. - Brass - types - properties and welding methods. - Copper - types - properties and welding methods. - Brazing cutting tools.
Professional Skill 21Hrs; Professional Knowledge 04Hrs	Choose appropriate welding process and perform joining of different types of metals and check its correctness. [appropriate welding process - OAW, SMAW; Different metal - SS, CI, Brass, Aluminium] Demonstrate arc gauging operation to rectify the weld joints.	OAW-19 SMAW-25 AG-01	55 Square Butt & Lap joint on M.S. sheet 2 mm thick by brazing in flat position. 56 Single "V" butt joint C.I. plate 6mm thick in flat position. **(1G)** 57 Arc gouging on MS plate 10 mm thick.	- Aluminium properties and weldability, Welding methods - Arc cutting & gouging,
Professional Skill 20Hrs; Professional Knowledge 04Hrs	Choose appropriate welding process and perform joining of different types of metals and check its correctness. [appropriate welding process - OAW, SMAW; Different metal - SS, CI, Brass, Aluminium]	OAW-20 OAW-21	58 Square Butt joint on Aluminium sheet. 3 mm thick in flat position. 59 Bronze welding of cast iron (Single "V" butt joint) 6mm thick plate **(1G).**	- Cast iron and its properties types. - Welding methods of cast iron.
Professional Skill 25 Hrs; Professional Knowledge 04Hrs	Test welded joints by different methods of testing. [different methods of testing- Dye penetration test, Magnetic particle test, Nick break test, Free band test, Fillet fracture test]	I&T-02 I&T-03 I&T-04 I&T-05 I&T-06	60 Dye penetrant test. 61 Magnetic particle test. 62 Nick- break test. 63 Free bend test. 64 Fillet fracture test.	- Types of Inspection methods - Classification of destructive and NDT methods - Welding economics and Cost estimation.

Professional Skill 166Hrs; Professional Knowledge 32Hrs	Set GMAW machine and perform welding in different types of joints on MS sheet/plate by GMAW in various positions by dip mode of metal transfer. [different types of joints- Fillet (T-joint, lap, Corner), Butt (Square & V); various positions- 1F, 2F, 3F,4F, 1G, 2G, 3G]	GMAW-01 GMAW-02	65 Introduction to safety equipment and their use etc. 66 Setting up of GMAW welding machine & accessories and striking an arc. 67 Depositing straight line beads on M.S Plate. 68 Fillet weld - "T" joint on M.S plate 10mm thick in flat position by Dip transfer. **(1F)**	- Safety precautions in Gas Metal Arc Welding and Gas Tungsten Arc welding. - Introduction to GMAW - equipment - accessories. - Various other names of the process. (MIG/MAG/ CO_2 welding.)
		GMAW-03 GMAW-04 GMAW-05	69 Fillet weld - Lap joint on M.S. sheet 3mm thick in flat position by Dip transfer. **(1F)** 70 Fillet weld - "T" joint on M.S. sheet 3mm thick in flat position by Dip transfer. **(1F)** 71 Fillet weld - corner joint on M.S. sheet 3mm thick in flat position by Dip transfer. **(1F)**	- Advantages of GMAW welding over SMAW , limitations and applications - Process variables of GMAW.
		GMAW-06 GMAW-07	72 Butt weld - Square butt joint on M.S sheet 3mm thick in flat position **(1G)** 73 Butt weld - Single "V" butt joint on M.S plate 10 mm thick by Dip transfer in flat position. **(1G)**	- Wire feed system - types - care and maintenance. - Welding wires used in GMAW, standard diameter and codification as per AWS.
		GMAW-08 GMAW-09	74 Fillet weld - "T" joint on M.S plate 10mm thick in Horizontal position by Dip transfer. **(2F)** 75 Fillet weld - corner joint on M.S plate 10mm thick in Horizontal position by Dip transfer. **(2F)**	- Name of shielding gases used in GMAW and its applications. - Flux cored arc welding - description, advantage, welding wires, coding as per AWS.
		GMAW-10 GMAW-11	76 Fillet weld - "T" joint on M.S. sheet 3mm thick in Horizontal position by Dip transfer. **(2F)** 77 Fillet weld - corner joint on M.S. sheet 3mm thick in Horizontal position by Dip transfer. **(2F)**	- Edge preparation of various thicknesses of metals for GMAW. - GMAW defects, causes and remedies
		GMAW-12 GMAW-13	78 Fillet weld - "T" joint on M.S plate 10mm thick in vertical position by Dip transfer. **(3F)** 79 Fillet weld - corner joint on M.S plate 10mm thick in vertical position by dip transfer. **(3F)**	- Heat input and techniques of controlling heat input during welding. - Heat distribution and effect of faster cooling
		GMAW-14 GMAW-15	80 Fillet weld - Lap joint on M.S. sheet 3mm thick in vertical position by Dip transfer. (3F) 81 Fillet weld - corner joint on M.S. sheet 3mm thick in vertical position by Dip transfer. (3F)	- Pre heating & Post Weld Heat Treatment - Use of temperature indicating crayons.
		GMAW-16 GMAW-17	82 Fillet weld - Lap and "T" joint on M.S sheet 3mm thick inoverhead position by Dip transfer. (4F) 83 Tee Joints on MS Pipe Ø 60 mm OD x 3 mm WT 1G position - Arc constant (Rolling)	- Submerged arc welding process -principles, equipment, advantages and limitations

		GMAW-18 GMAW-19	84 Depositing bead on S.S sheet in flat position. 85 Butt joint on Stainless steel 2 mm thick sheet in flat position by Dip transfer.	- Thermit welding process- types, principles, equipments, Thermit mixture types and applications. - Use of backing strips and backing bars
Professional Skill 80 Hrs; Professional Knowledge 14Hrs	Set the GTAW machine and perform welding by GTAW in different types of joints on different metals in different position and check correctness of the weld. [different types of joints- Fillet (T-joint, lap, Corner), Butt (Square & V) ; different metals- Aluminium, Stainless Steel; different position- 1F & 1G]	GMAW-01 GMAW-02	86 Depositing bead on Aluminium sheet 2 mm thick in flat position. 87 Square butt joint on Aluminium sheet 1.6mm thick in flat position.	- GTAW process - brief description. Difference between AC and DC welding, equipments, polarities and applications. - Power sources for GTAW - AC &DC
		GMAW-03 GMAW-04	88 Fillet weld - "T" joint on Aluminium sheet 1.6 mm thick in flat position. **(1F)** 89 Fillet weld - Outside corner joint on Aluminium sheet 2 mm thick in flat position. **(1F)**	- Tungsten electrodes - types & uses, sizes and preparation - GTAW Torches- types, parts and their functions - GTAW filler rods and selection criteria.
		GMAW-05	90 Butt weld - Square butt joint on Stainless steel sheet 1.6 mm thick in flat position with purging gas **(1G)**	- Edge preparation and fit up. - GTAW parameters for welding of different thickness of metals
		GMAW-06	91 Fillet weld - "T" joint on Stainless steel sheet 1.6 mm thick in flat position. **(1F)**	- Argon / Helium gas properties - uses. - GTAW Defects, causes and remedy.
Professional Skill 20Hrs; Professional Knowledge 04Hrs	Perform Aluminium & MS pipe joint by GTAW in flat position.	GMAW-07	92 Pipe butt joint on Aluminium pipe Ø 50 mm x 3 mm WT in Flat position. **(1G)**	- Friction welding process- equipment and application - Laser beam welding (LBW).
Professional Skill 20Hrs; Professional Knowledge 03Hrs	Perform Aluminium & MS pipe joint by GTAW in flat position. Set the Plasma Arc cutting machine and cut ferrous & non-ferrous metals.	GMAW-08 PAC-01	93 "T" Joints on MS Pipe Ø 50 mm OD x 3 mm WT, position - Flat **(1F)** 94 Straight cutting on ferrous and non ferrous	- Plasma Arc Welding (PAW) and cutting (PAC) process - equipments and principles of operation. - Types of Plasma arc, advantages and applications.
Professional Skill 20Hrs; Professional Knowledge 02Hrs	Set the resistance spot welding machine and join MS & SS sheet.	RW-01 RW-02	95 Lap joint on Stainless steel sheet by Resistance Spot welding. 96 MS sheets joining by Resistance Spot welding	- Resistance welding process -types, principles, power sources and welding parameters. - Applications and limitations.

Professional Skill 41 Hrs; Professional Knowledge 10Hrs	Perform joining of different similar and dissimilar metals by brazing operation as per standard procedure. [different similar and dissimilar metals- Copper, MS, SS]	OAW-01 OAW-02	97 Square butt joint on Copper sheet 2mm thick in flat position. **(1G)** 98 "T" joint on Copper to MS sheet 2mm thick in flat position by Brazing **(1F)**	- Metalizing - types of metalizing principles. - Manual Oxy - acetylene powder coating process- principles of operation and applications
		OAW-03 OAW-04	99 Silver brazing on S.S Sheet with copper sheet "T" joint. 100 Silver brazing on copper tube to tube.	- Reading of assembly drawing - Welding Procedure Specification (WPS) and Procedure Qualification Record (PQR)
Professional Skill 24Hrs; Professional Knowledge 01Hrs	Repair Cast Iron machine parts by selecting appropriate welding process. [Appropriate welding process- OAW, SMAW] Hard facing of alloy steel components / MS rod by using hard facing electrode.	OAW-05 SMAW-01 SMAW-02	101 Repair welding of broken C.I. machine parts by oxy-acetylene welding with C.I and bronze filler rod. 102 Repair welding of broken C.I machine parts by C.I. electrode. 103 Repair plastic broken parts or pipes by plastic welding machine. 104. Make a plastic tank with plastic sheet of PVC. Dimensions 150*100*100	- Hard facing/ surfacing necessity, surface pre paration, various hard facing alloys and a dvantages of hard facing. - Plastic welding machine with hot air gun and plastic material: Polypropylene (PP) Polyethylene (PE) Polyvinylchloride (PVC)

Importance of trade training

Objectives: At the end of this lesson you shall be able to
- **state the competencies achieved in this welder trade**
- **describe the further learning path ways craftsman training scheme**
- **explain the employment opportunities on completion of welder trade.**

This trade is meant for the candidates who aspire to become a professional WELDER. The duration of the trade is two semesters under craftsman training scheme.

Competencies achieved

After successful completion of this trade trainee shall be able to perform the following skills with proper sequence.

1 Welding of M.S. sheet and M.S. pipe by Gas welding process.

2 Welding of M.S. plate in all position by SMAW process.

3 Straight, bevel & circular cutting on MS. plate by Oxy-acetylene cutting process.

4 Repair & Maintenance works

5 GMAW welding on M.S sheet & M.S plate.

6 Operating skills of spot welding machine, PUG cutting machine,

7 Welding C.I using SMAW process.

Further learning pathways

Also on successful completion of the trade the candidate can pursue apprenticeship training in Registered Industries/ Organization, further for a period of one year under Apprenticeship Training scheme to acquire practical skills and knowledge.

Employment Opportunities

On successful completion of this trade, the candidates shall gain to be fully employed in the following industries:

1 Structural fabrication like bridges, Roof structures, Building & construction.

2 Automobile and allied industries.

3 Site construction activities for power stations, process industries and mining.

4 Service industries like road transportation and railways.

5 Ship building and repair.

6 Infrastructure and defense organizations.

7 In public sector industries like BHEL, NTPC, etc, and private industries in India & Abroad.

8 Petrochemical industries like ONGC, LOCL, and HPCL etc.,

9 Self employment.

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**
- **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 safe as well as other's safety while doing the practical.

Scan QR code for this exercise

Elementary first aid

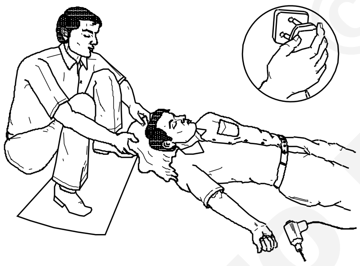
Objective: At the end of this lesson you shall be able to
- **understand the first aid treatment various problems.**

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



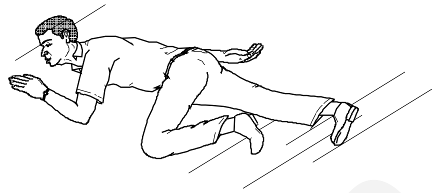
If you remain un-insulated, do not touch the victim with your bare hands until the circuit is made dead or he is moved away from the equipment.

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 comfor table (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 causality 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.

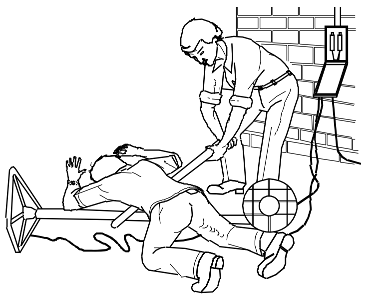
Treatment for electric shock:

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 tubing, Bakelite paper, tube etc. (Fig 5)

Fig 5



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.

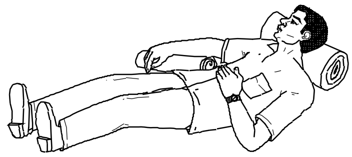
Burns and scalds: Burns are very painful. If a large area of the body is burnt, give no treatment, except to exclude the air. eg, by covering with water, clean paper, or a clean shirt. This relieves the pain.

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)

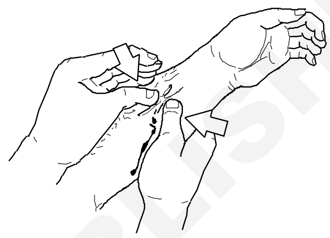
Fig 6



- 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)

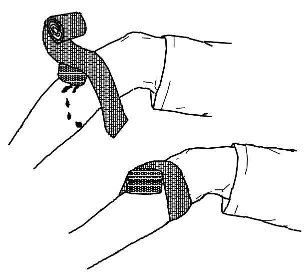
Fig 7



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



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
- **state the importance of welding in industry**
- **state the advantages of welding.**

In engineering industry, joining of different type of metals is necessary to make various components/parts having different shapes. Various type of parts is 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 fabrication 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 precaution in Shielded Metal Arc Welding, and Oxy - Acetylene Welding and cutting

Scan QR code for this exercise

Objectives: At the end of this lesson you shall be able to
- **identify safety precaution in SMAW, OAW**
- **identify safety precaution in cutting process.**

Arc welding safety precautions

Arc welding can be hazardous shielded metal arc welding and oxy-acetyl CNC welding therefore you need to protect yourself and others from possible serious injury or death.

- Keep children away
- Pacemaker wearers, consult your doctor first
- Have all installation, operation, maintenance and repair work performed only by qualified people

Prevent Electric Shocks

Touching live electrical parts can cause fatal shocks or severe burns. The electrode and work circuit is electrically live whenever the output is on.

The input power circuit and machine internal circuits are also live when power is on. In semi-automatic or automatic wire welding, the wire, wire reel, drive roll housing, and all metal parts touching the welding wire are electrically live. Incorrectly installed or improperly grounded equipment is a hazard. Therefore:

- Do not touch live electrical parts.
- Wear dry, hole-free insulating gloves and body protection.
- Insulate yourself from work and ground using dry insulating
- Disconnect input power or stop engine before installing or
- Properly install and ground this equipment according to its Owner's Manual and national and local codes.
- When making input connections, attach proper grounding conductor first.
- Turn off all equipment when not in use.
- Do not use worn, damaged, undersized, or poorly spliced cables.
- Do not wrap cables around your body.
- Ground the work piece to a good electrical (earth) ground.
- Do not touch electrode if in contact with the work or ground.
- Use only well-maintained equipment. Repair or replace damaged parts at once.
- Wear a safety harness if working above floor level.
- Keep all panels and covers securely in place.
- Use approved earplugs or ear muffs if noise level is high.
- Wear a welding helmet fitted with a proper shade of filter lens (see ANSI Z49.1 listed in Safety Standards) to protect your face and eyes when welding or watching.
- Wear approved safety glasses. Side shields recommended.
- Use protective screens or barriers to protect others from flash and glare; warn others not to watch the arc.
- Keep your head out of the fumes.
- Do not breathe the fumes.
- If inside, ventilate the area and/or use extractor at the arc to remove welding fumes and gases.
- Protect yourself and others from flying sparks and hot metal.
- Do not weld where flying sparks can strike flammable material.
- Remove all flammables within 10m of the welding arc. If this is not possible, tightly cover them with approved covers.
- Wear approved face shield or safety goggles. Side shields recommended.
- Wear proper body protection to protect skin.
- Keep cylinders away from any welding or other electrical circuits.
- Never allow a welding electrode to touch any cylinder.
- Install and secure cylinders in upright position by chaining them to a stationary support or equipment cylinder rack to prevent falling or tipping.
- Keep away from pinch points such as drive rolls.
- Keep all doors, panels, covers and guards closed and securely in place.

Magnetic fields from high currents can affect pacemaker operation. Pacemaker wearers should keep away from arc welding equipment.

OAW welding safety precautions

1 Secure in vertical position

2 Store in right spaces

3 Keep grease and oil away

4 Ensure flame arresters are properly fitted
5 Keep pressure of oxygen higher
6 Handle acetylene with care
7 Rectify cause of backfire
8 Handle flashback carefully
9 Ensure proper connections
10 Keep a steady watch
11 Prevent interchange of hoses
12 Replace old and faulty hoses
13 Handle hoses properly
14 Use only approved leak detection fluid
15 Never use sealing tape
16 Never over tight connections
17 Take proper steps for maintenance
18 Use safe ignitors only
19 Never use oxygen
20 Discard hoses that had flashback

Introduction and definition of welding

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

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 fabrication 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.

Welding definition

Welding is a fabrication process by which two or more parts are fused together by means of heat, pressure or both forming a join as the parts cool. Welding is usually used on metals and thermoplastics. The completed welded joint may be referred to a weldment.

The parts that are joined are known as a parent material. The material added which helps to form the joint is called **filler** or **consumable.**

Consumable are usually chosen to be similar in composition to the parent material, forming a homogenous weld. Welding brittle cast irons, a filler with different composition is used.

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.

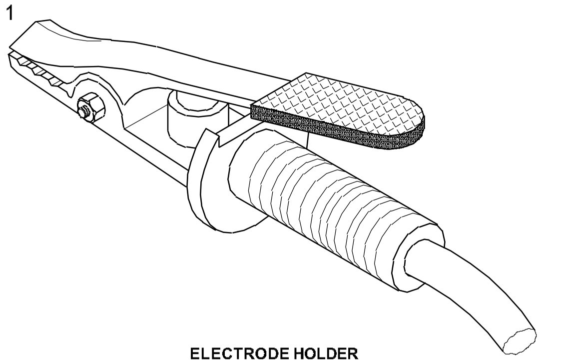
Arc & Gas welding equipment tools and accessories

Objectives: At the end of this lesson you shall be able to
- **name the arc & gas welding equipment's tools & accessories**
- **describe the uses of tools & accessories.**

Scan QR code for this exercise

Arc welding accessories

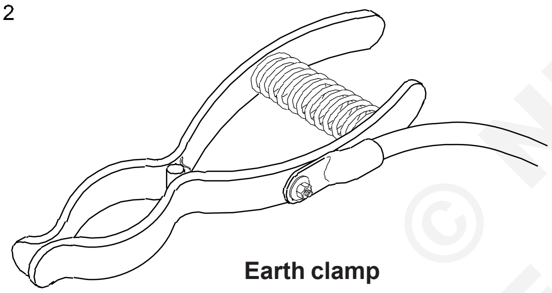
Fig 1



ELECTRODE HOLDER

WL20N110721

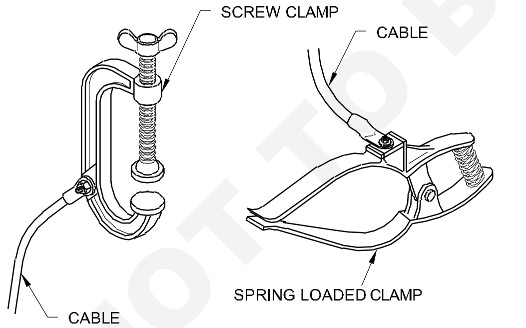
Fig 2



Earth clamp

WL20N110722

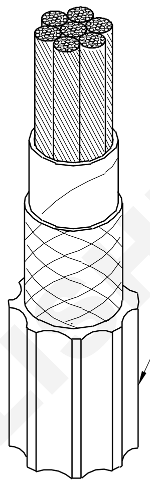
Fig 3



WORK CABLE ATTACHMENTS

WL20N110723

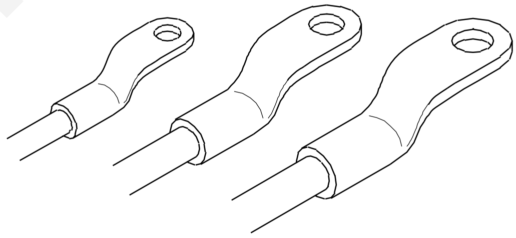
Fig 4



WELDING CABLE WITH HEAVY RIBBED OUTER RUBBER COVERING

WL20N110724

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

WL20N110725

Table 1

Recommendations of copper cable for arc welding

Cable dia.	Lengths of cable in metres current capacity in amperes		
(mm)	0 - 15	15 - 30	30 - 75
24.0	600	600	400
21.0	500	400	300
19.0	400	350	300
18.0	300	300	200
16.5	250	200	175
15.5	200	195	150
14.5	150	150	100
13.5	125	100	75

Oxy-acetylene welding equipment and accessories

Fig 6

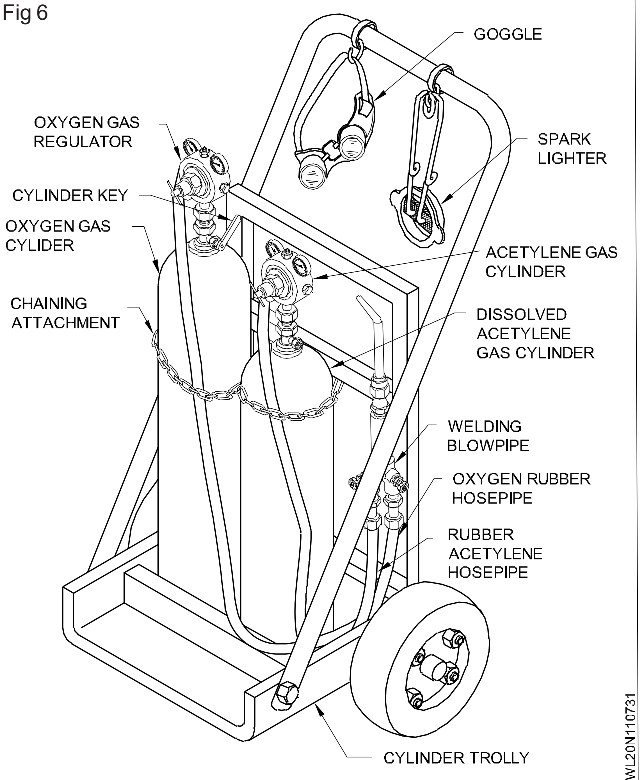


Fig 7

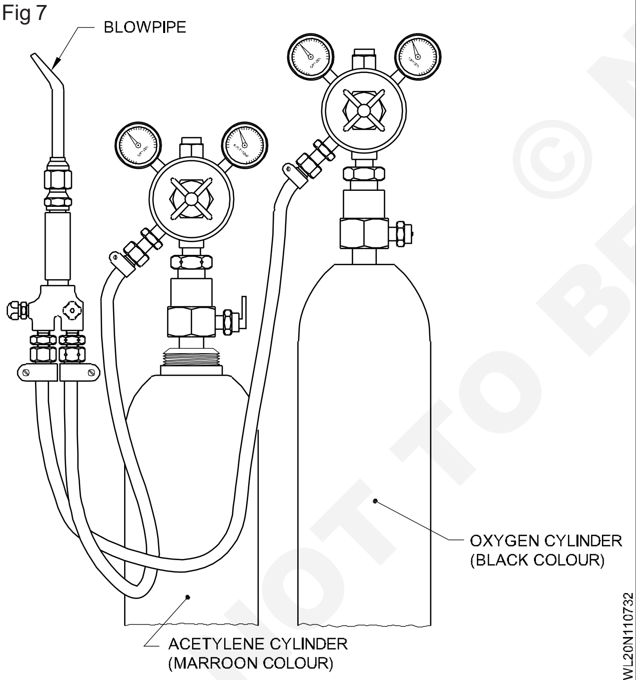


Fig 8

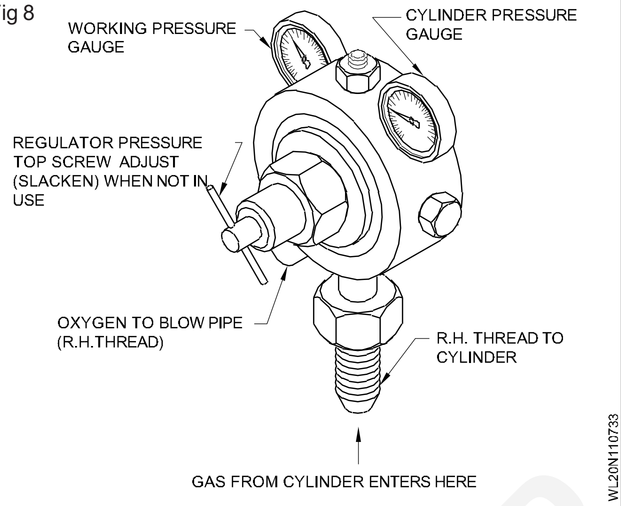
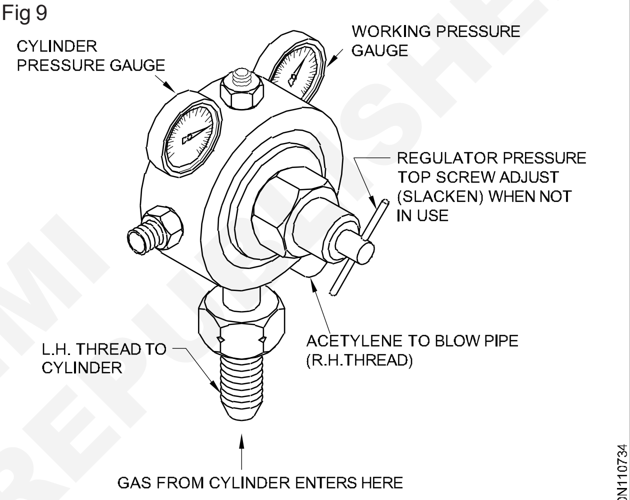


Fig 9



ACETYLENE PRESSURE REGULATOR

Fig 10

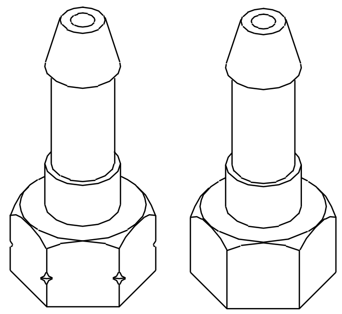
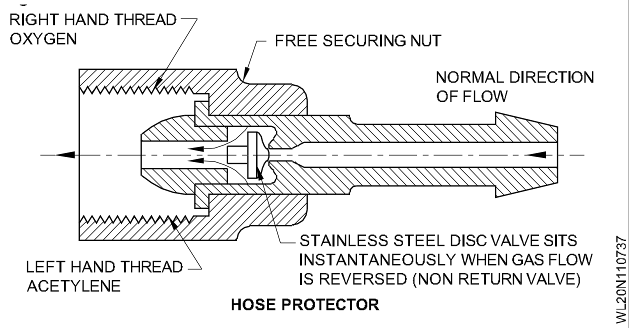


Fig 11



HOSE PROTECTOR

Fig 12

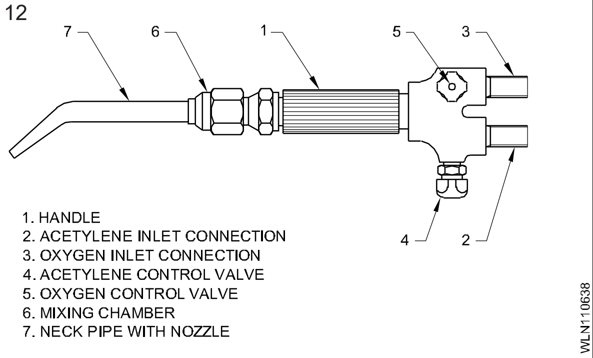
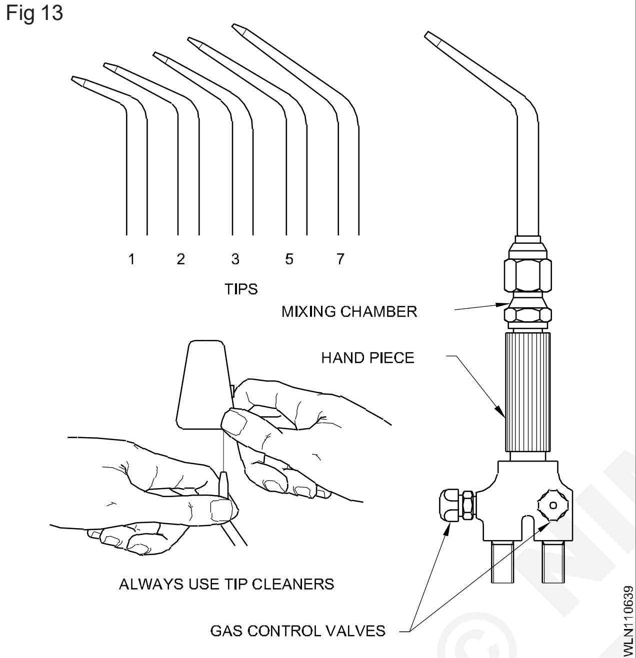


Fig 13



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

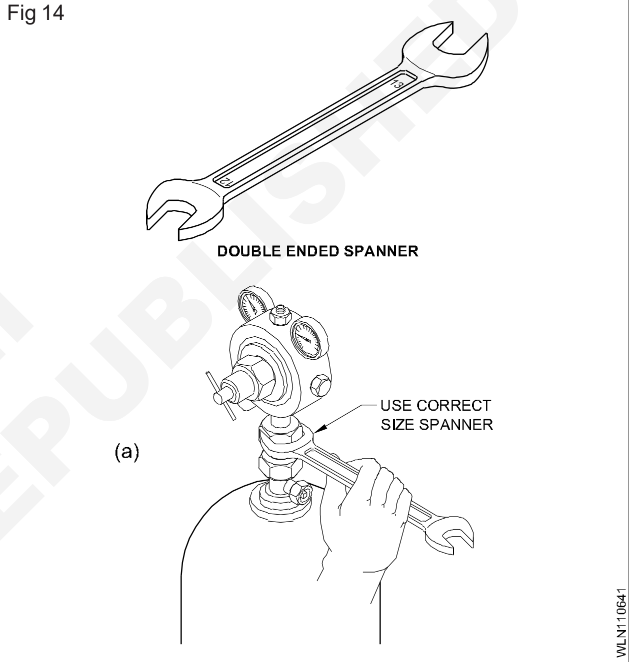
Gas welding hand tools

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

Double ended spanner: A double ended spanner is shown in Fig 14 and 15a. 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 14. 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 14



Cylinder Key: A cylinder key is shown in Fig 15. 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.

Nozzle or tip cleaner

Cleaning the tip: All welding torch tips are made of copper alloy. 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 16)

Before cleaning the tip, select the correct drill and move it, without turning, up and down through the tip Fig 17.

The smooth file is then used to clean the surface of the tip Fig 18. While cleaning, leave the oxygen valve partly open to blow out the dust.

Fig 15

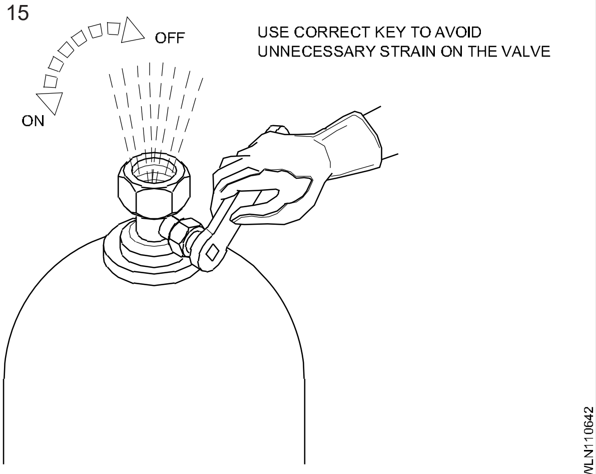


Fig 16

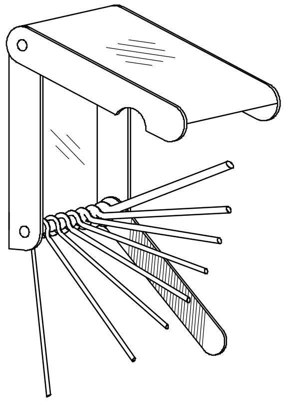


Fig 17

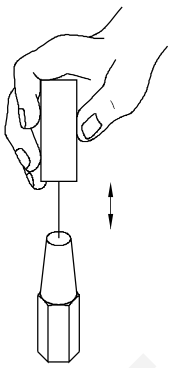
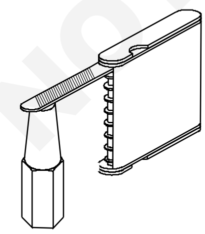


Fig 18



Spark lighter: The spark lighter, as illustrated in Fig 19 & 20 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 19

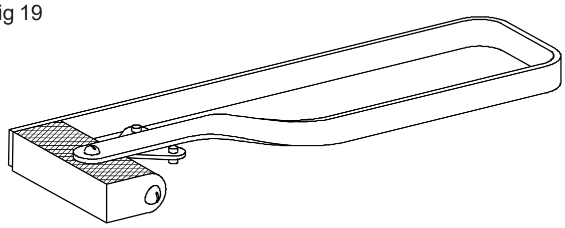
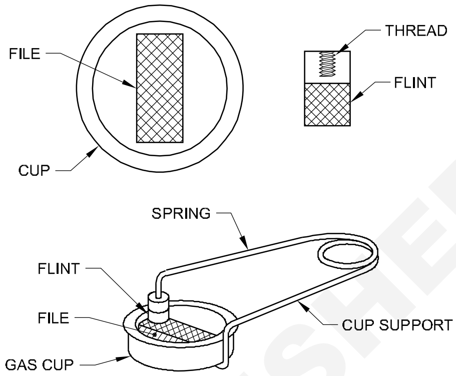
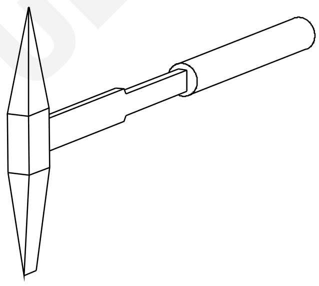


Fig 20



Chipping hammer: chipping hammer is a tool used to remove welding slag after arc welding

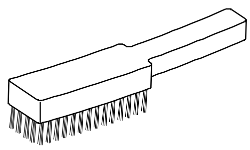
Fig 21



CHIPPING HAMMER

Wire brush: A wire brush is used for cleaning the welding surface, removal of slag, rust etc.

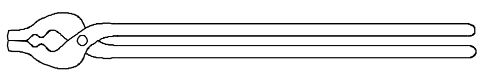
Fig 22



WIRE BRUSH

Tongs: an instrument with two movable arms that are joined at one end. It is used to pick up and hold hot pieces of metal

Fig 23



TONGS

Various welding processes and its application

Objectives: At the end of this lesson you shall be able to
- **classified the electric arc & gas welding process**
- **name 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-liquefied petroleum gas welding
- Air acetylene gas welding.

The other welding processes are:

- Thermite 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	Thermite
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 welding 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 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 nonferrous metals, generally of 3mm thickness and below.

Oxy-other fuel gases welding: Fuel gases like hydrogen, coal gas, liquefied 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.

Thermite 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 & definitions

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

Arc & Gas welding terms & Its Definition

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).

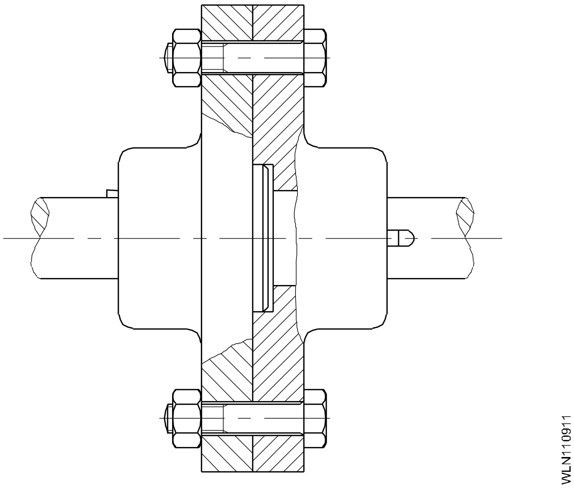
25 **Electrode** (Flux coated) A metal stick which is coated with flux and having parts indicated as stub end, tip, bare/core wire and flux coating. The size of this is determined by size of bare/core wire diameter. (This is used in shielded Metal Arc welding as consumable material).

Different process to metal joining method

Objectives: At the end of this lesson you shall be able to
- **identify the different types of bolts and nuts and their uses**
- **identify the types of rivets and its uses**
- **explain soldering and brazing methods.**

Bolts and nuts (Fig 1)

Fig 1



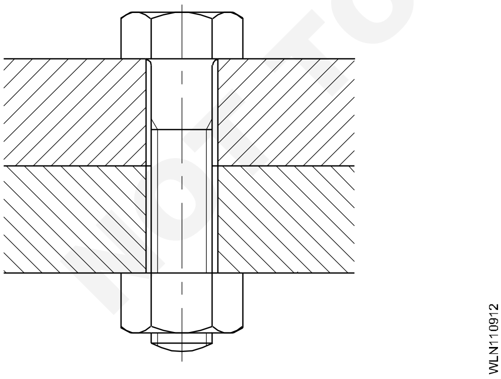
These are generally used to clamp two parts together.

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

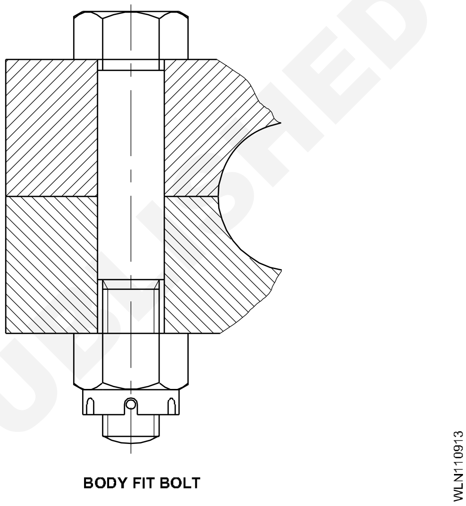


This is the most common type of fastening arrangement using bolts. The size of the hole is slightly larger than the belt (Clearance hole).

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

Body fit bolt (Fig 3)

Fig 3

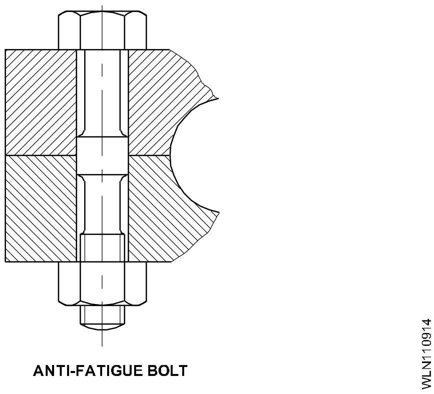


This type of bolt assembly is used when the relative movement between the work pieces has to be prevented. The diameter of the threaded portion is slightly smaller than the shank diameter of the bolt.

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

Anti-fatigue bolt (Fig 4)

Fig 4

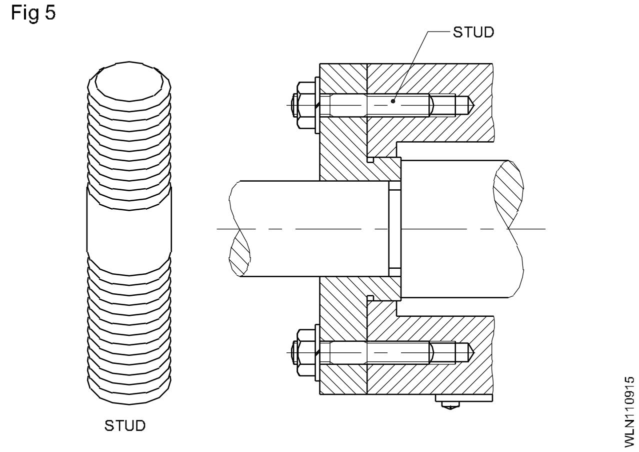


This type of bolt is used when the assembly is subjected to alternating load conditions continuously. Connecting rod with big ends in engine assembly are examples of this application.

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 joins

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

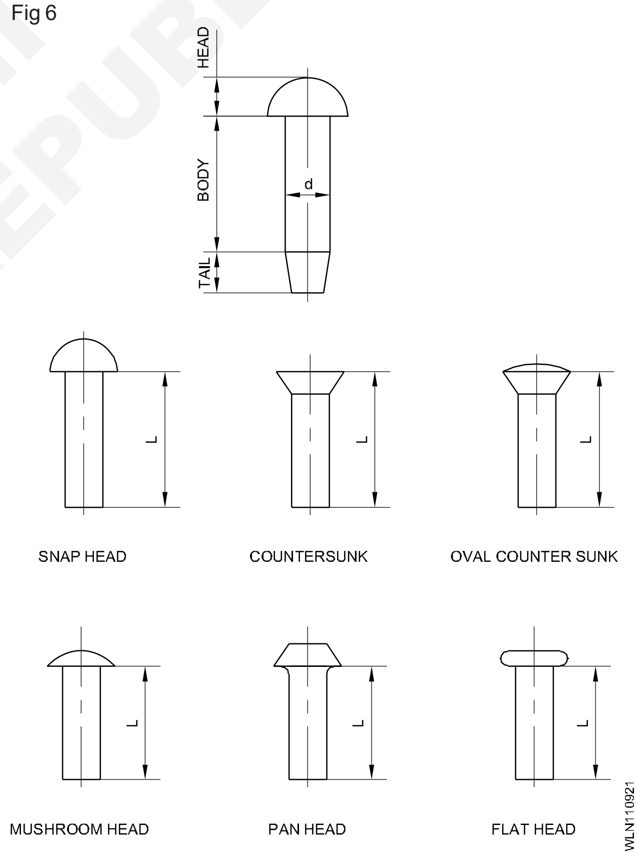
There are various kinds of rivets as shown in Fig 1. Snap head rivets, countersink rivets and thin bevel head rivets are widely used in sheet metal work.

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 6)

Fig 6



Rivet joints (Fig 7)

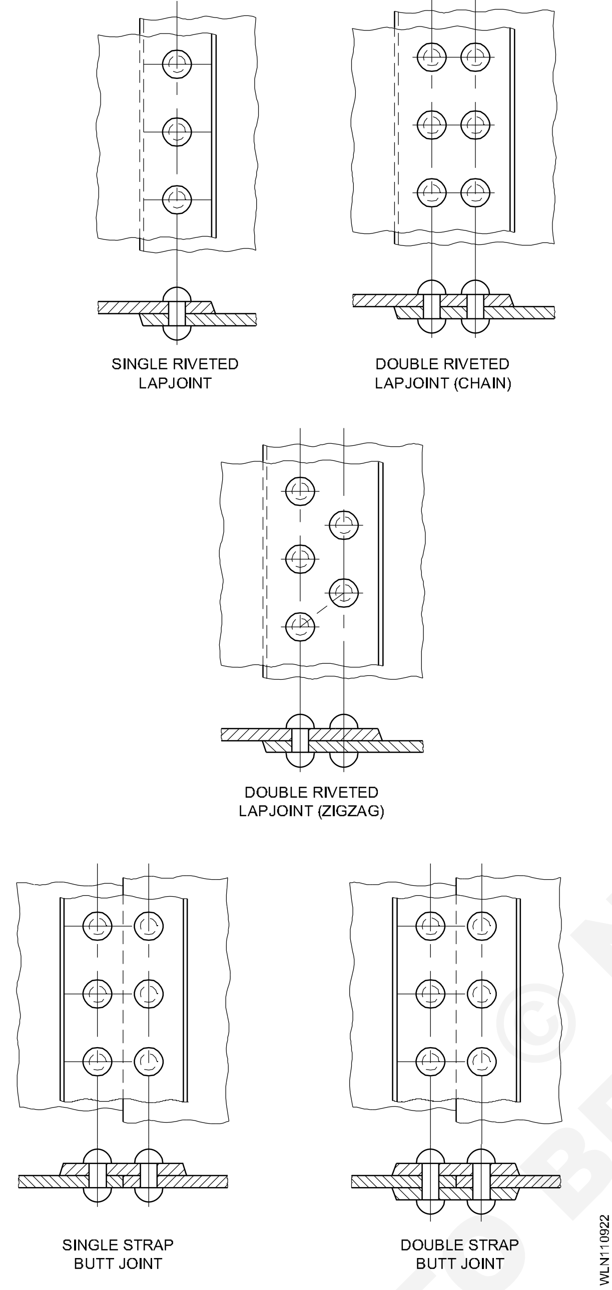
Rivet joints are classified as lap joints and butt joints.

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.

Fig 7



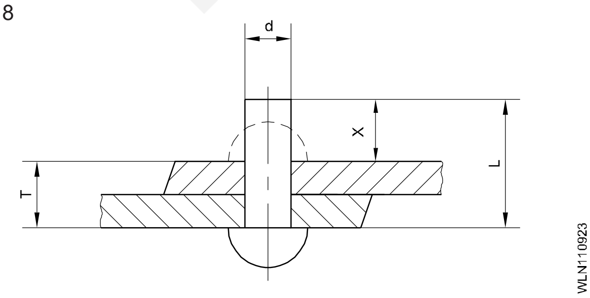
When forming a round head (Fig 8) the interference X is given as

X = d X (1.3, -- 1.6)

where = rivet interference(mm)

d = rivet diameter (mm)

Fig 8



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.

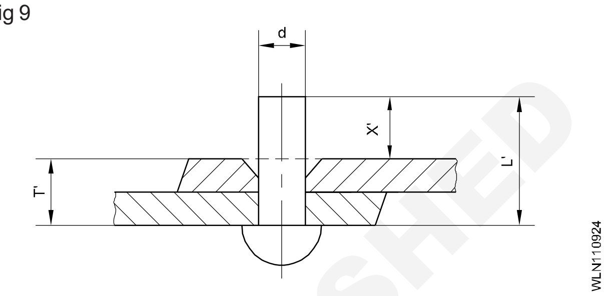
L = T + d (1.3 - 1.6)

When forming a flat head (Fig 9) 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 9



Soldering

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.

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, fluoroborates, boric acid, wetting agents and water. So suitable flux combination is selected based on metal being used.

Brazing is employed where a ductile joint 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.

Advantages of brazing

The completed joint requires little or no finishing.

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

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

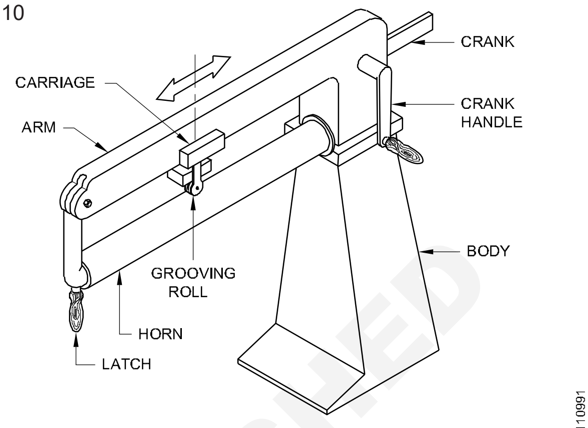
The colour of the brazing alloy which ranges from silver white to copper red may not match the base metal very closely.

Seaming and Machine

Grooved seam can also be closed or locked mechanically by means of the seam closing machine. This machine is also called “Seaming machine”

Parts shown in Fig 10 are Body, Arm, Pressure roller, Carriage, Crank handle, Latch and Crank rack.

Fig 10

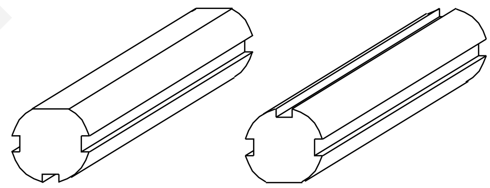


GROOVING MACHINE

Horn: It contains grooves of various widths on throughout the length as shown in Fig 11.

Pressure roller: Two types of pressure rollers are available along with the machine. One is flat roller and the other is grooved one. Grooved roller is having grooves of 3 mm, 4 mm, 5 mm and 6 mm widths.

Fig 11



Types of welding joints and its application, edge preparation & fit-up for different thickness

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

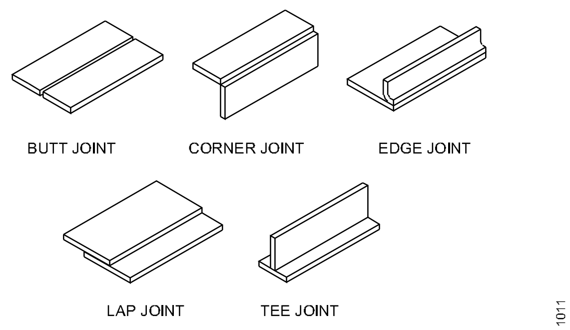
Scan QR code for this exercise

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

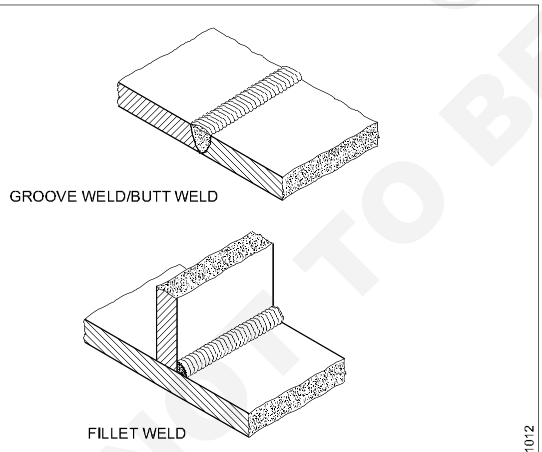


FUNDAMENTAL TYPE OF JOINTS

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

- Groove weld/butt weld
- Fillet weld

Fig 2



TYPE OF WELD

Application

Edge Joint: This type of joint used in muffler or for joining sheet metal.

Corner Joint: This kind of joint is used when making rectangular frame and fabricating box etc.

Lap joint: This type of weld joint is usually used in the temporary frame making, cabinet making, table making etc.

Butt joint: Generally, this kind of welded joint is used in joining flanges, valves, equipment's, pipes, tubes and other fitting works etc.

Nomenclature of butt and 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)

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)

Fig 3

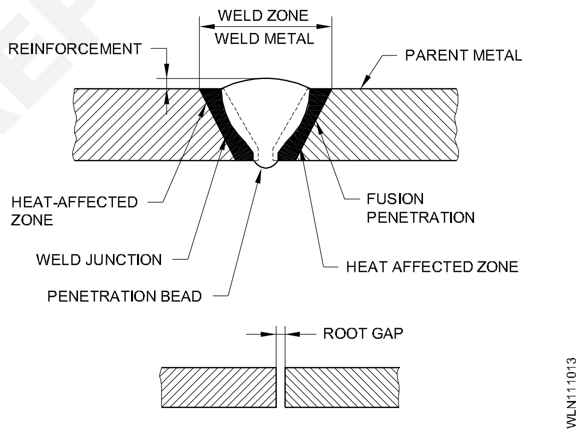
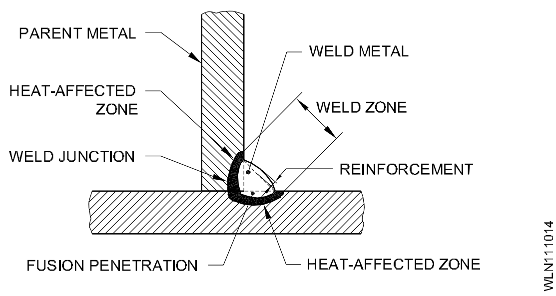


Fig 4



Reinforcement: Metal deposited on the surface of the parent metal of the excess metal over the line joining the two toes. (Fig 5)

Root: The parts to be joined that are nearest together. (Fig 6)

Fig 5

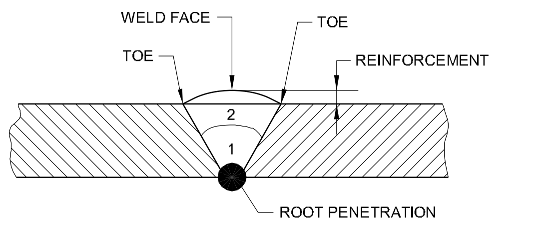
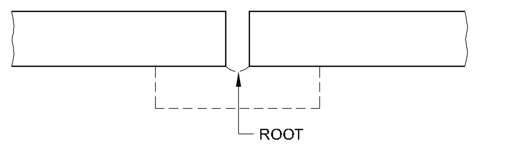
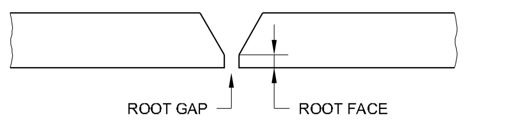


Fig 6



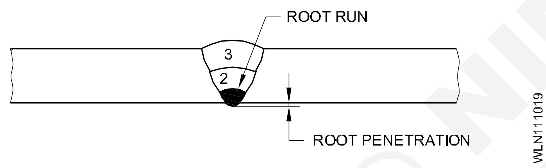
Root face: The surface formed by squaring off the root edge of the fusion face to avoid a sharp edge at the root. (Fig 7)

Fig 7



Root run: The first run deposited in the root of a joint (Fig 8)

Fig 8



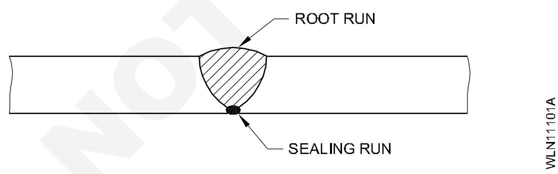
Root penetration: It is the projection of the root run at the bottom of the joint.

Run: The metal deposited during one pass.

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 9)

Fig 9



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

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

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

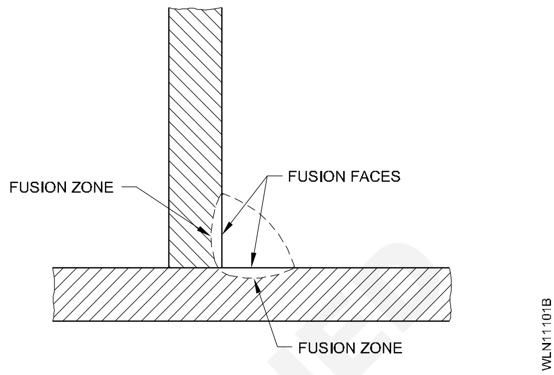
Weld face: The surface of a weld seen from the side from which the weld was made. (Fig 5&6.)

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 10)

Fusion zone: The depth to which the parent metal has been fused. (Fig 10)

Fig 10



Edge preparation

Necessity of edge preparation: Joints are prepared to weld metals at less cost. The preparation of edges is 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.

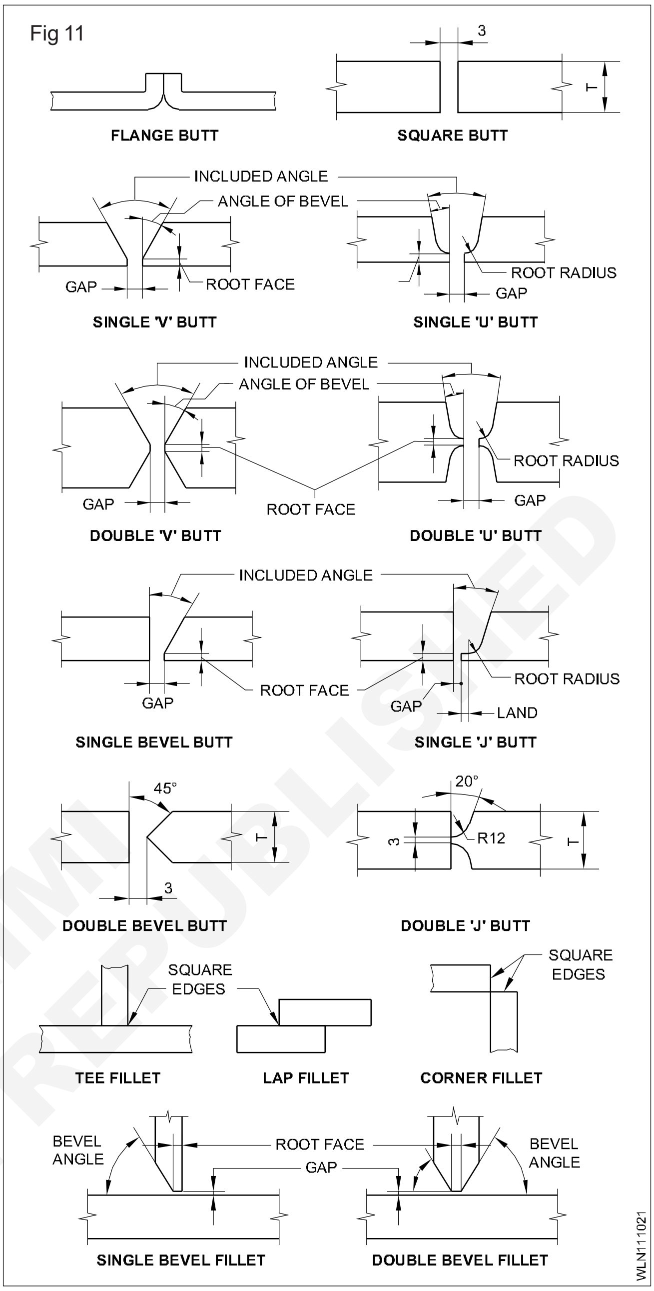
Method of edge preparation: The joining edges may be prepared for welding by any one of the methods mentioned below.

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

Types of edge preparation and fit-up

Different edge preparation generally used in arc welding are shown in Fig 11 below.

Fig 11



Surface cleaning

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

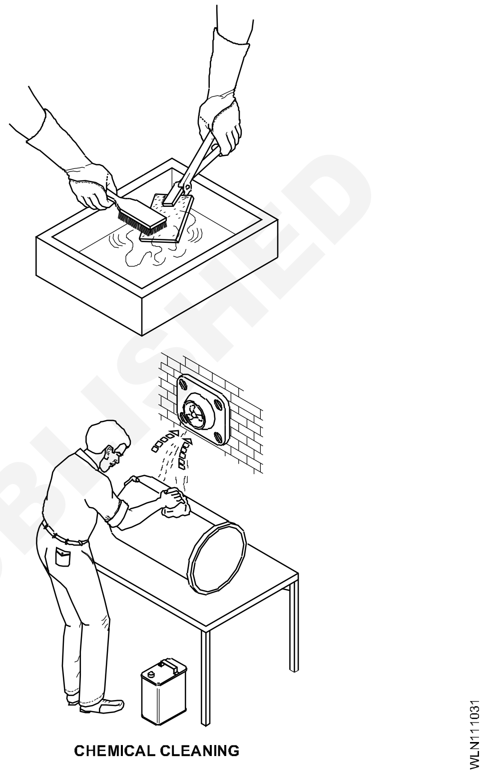
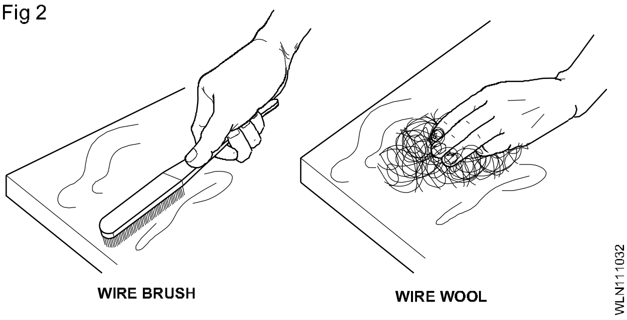


Fig 2



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

Objectives : At the end of this lesson you shall be able to
- **define simple electrical terms**
- **state the differentiate between electric current, pressure and resistance.**

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.

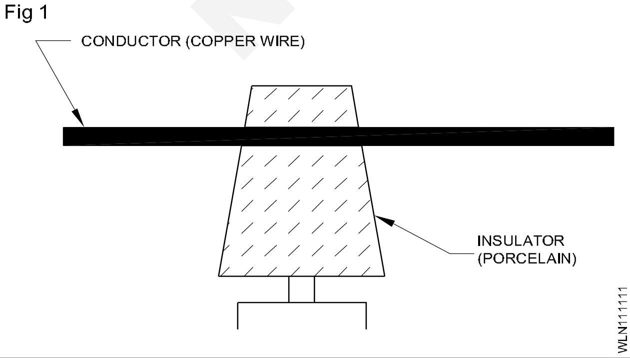
Electric resistance; It is the property of a substance to oppose the flow of electric current passing through it.

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)

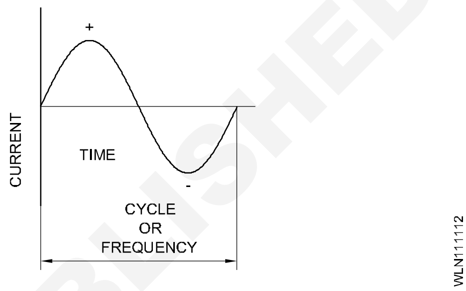
Fig 1



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 2)

Fig 2



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.

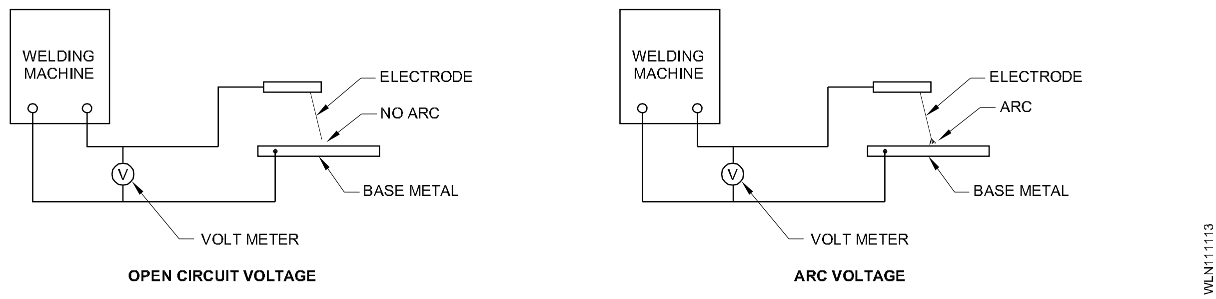
Series circuit: The resistances of a circuit are connected in a series end-to-end making only one path in which the current flows.

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 mean it changes its direction 50 times per second. Its rate of change is called frequency i.e. hertz (Hz). (Fig 3)

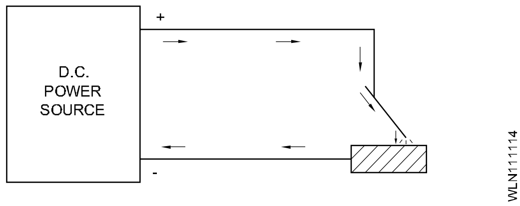
Direct current (DC) (Fig 4): Electric current which always flows in a particular direction is known as direct current. (i.e) Negative to positive (electronic direction). Positive to negative (conventional direction).

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.

Use of electricity as applied to welding: For fusion welding, the pieces to be joined are to be melted by:

- creating a high temperature (4500°C) arc between the electrode and the work using electric voltage and high current. (All types of arc welding)
- heating the work to red hot condition by using the resistance property of the metal and passing a very high current for a fraction of a second and then applying a very heavy pressure. (All types of resistance welding)
- using highly concentrated electron beam on the joint of the work piece (Electron beam welding)
- Using the resistance of the slag and the current to flow through the molten slag (Electro slag welding)

In all the above welding processes, the electrical energy is converted to heat energy which is used to either melt the metal fully or heat them to red hot condition and then melted by applying heavy pressure. So electricity is used to a very large extent in many welding processes.

Heat and temperature and its terms related to welding

Objectives : At the end of this lesson you shall be able to
- **describe the different between heat and temperature**
- **explain the application of heat and temperature in welding.**

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 degrees (212°F).

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

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.

Given below is a chart showing welded plate thickness, nozzle size used and volume of gasses used.

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

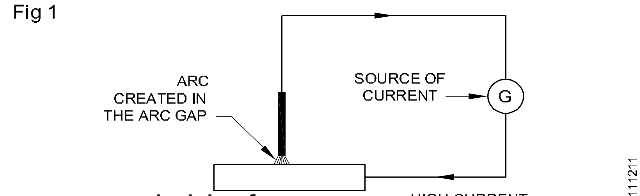
Principles of arc welding and characteristics of arc

Objective: At the end of this lesson you shall be able to
- **describe the principle and characteristics of arc.**

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)

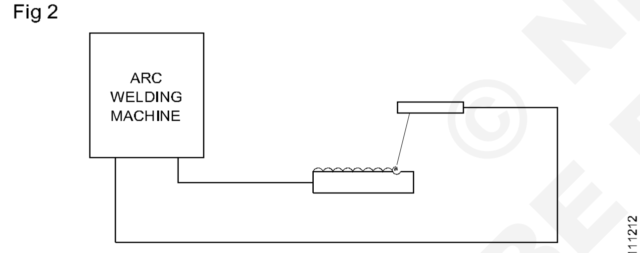
Fig 1



principle of arc

Characteristics of arc 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 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.

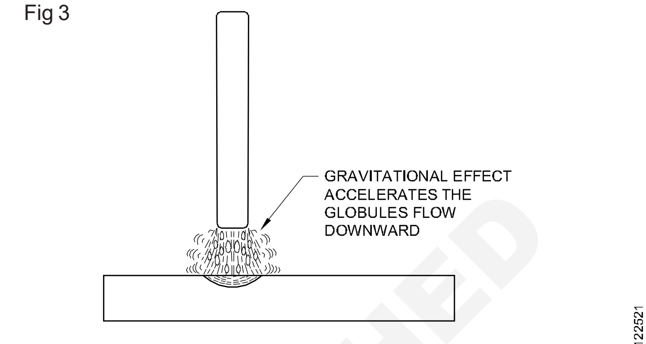
Gravity force (Fig 3): Molten globules formed at the arcing end of the electrode travel downwards towards the job in the molten pool.

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

Gas expansion force (Fig 4): Flux coating on the electrode melts due to the arc heat, resulting in the:

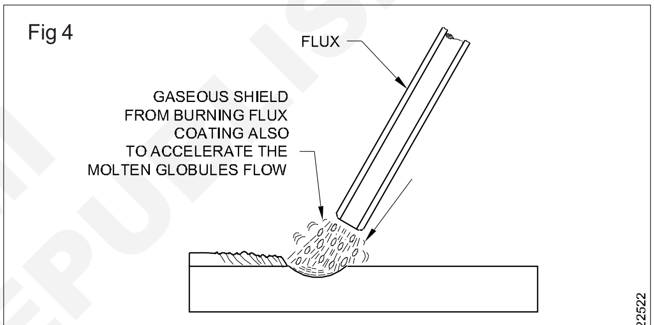
- Production of carbon monoxide and hydrogen mainly
- Formation of a sleeve of the flux at the arcing end due to a little higher melting point of the flux coating than the core wire.

Fig 3



GRAVITY FORCE

Fig 4



GAS EXPANSION EFFECT

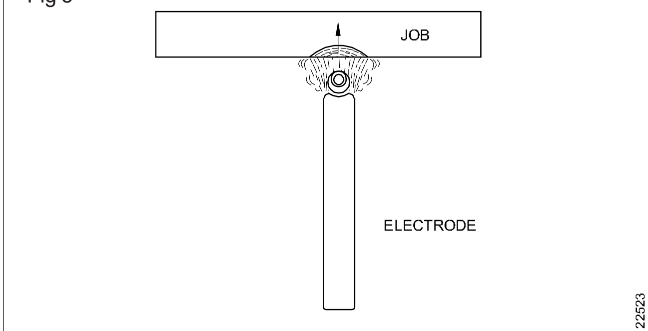
These gases expand and gain velocity. The flux sleeve directs these gases to flow in the direction of the molten metal. The gases flowing from the tip of the electrode have a pushing effect. Thus the metal globules are carried deep into the weld pool and influence penetration.

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

Surface tension (Fig 5): 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 5

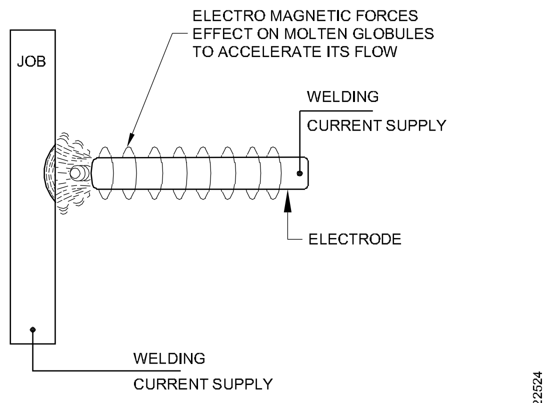


SURFACE TENSION EFFECT

Electromagnetic force (Fig 6): 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 6



ELECTRO MAGNETIC EFFECT

Common gases used for welding & cutting - flame temperature & uses

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

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 temperature)	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

Scan QR code for this exercise

Objectives: At the end of this lesson you shall be able to
- **identify the different types of oxy-acetylene flames**
- **explain the uses of flames.**

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.

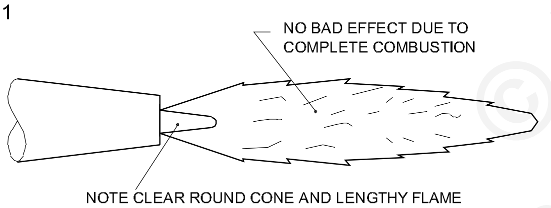
Three different types of oxy-acetylene flames as given below can be set.

- 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)

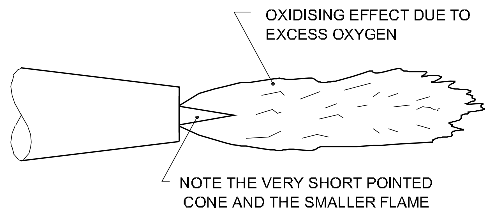
Complete combustion takes place in this flame.

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



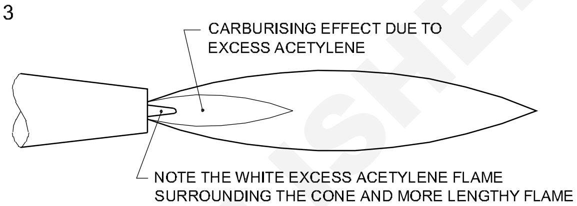
OXIDISING FLAME (EXCESS OXYGEN)

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 stellateing (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	Cast iron	Neutral (slightly oxidising)
4	Stainless steel	Neutral
5	Aluminium (Pure)	Neutral (slightly carburising)
6	Brass	Oxidising
7	Stellite	Carburising

Oxy - acetylene cutting equipment's principle, parameters and application

Scan QR code for this exercise

Objectives : At the end of this lesson you shall be able to
- **explain the principle of gas cutting and equipment's**
- **describe the cutting operation parameters and its 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.

Oxy-acetylene cutting equipment

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.

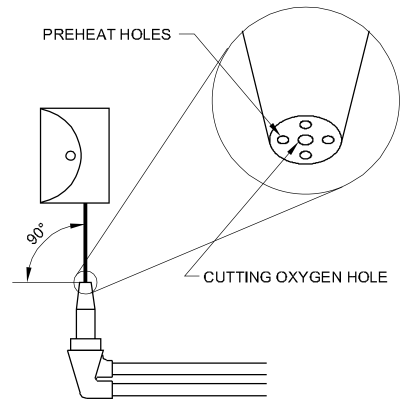
Oxy-acetylene cutting procedure: Fix a suitable size cutting nozzle in the cutting blowpipe. lignite the cutting torch the same way as was done in the case of the welding blowpipe. Set the neutral flame for preheating. To start the cut, hold the cutting nozzle at angle 90° with the plate surface, and the inner core 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.

Care and maintenance: The high pressure cutting oxygen lever should be operated only for gas cutting purposes.

Care should be taken while fitting the nozzle with the torch to avoid wrong thread. Dip the torch after each cutting operation in water to cool the nozzle.

To remove any slag particles of dirt from the nozzle orifice use the correct size nozzle cleaner Fig 1. Use an emery paper if the nozzle tip is damaged to make it sharp and to be at 90° with the nozzle axis.

Fig 1



CLEANING THE HOLES OF CUTTING NOZZLE

Oxy-acetylene machine cutting

There are two types of cutting machines.

- Manually driven cutting machines
- Electrically driven cutting machines

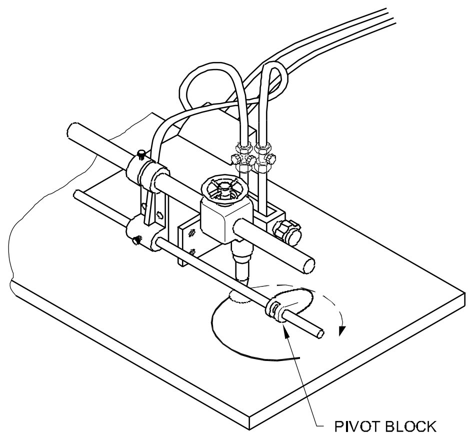
Manually operated cutting machines

A manually driven cutting machine normally consists of:

- a crank or wheel to drive the cutter via a screw thread and this machine can be used for straight line cutting and bevel cutting

- a system of links or rods which are used with the machines and by which simple circles, ellipses, squares, etc. can also be cut. (Fig 6)

Fig 2



SMALL CIRCLE CUTTING

The speed of the manually operated cutting machines is liable to variation and the range of speed is also limited.

Electrically driven cutting machines

There are two types of machines available.

Portable machines

Static machines

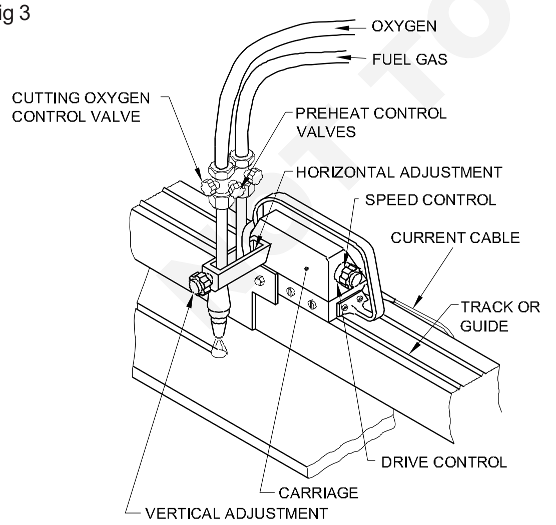
Portable machines

An electrically driven portable cutting machine generally consists of:

- cutting instruments
- carriage (Consisting of a variable speed motor)
- guide (to guide the carriage).

This machine can be used for straight line cutting, bevel cutting, circular cutting and profile cutting. (Fig 3)

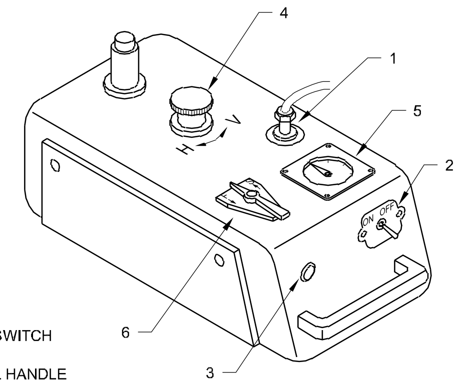
Fig 3



Provision is also made to enable full adjustment of the cutting head to be carried out over the cutting area.

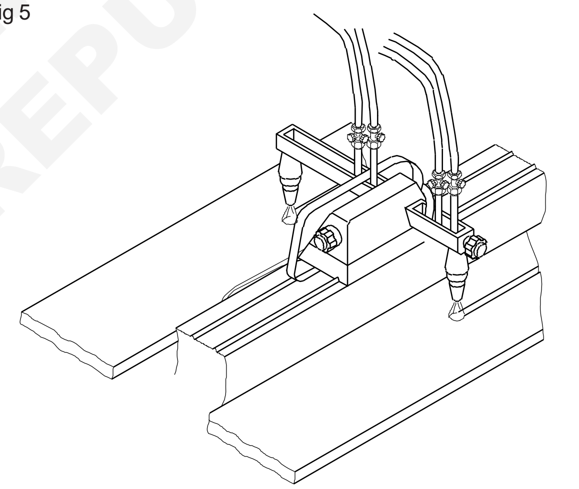
The electrical control unit fitted to the carriage is shown in Fig 4.

Fig 4



The speed of an electrically driven machine, when it, is constant, and normally it is able to produce better cuts than a manually driven machine. The speed range of an electrically driven machine is greater than that of the manual type and the adjustment of speed helps to control more accurately. Multiple cutting heads can be mounted to increase the volume of cutting, these cutting heads may be mounted on an adjustable bar extending to either side of the track at 90° to the direction of travel. (Fig 5)

Fig 5



PORTABLE MACHINE WITH MULTIPLE CUTTING HEADS

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.

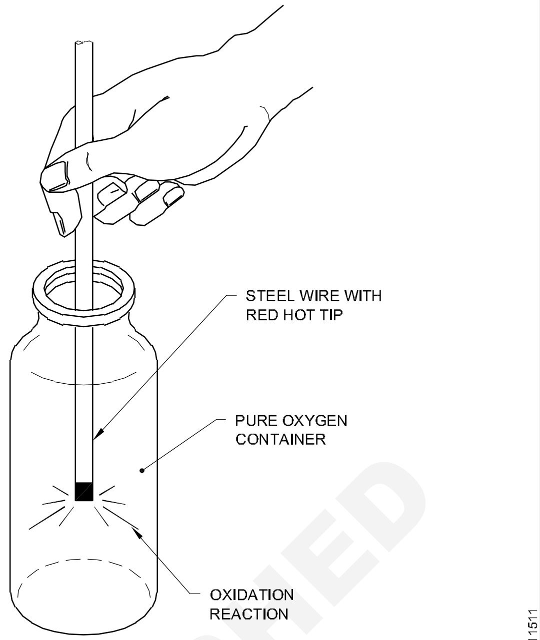
When a piece of wire with a red hot tip is placed in a container of pure oxygen, it bursts in to flame immediately and is completely consumed. Fig 6 illustrates this reaction. Similarly in oxy-acetylene cutting the combination of red hot metal and pure oxygen causes rapid burning and iron is changed into iron oxide (oxidation).

BY this continuous process of oxidation the metal can be cut through very rapidly.

The iron oxide is less in weight than base metal.

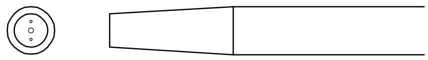
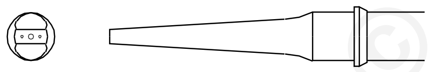
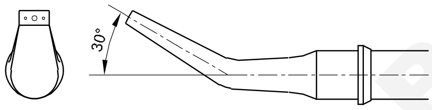
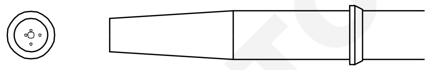
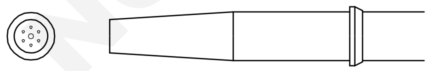
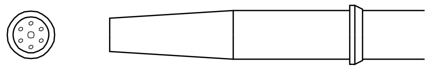
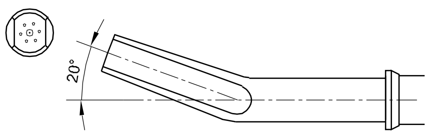
Also the iron oxide is in molten condition called slag. So the jet of oxygen coming from the cutting torch will blow the molten slag away from the metal making a gap called 'Kerf'.

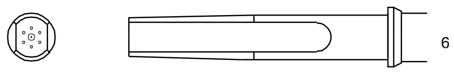
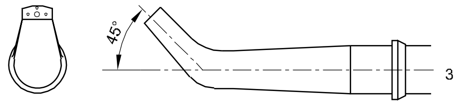
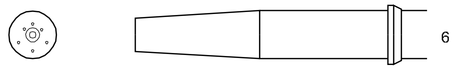
Fig 6



OXIDATION

Table of some common cutting torch tips and their uses

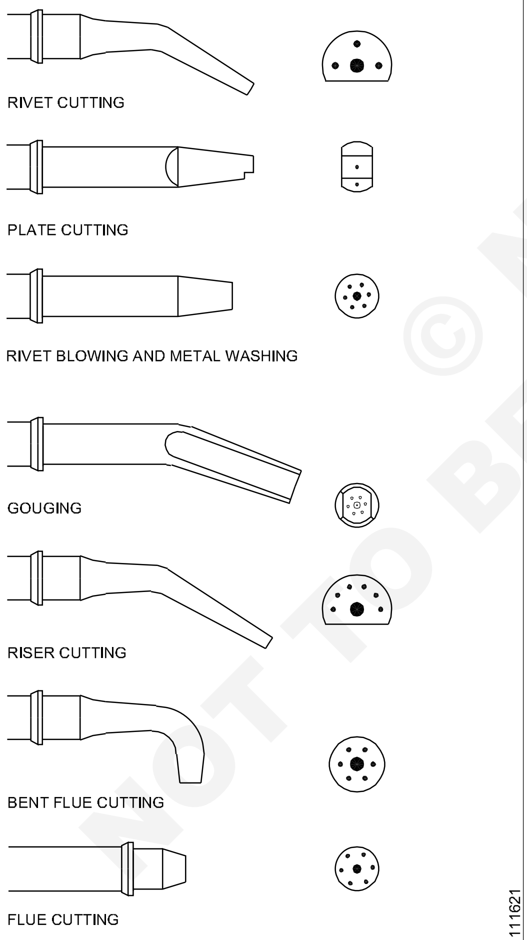
Number of preheat orifices in cutting torch tips	Degree of preheating	Application
 2	Medium	For straight line or circular cutting of clean plates.
 2	Light	For splitting angle iron, trimming plates and sheet metal cutting.
 30° 2	Light	For hand cutting rivet heads and machine cutting 30 deg. bevels.
 4	Light	For Straight line and shape cutting clean plate.
 4,6,8	Medium	For rusty or painted surfaces.
 6	Heavy	For cast iron cutting and preparing vee for cast iron welding.
 6	Very heavy	For general cutting; also for cutting and stainless steel.
 20° 6	Medium	For grooving, flame machining, gouging and removing imperfect welds.

	Medium	For grooving, gouging or removing imperfect welds.
	Medium	For machine cutting 45° deg. bevel or hand cutting rivet heads.
	Heavy	Flared cutting orifices provide a large oxygen stream of low velocity for rivet head removal (Washing).

Oxy-acetylene hand cutting - piercing hole and profile cutting

Special purpose nozzle: For profile cutting. Different types of nozzles are used for cutting metals in different shapes.Nozzles used for cutting profiles are shown in Fig 7

Fig 7



SPECIAL TYPES OF NOZZLES USED FOR GAS CUTTING

Cutting torch: Fig 8 Oxygen and fuel gas are mixed and then the gas is carried to the tip of the orifice to form 'preheat' flames. If oxygen is carried directly to the tip it oxidises the metal and blows it away to form the cut.

Method of piercing a hole: Hold the cutting blow pipe at right angles on the point where the hole is to be made. The point will be brightened. Release the cutting oxygen slowly. Raise the torch, tilt the nozzle slightly to the left and right direction so that the sparks may not fuel the nozzle. Thus the hole may be pierced.

For cutting of the profile hold the blow pipe head in such a way that the oxygen stream is directed by the correct tilting of the blow pipe. It is obvious that the angle between the nozzle and the plate must remain constant and this poses the greatest difficulty for the beginners.

Position of the preheating flame as related to the plate surface is very important.

Fig 8

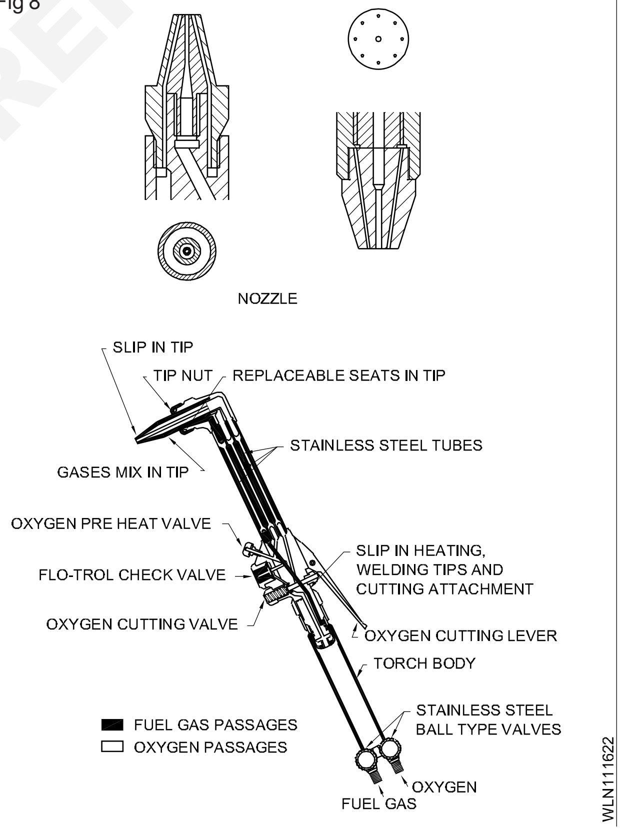
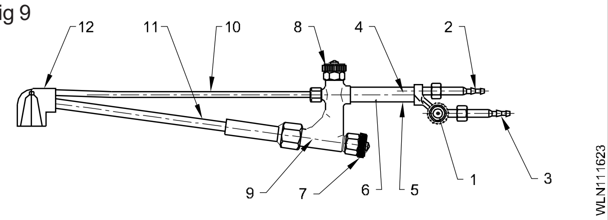


Fig 9



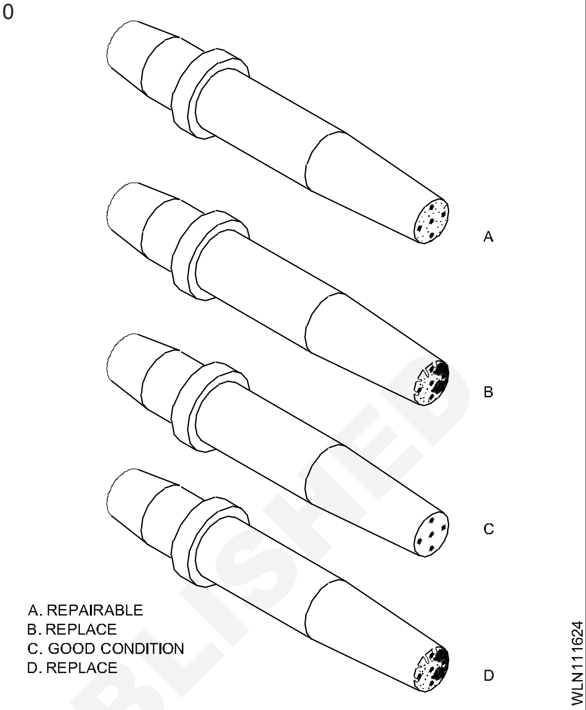
Names and function of the parts of a cutting torch (Fig 9 and Table 1)

Table 1

No.	Name	Function
1	Acetylene gas valve	To adjust the flow rate of acetylene gas.
2	Oxygen Regulator	To connect Regulator
3	Acetylene gas hose joint	To connect with the acetylene gas hose.
4	Oxygen conduit	To lead oxygen.
5	Acetylene gas conduit	To lead acetylene gas.
6	Grip	To hold the torch.
7	Preheating oxygen valve	To adjust the preheating flame.
8	Cutting oxygen valve	To adjust the cutting oxygen flow rate.
9	Injector	To mix the acetylene gas with oxygen.
10	Cutting oxygen conduit	To lead the cutting oxygen.
11	Mixed gas conduit	To lead the mixture of acetylene gas and oxygen.
12	Torch head	To attach the nozzle.

Care and maintenance: The cutting oxygen orifice should be cleaned at regular intervals by using different size wire of nozzle cleaner. (Fig 10)

Fig 10



Troubleshooting

Object	Trouble	part to be	Method	Remedy	
Torch	Gas leakage	Hose joint	soap water or water	Tighten further or replace.	At the beginning of the work.
		Valve & regulator	Soap water or water	Replace the torch.	At the beginning of the work.
		Cutting tip attaching part	soap water or water	Tighten further or replace.	At the beginning of the work.
	Suction of Acetylene	Injector	plug the fuel gas hose mouth with your finger.	Replace.	Periodical check for the low pressure torch.
	Preheating flame shape		Neutral flame visual inspection	Clean or replace.	At the beginning of the work or at random.
	Cutting oxy gen flow		Visible gas Visual inspection	Clean or replace.	At the beginning of the work or at random.

Characteristics of analysis of cutting: This analysis has been made on referring to the cutting face and the formation of cut in this surface.

This can be analyses as shown in the Fig 11

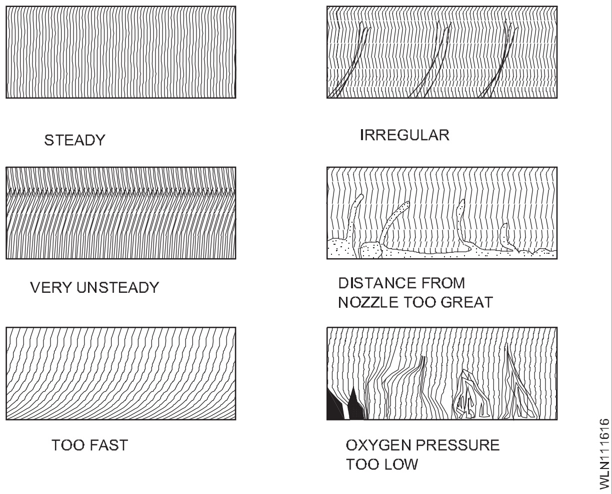


Fig 11

Common defects in gas cutting

Common faults in cutting

(Fig 12) The tip is too high off the steel. The top edge is heated or rounded, the cut face is not smooth, and often the face is slightly beveled where preheat effectiveness is partially lost due to the tip being held so high. The cutting speed must be reduced because of the danger of losing the cut.

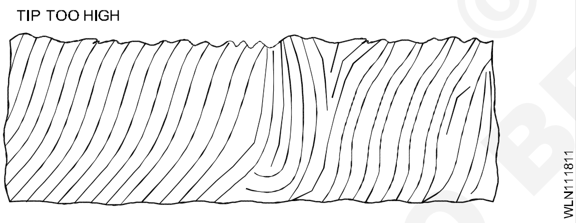


Fig 12

(Fig 13) Extremely slow cutting speed. Pressure marks on the cut face indicate too much oxygen for the cutting conditions. Either the tip is too big, the cutting oxygen pressure is too high, or the speed is too slow as shown by the rounded or beaded top edge. On reducing the cutting oxygen volume to the correct proportions for the thickness of the cut, the pressure marks will recede toward the bottom edge until they finally disappear.

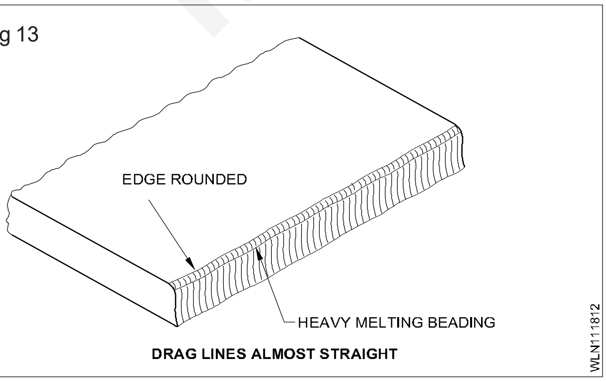


Fig 13

(Fig 14) Tip too close to the steel. The cut shows grooves and deep drag lines, caused an unstable cutting action. Part of the preheat cones burned inside the kerf, where normal gas expansion affected the oxygen cutting stream.

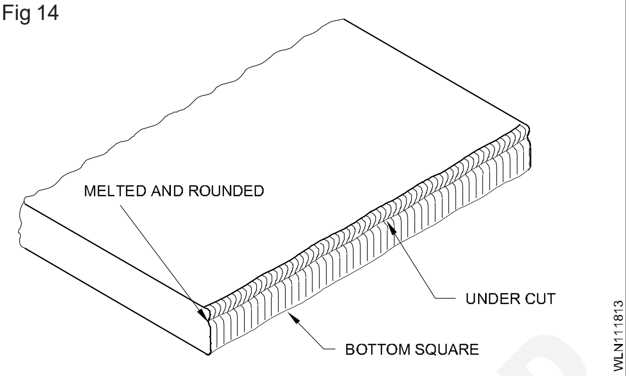


Fig 14

(Fig 15) Too much cutting oxygen. The cut shows pressure marks caused by too much cutting oxygen. When more oxygen is supplied than can be consumed in oxidation, the remainder flow around the slags, creating gouges or pressure marks.

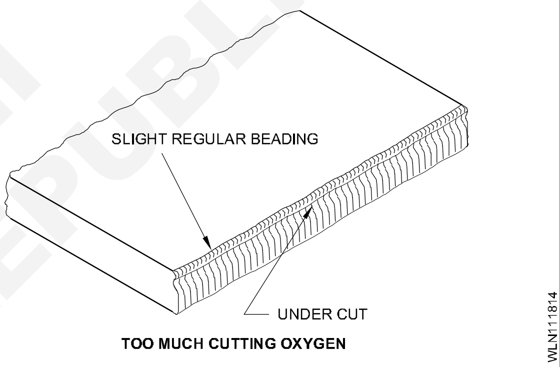


Fig 15

(Fig 16) Too much preheating. The cut shows a rounded top edge caused by too much preheat. Excess preheating does not increase the cutting speed, it only wastes gases.

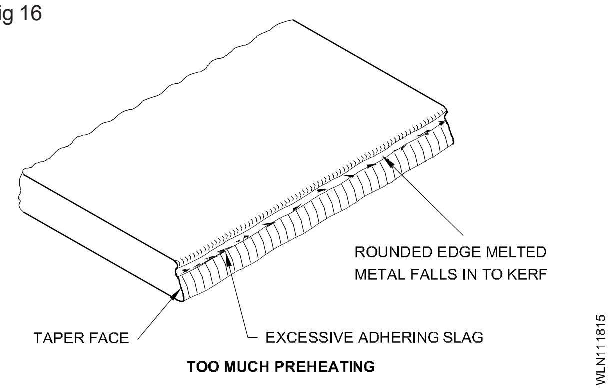
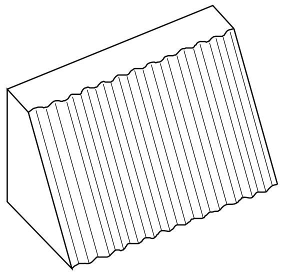


Fig 16

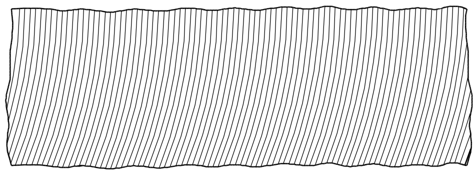
(Fig 17) Poor quality bevel cut. The most common fault is gouging, caused by either excessive speed or inadequate preheat flames. Another fault is a rounded top edge caused by too much preheat, indicating excessive gas consumption.

Fig 17



(Fig 18) Slightly too fast a cutting speed. The drag lines on this cut incline backwards, but a 'drop cut' is still attained. The top edge is good; the cut face is smooth and slag-free. This quality is satisfactory for most production work.

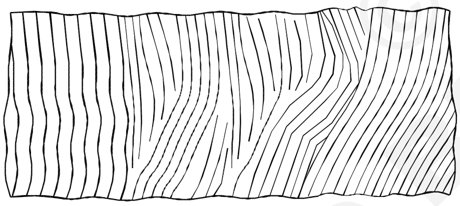
Fig 18



SLIGHTLY TOO FAST CUT

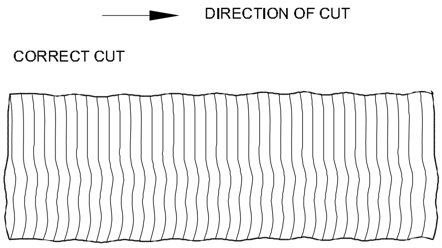
(Fig 19) Slightly too slow a cutting speed. The cut is of high quality although there is some surface roughness caused by the vertical drag line. The top edge is usually slightly beaded. This quality is generally acceptable, but faster speeds are more desirable because the labour cost for this cut is too high.

Fig 19



In a good cut, the edges are square, and the lines of cut are vertical. (Fig 20)

Fig 20



Gas cutting applications

Wheel cut by oxyacetylene

- Oxyfuel is one of the most widely used cutting processes with the following benefits.
- Low cost equipment
- Basic equipment suitable for cutting, gouging and other jobs such as welding and heating.
- Portable, suitable for site work.
- Manual and mechanised operations
- Mild and low alloy steels (but not aluminium or stainless steel)
- Wide range of thickness (typically from 1 mm to 1000mm).

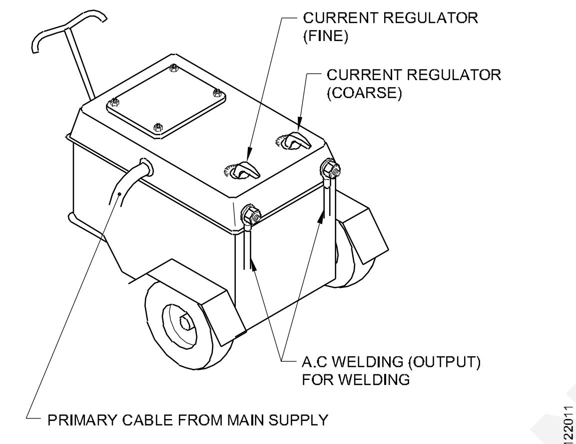
A.C welding power sources transformer rectifier and inverter type welding machine and care maintenance

Objectives: At the end of this lesson you shall be able to
- **identify the features of welding transformer, rectifier & inverter**
- **describe the principle of the above welding machines**
- **explain the advantages and disadvantages of the above machine**
- **identify care and maintenance of welding machines.**

Scan QR code for this exercise

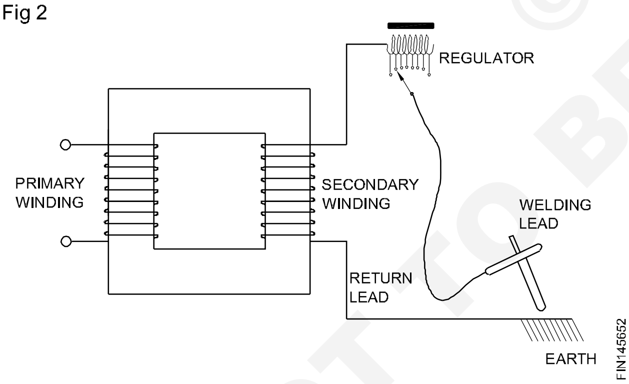
AC welding transformer: This is a type of AC welding machine which converts AC main supply into AC welding supply. (Fig 1)

Fig 1



AC WELDING TRANSFORMER

Fig 2



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.

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

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 affect 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 =

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.

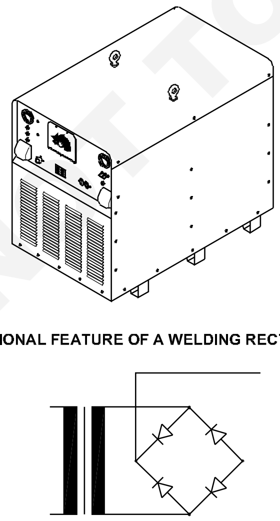
Always keep and install the machine on dry floor.

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 3) The rectifier cell consists of a supporting plate made of steel or aluminium (Fig 4) 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.

Fig 3

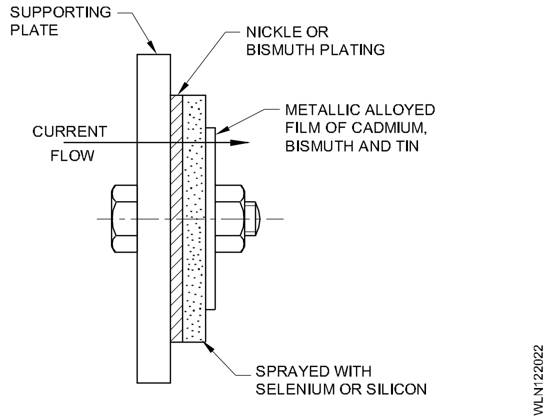


CONSTRUCTIONAL FEATURE OF A WELDING RECTIFIER SET

SYMBOLIC REPRESENTATION

The coating of nickel or bismuth over the supporting plate serves as one electrode (ANODE) of the rectifying cell.

Fig 4



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.

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

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.

Care and maintenance of rectifier welding set

Keep all the connections in tight condition.

Lubricate the fan shaft once 3 months.

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

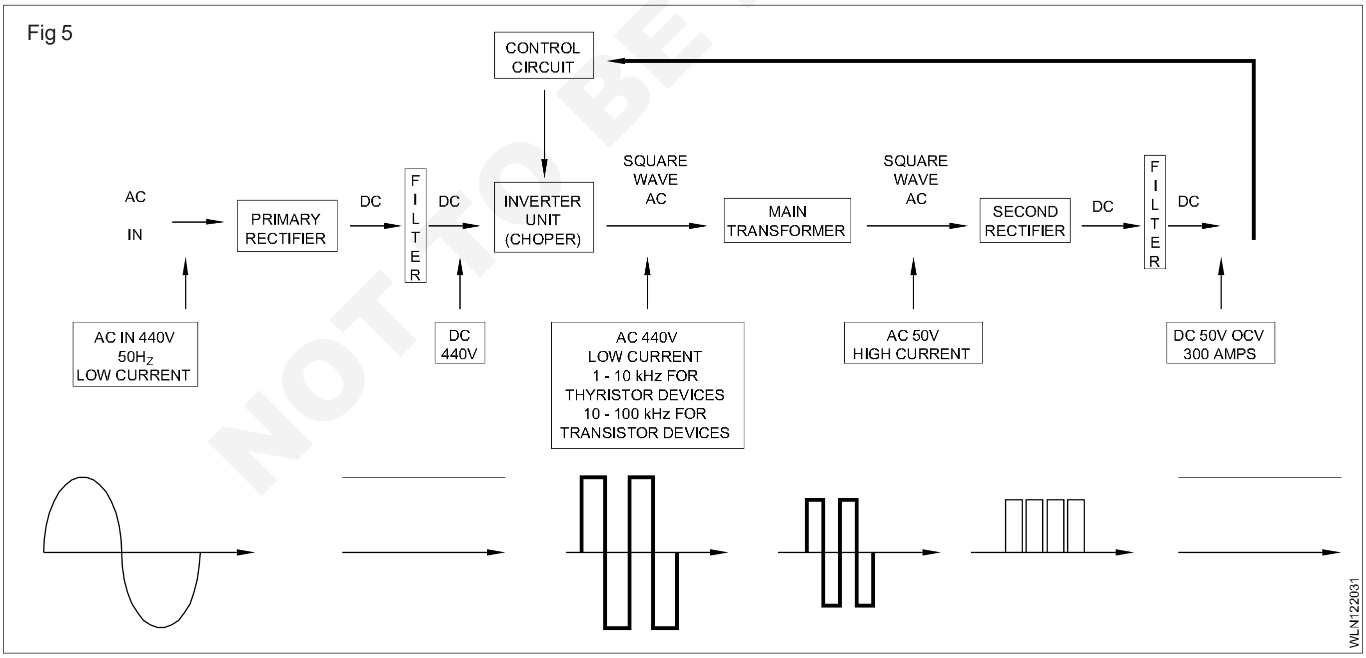
Keep the rectifier plates clean.

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.

Fig 5



Advantages and disadvantages of AC and DC welding machines

Objective: At the end of this lesson you shall be able to
- **explain advantages and disadvantages of AC & DC welding machines.**

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 blows during welding
- a lower working efficiency
- noisy operation in the case of a welding generator
- occupies more space.

Welding positions as per EN & ASME

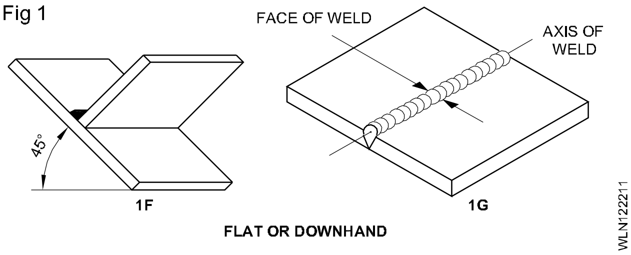
Scan QR code for this exercise

Objectives : At the end of this lesson you shall be able to
- **identify the basic welding positions as per EN & ASME (Flat, horizontal, vertical and overhead position).**

Basic welding positions

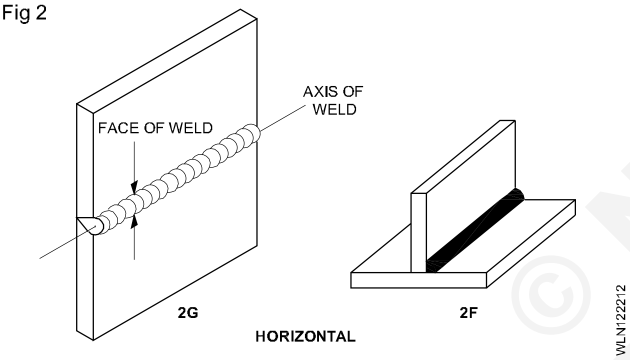
- Flat or down hand position (Fig 1)

Fig 1



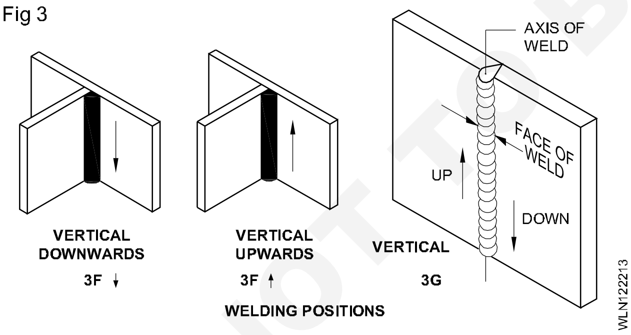
- Horizontal position (Fig 2)

Fig 2



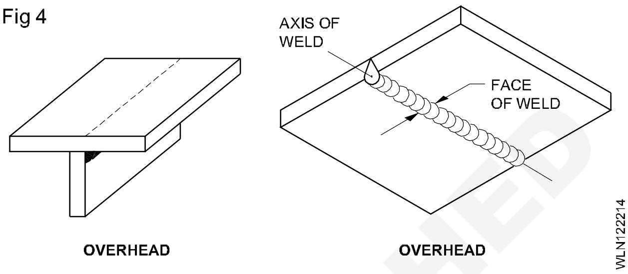
- Vertical position (Vertical up and down) (Fig 3)

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

Scan QR code for this exercise

Objectives : At the end of this lesson you shall be able to
- **describe the weld slope and rotation**
- **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

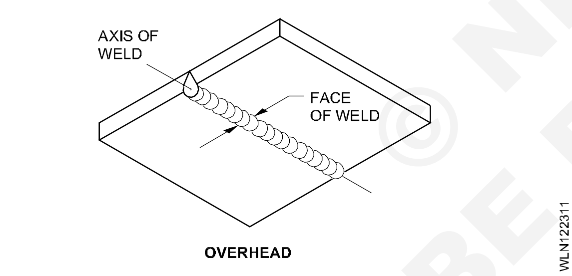
4 Overhead

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)

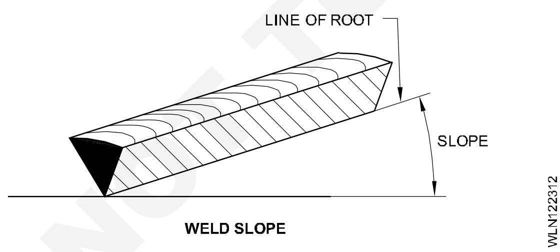
Fig 1



OVERHEAD

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

Fig 2



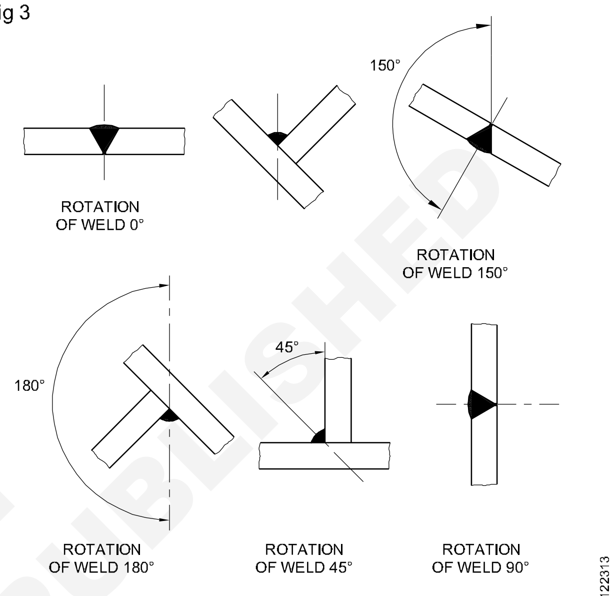
WELD SLOPE

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)

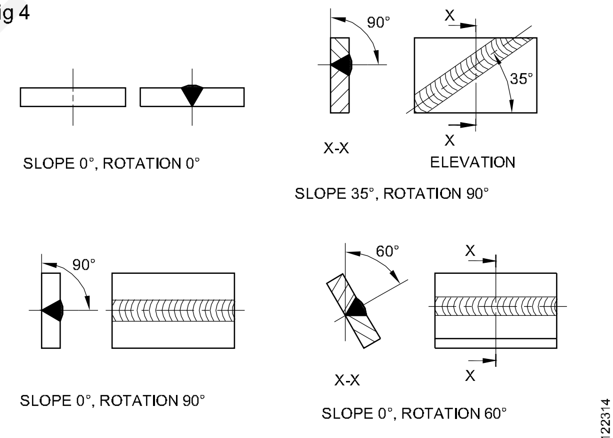
Weld in flat position. (Fig 5)

Fig 3



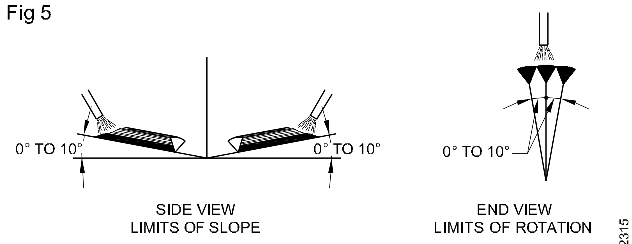
WELD ROTATION

Fig 4



SLOPE AND ROTATION

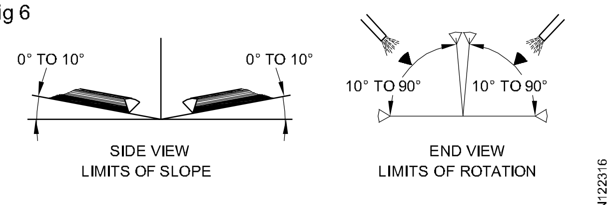
Fig 5



WELD IN FLAT POSITION

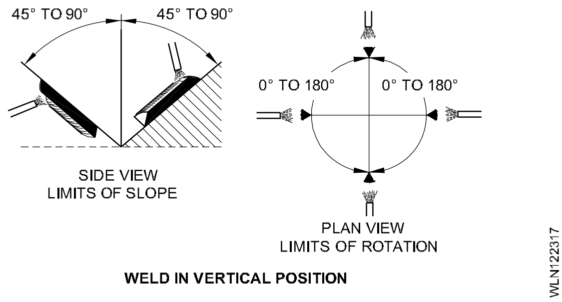
Weld in horizontal and vertical position. (Fig 6 & 7)

Fig 6



WELD IN HORIZONTAL POSITION

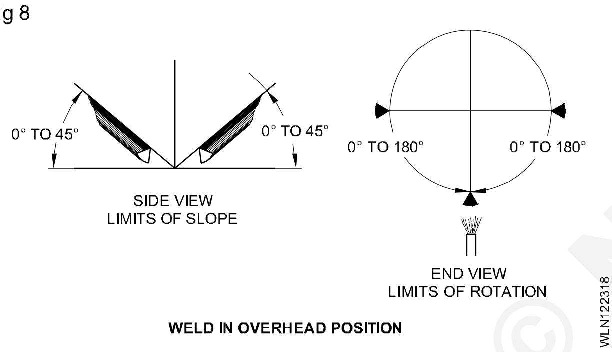
Fig 7



WELD IN VERTICAL POSITION

Weld in overhead position. (Fig 8)

Fig 8



WELD IN OVERHEAD POSITION

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.

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°.

Welding symbol as per BIS and AWS

Scan QR code for this exercise

Objectives : At the end of this lesson you shall be able to
- **identify the necessity of weld symbol**
- **define elementary symbols and supplementary symbols**
- **explain welding symbol and its application.**

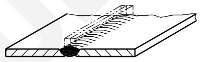
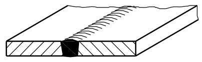
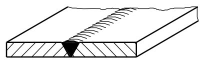
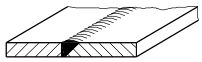
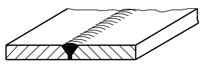
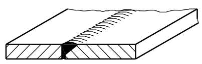
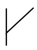
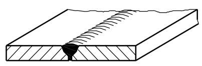
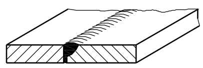
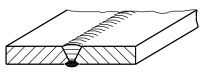
Necessity: For conveying the information required for welding for designers and welders, standard symbols are used. The symbols described below provide the means of placing on drawing the information concerning type, size, location of weldment.

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		

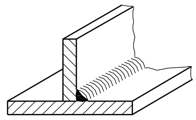
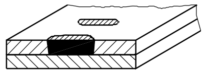
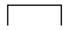
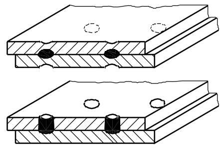
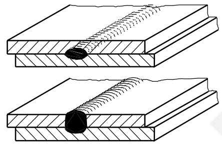
Sl. No.	Designation	Illustration	Symbol
10	Fillet weld		
11	Plug weld; Plug or slot weld/USA		
12	Spot weld		
13	Seam weld		

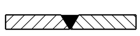
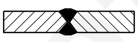
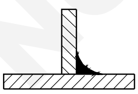
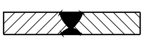
TABLE 2

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

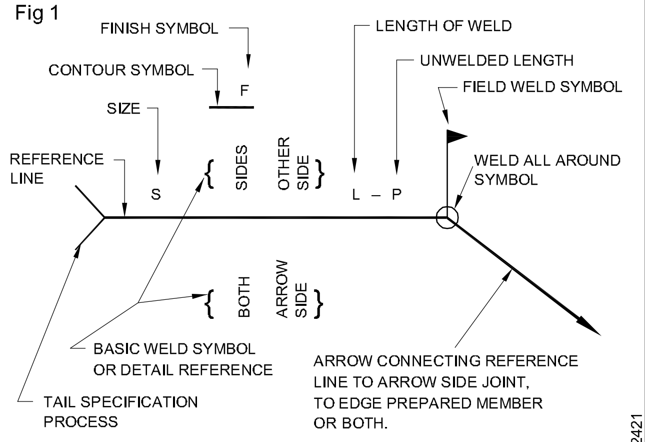
4 Dimensions and other details

5 Supplementary symbols

6 Finish symbols

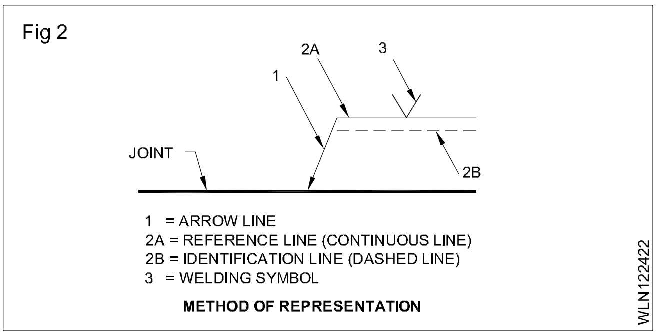
7 Tail (Specification, process)

Fig 1

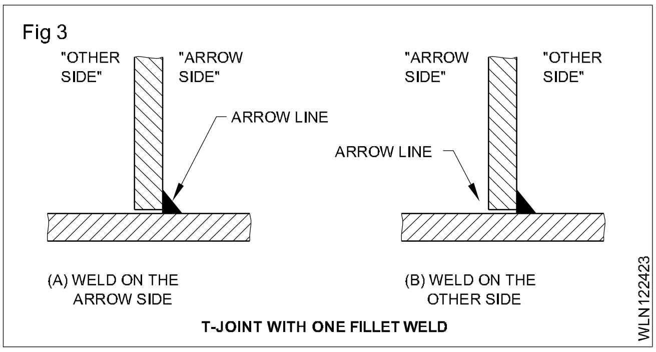


STANDARD LOCATION OF ELEMENTS OF A WELDING SYMBOL

Methods of representation (Fig 2 and 3)



METHOD OF REPRESENTATION



T-JOINT WITH ONE FILLET WELD

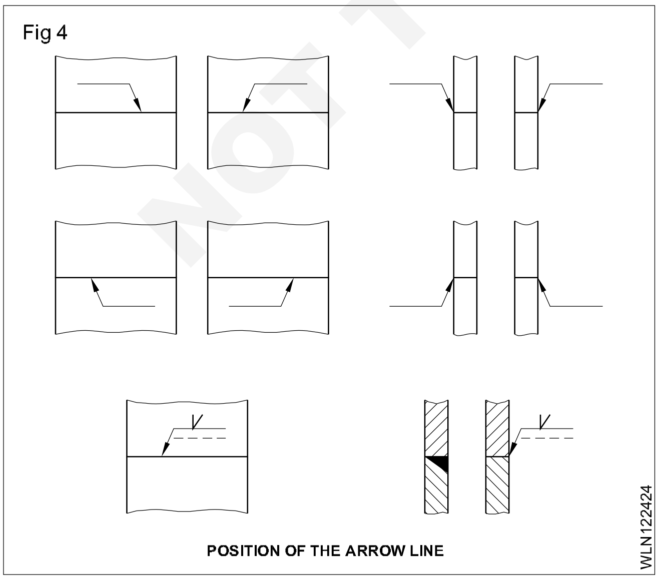
The reference line, arrow-head and tail

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.

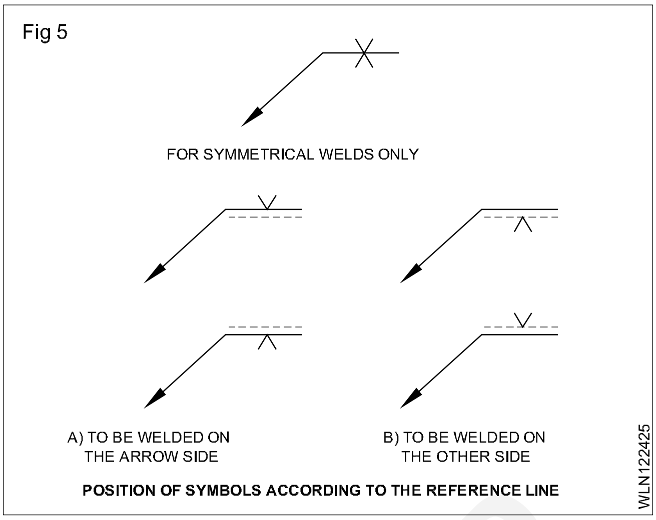
Arrow: The arrow may be drawn from either end of the reference line. The arrow always touches the line which represents the welded joint.

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.



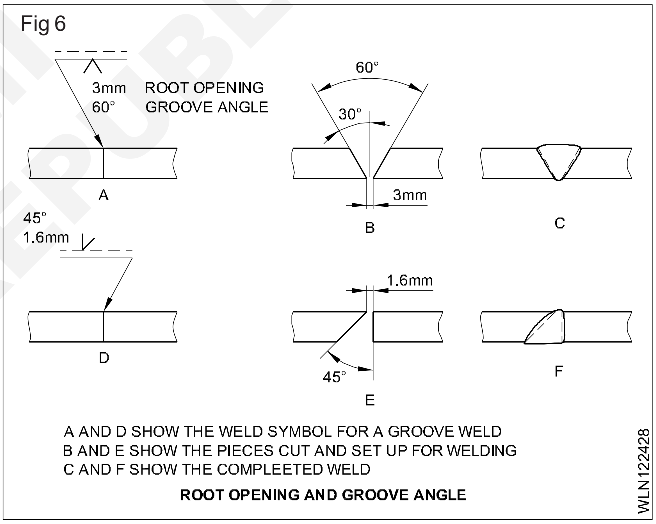
POSITION OF THE ARROW LINE



POSITION OF SYMBOLS ACCORDING TO THE REFERENCE LINE

Welding/elementary symbol: Illustrate how some of the various types of weld symbols are used in welding symbols.

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 6)



ROOT OPENING AND GROOVE ANGLE

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 7)

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. (Fig 8) 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.

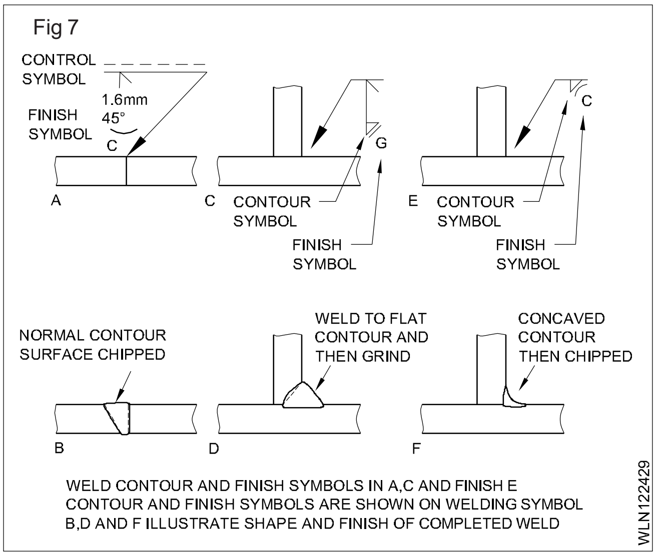


Fig 7
CONTROL SYMBOL
FINISH SYMBOL
1.6mm
45°
C
A
C
CONTOUR SYMBOL
G
FINISH SYMBOL
E
CONTOUR SYMBOL
C
FINISH SYMBOL
NORMAL CONTOUR SURFACE CHIPPED
WELD TO FLAT CONTOUR AND THEN GRIND
CONCAVED CONTOUR THEN CHIPPED
B
D
F
WELD CONTOUR AND FINISH SYMBOLS IN A,C AND FINISH E
CONTOUR AND FINISH SYMBOLS ARE SHOWN ON WELDING SYMBOL
B,D AND F ILLUSTRATE SHAPE AND FINISH OF COMPLETED WELD
WLN122429

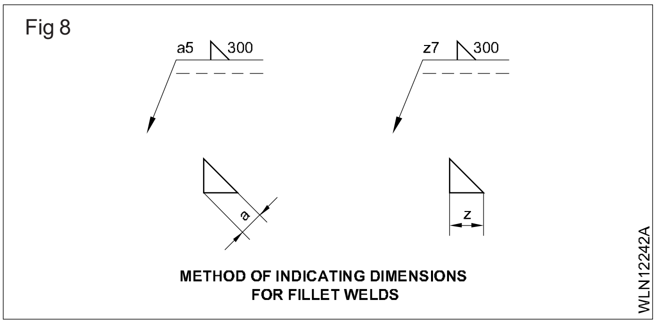


Fig 8
a5
300
z7
300
a
z
METHOD OF INDICATING DIMENSIONS
FOR FILLET WELDS
WLN12242A

Arc length types effects of arc length

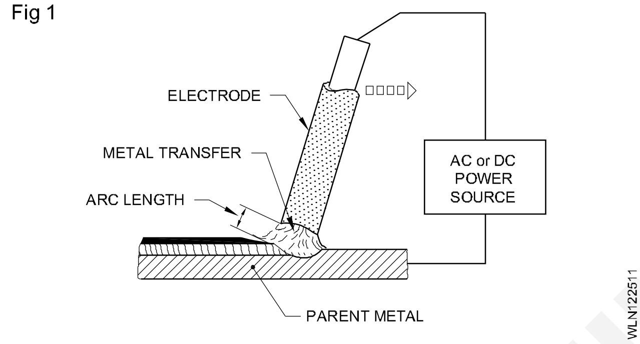
Scan QR code for this exercise

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

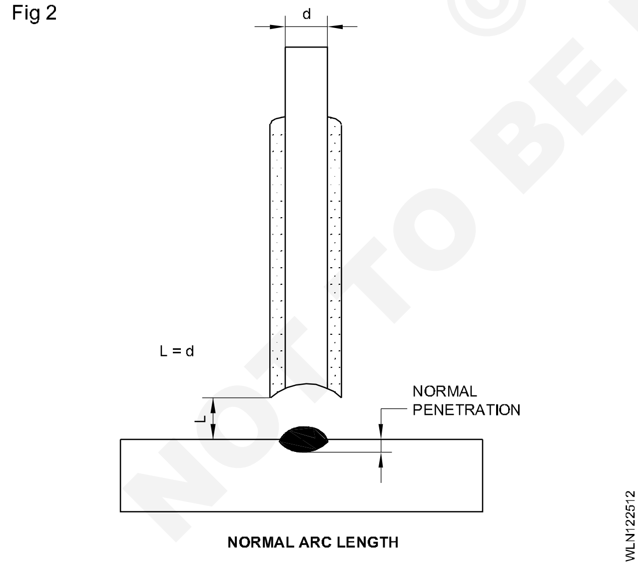
- Medium or normal
- Long
- Short

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



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

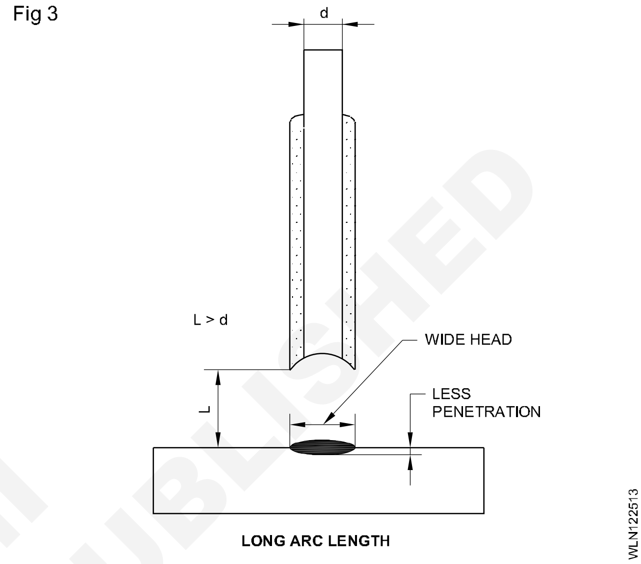
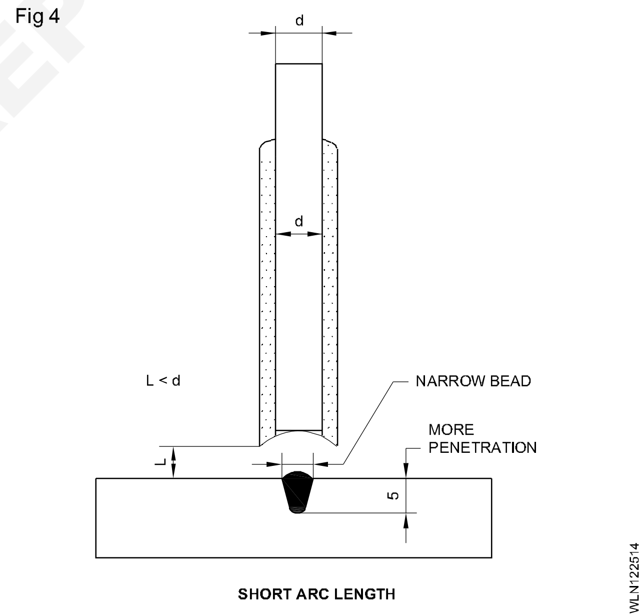


Fig 4



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 fatly 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.

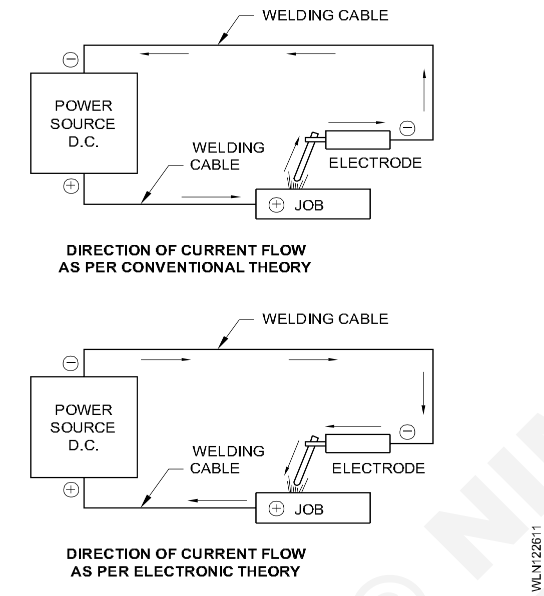
Polarity types and application

Scan QR code for this exercise

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

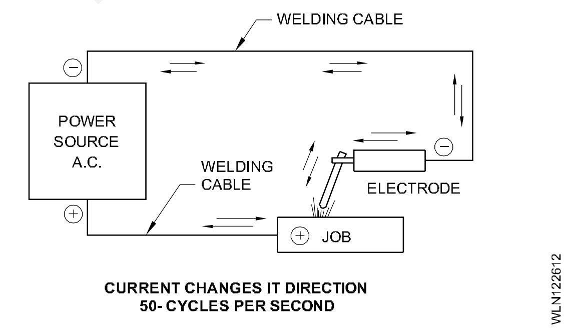
- the positive (higher potential) terminal to the negative (lower potential) terminal, as per the conventional theory
- negative terminal to positive terminal as per electronic theory.

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.

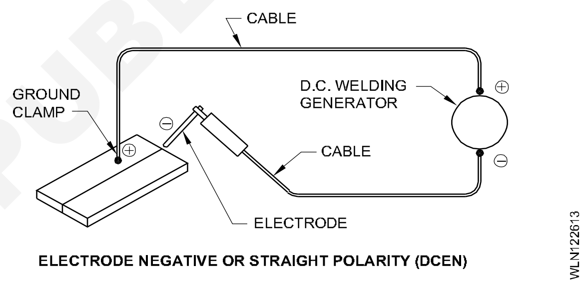
To have this advantage of unequal heat distribution in the electrode and base metal, the polarity is an important factor for successful welding.

Kinds of polarity

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

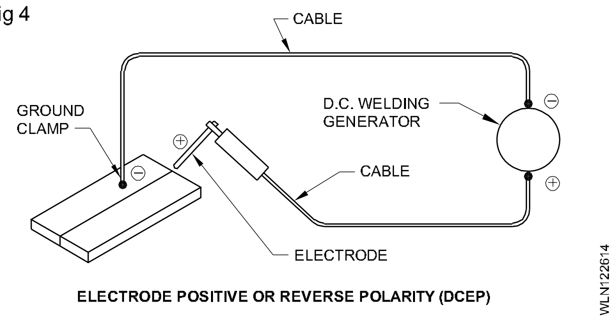
Straight polarity: In straight polarity the electrode is connected to the negative and the work to the positive terminal of the power source. (Fig 3)

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.

- 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.

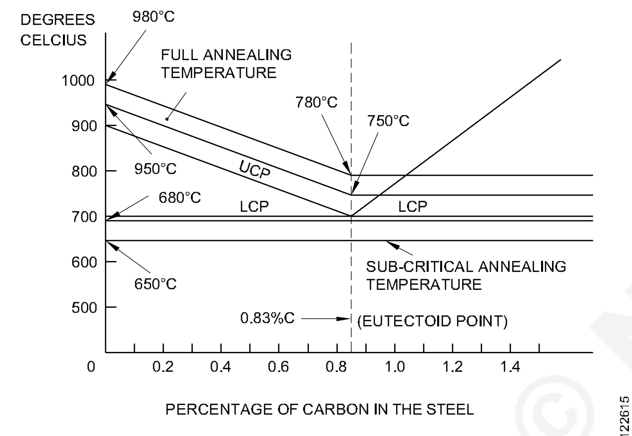
Choice of the polarity also depends on the instruction of the electrode manufacturers.

Determination of polarity: In order to get the best result's 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

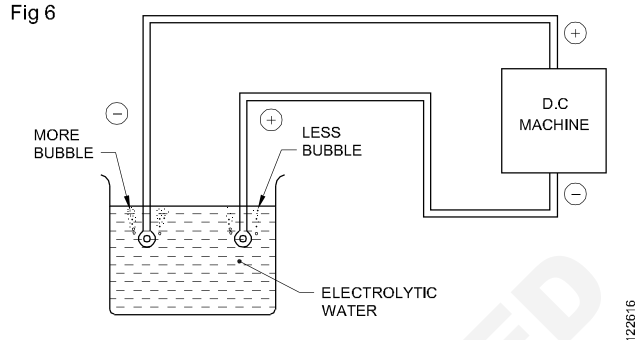


ANNEALING TEMPERATURES FOR PLAIN CARBON STEELS

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.

Weld quality and inspection common welding mistakes and apperance of good and defective welds

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of weld qualifies and inspection**
- **identify the appearance of good and defective welds.**

Introduction

Welded joint in a welded structure (e.g. a bridge) are expected to possess certain service related capabilities. Welded joint are generally required to carry loading of various type which is subject to stress of either a simple or complex character as good or as bad as it may appear to be its in surface.

Welding qualify and inspection:

Inspection has to do with observation of the processes and product of manufacture to ensure the presence of desired qualities or properties.

In certain cases inspection may be entirely qualitative and involve only visual observation of surface defects of welded joints, etc. Whereas in other instances, inspection may involve the performance of the complicated test to determine whether specification required is met or not. Testing on the other hand, specifically refer to the physical performance of operation (Test) to determine quantitative measure of certain properties such as mechanical which will be explained later.

Testing aims to determine quality, i.e. to discover facts regarding the implication of the result, whereas inspection intends to control quantity through the application of established criteria and involves the idea of rejection of substandard product.

1 **Porosity:** It is entrapment of gases evolved during weld metal solidification

2 **Slag inclusions:** The oxides and non-metallic solid materials that and entrapped in the weld metal or between the base metal and used metal

3 **Overlap:** An excess or over flow of unfused used metal extending beyond the fusion limits over the surface of the base metal.

4 **Toe crack:** The crack occurs at the location of the toe at weld joint of base metal and weld metal. This may section the longitudinal or transverse cable.

5 **Lack of fusion:** It is incomplete or partial melting and fusion of weld metal.

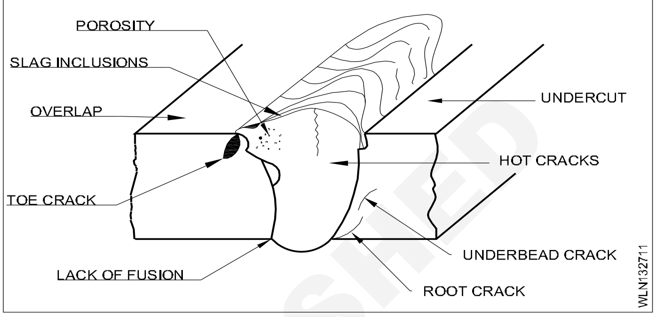
6 **Root crack:** The crack occurs at the root of a used joint

7 **Under bead crack**: It occurs under base metal due to improper, of used metal, at heat affected zone,

8 **Hot cracks:** It occurs at elevated temperature during cooling solidifying from the molten stage.

9 **Undercut:** It is a spot or continuous groove melted into base metal along the edge of weld and let in filled with weld metal.

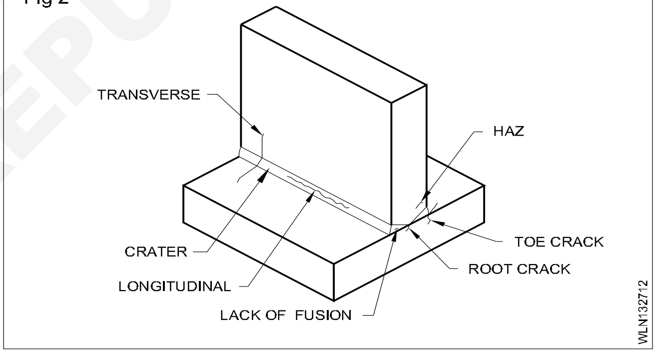
Fig 1



Common welding mistakes (Defects)

10 **Transverse crack:** The crack occurs at the location of the weld joint of base metal and weld, method across weld bead.

Fig 2

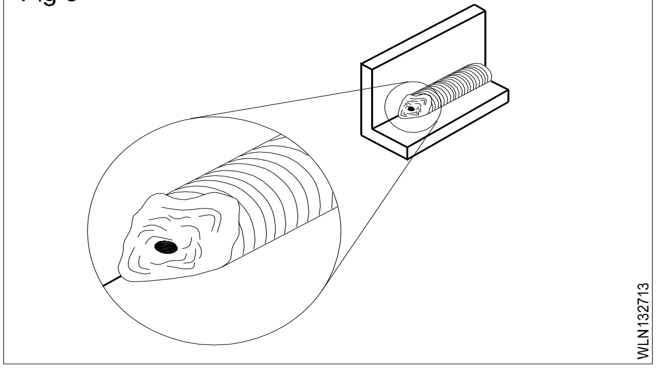


11 **Crater:** It is surface of the cavity extending into the weld bead as shown in figures.

12 **Longitudinal crack:** The crack covers at the location of the weld joint of base metal and weld metal along the face of weld seam

13 **HAZ - Heat affected zone:** The area of base metal which is melted and its micro structure properties affected by welding heat.

Fig 3



Weld gauges and its uses

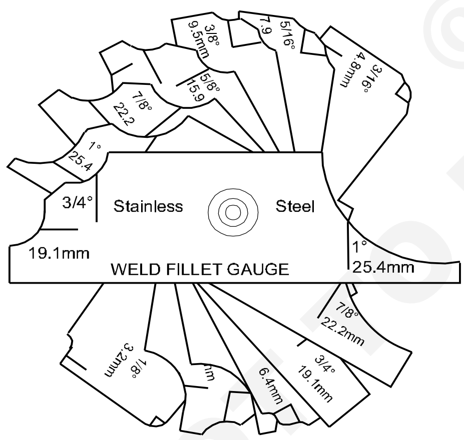
Objectives: At the end of this lesson you shall be able to
- **types of welding gauge**
- **uses at weld fillet gauge.**

Welding gauge: A set of individual leaves having the profile, made of, hardened and tempered , weld to straight with a clamping arrangement, The gauge is used to measure the leg size of weld reinforcement in butt welds, (concave and convex in case of fillet welder and) The weld joints are frequently checked for the above features, to ensure a proper weld to meet the size requirement of the component of structure which are inspected for coupling standards need stage inspection and the most suitable inspection procedure is to use the weld gauge, to attain better quality standard. The type of weld gauge weld belong the category of weld in section, to check weld profile and its required size of bead.

- weld fillet gauge (Fig 1)
- AWS type weld measurement gauge (Fig 2)

Weld fillet gauge: To check fillet weld profile for acceptable limit, the fillet weld is checked for the leg size, using weld fillet gauge. Also concaving in weld face is also to be determined by comparing the weld face adjusting the gauge. (Fig 1)

Fig 1



The fig no.1 shown is set of weld fillet gauge, which are marked with metric and equivalent inch standard. The measuring blade is made of stainless steel and accordingly finished with are end for checking the leg size and concaving of the weld face. (Fig 2)

If one of the leg sizes is short then welding size is undersized, and this is not acceptable, (Fig 3)

Also the less concaving shows a gap between measuring face to face re-weld and this is also not acceptable.

Causes of the throat thickness of weld is less is also not acceptable.

Fig 2

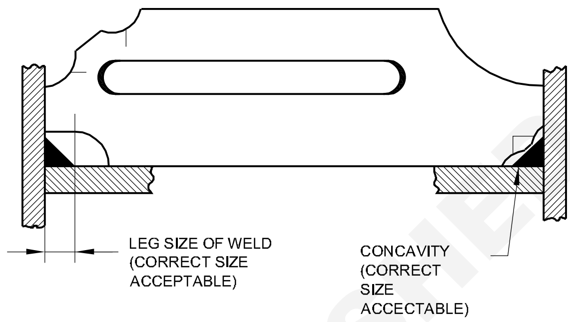
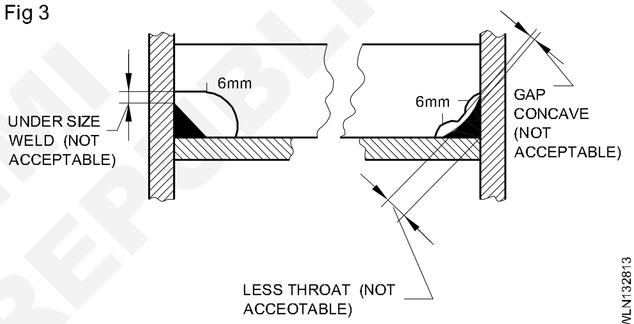


Fig 3



All weld measurement gauge

This gauge is more powerful than the standard fillet gauge. The following are the functions of this weld measurement gauge.

1 Leg size of fillet used.

2 Acceptable size of convexity.

3 Acceptable size of concavity.

4 Acceptable reinforcement height on butt weld

The gauges consist of struck which can be suitably altered according to the position of the used bead for fillet used butt weld.

It consists of blade whose alignment is adjusted according to the weld bead surface.

According to the type of measurement the blade after positioning over the weld bead the locking screw as shown in (Fig 4) Is tightened suitably to determine the measurement.

1 **Leg size of fillet weld:** To determine the fillet weld leg size the slot is placed against the toe of the weld as shown in (Fig 5)

Fig 4

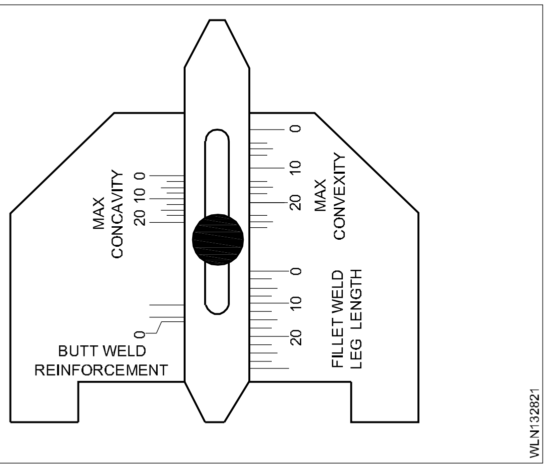
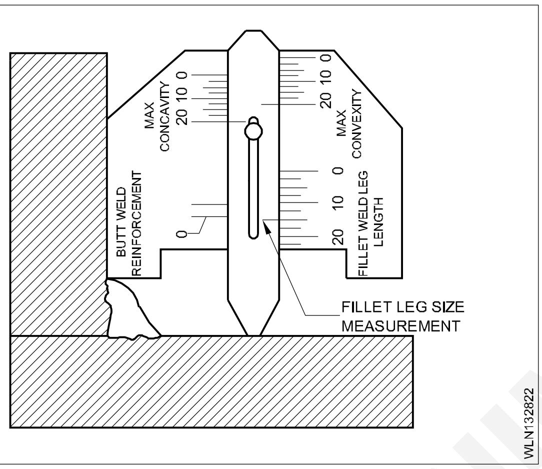


Fig 5



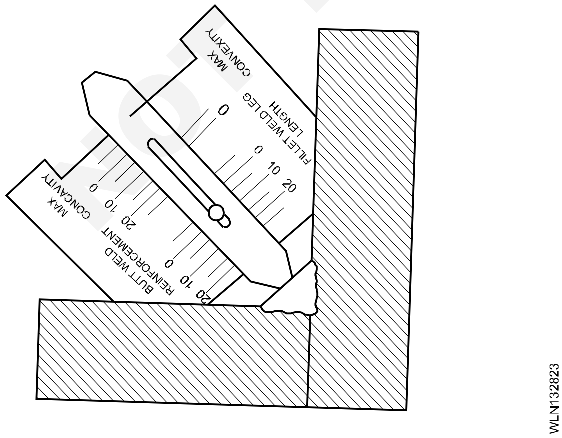
On moving the pointer blade as shown in the figure down wards on the face of the other joint number.

The coincidence of the graduation scale defines the fillet issued leg measurement.

2 Acceptable size of convexity: To determine the acceptable size of convexity, the stock portion of the gauge having 45° angle sides to which both the members of the joints is placed as shown in Fig 6.

On sliding due pointer blade to touch the face of the weld determines the convexity of reinforcement.

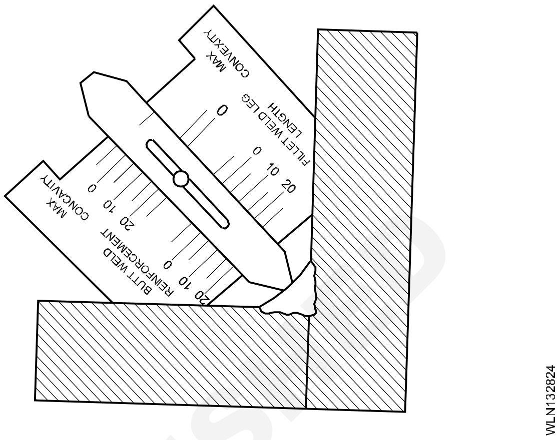
Fig 6



3 Acceptable size of convexity: To determine the acceptable size of convexity the stock portion of the gauge having 45° angle sides touching both the members of the joints is placed as shown in Fig 7.

On sliding the pointer blade to touch the face of the weld determines the concavity, formed due to under fill of the weld bead as shown in Fig 7.

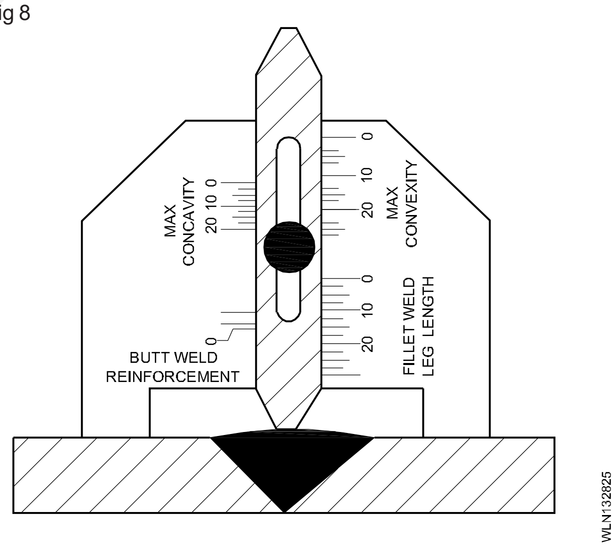
Fig 7



4 Acceptable reinforcement height on butt weld: To determine the acceptable size of reinforcement height on butt weld, the spoke portion of the gauge, flat portion may be scatted on either size of butt weld as shown in Fig 8, on sliding the pointer blade downwards to touch the reinforcement placed on the butt weld.

The coincidence of the graduated scale determines the acceptable reinforcement height of the weld bead.

Fig 8



Calcium carbide and its uses & hazards

Objectives: At the end of this lesson you shall be able to
- **state the composition of calcium carbide**
- **explain the calcium carbide uses and 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 CaC_2

Calcium carbide uses

Application of calcium carbide includes manufacture of acetylene gas and for generation of acetylene in carbide lamps, manufacture of chemicals for fertilizer and in steel making.

Calcium carbide hazards

Calcium carbide can irritate the skin causing a rash, redness and burning feeling on contact permanent damage(corneal opacities) exposure make us built us on fluid in the lungs(pulmonary enema) a medical emergency.

Acetylene gas - Properties and flash back arrester

Objectives: At the end of this lesson you shall be able to
- **explain the composition and properties of acetylene gas**
- **explain the flash back arrester.**

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.

Flash back arrester

When a flammable mixture of fuel gas and air or oxygen is present in a gas line upstream of a welding or cutting blowpipe, flame can flash back into the gas line and there is the possibility of a serious accident.

A flame or flashback arrestor is a safety device designed to stop a flame in its tracks. It is therefore used to prevent flashback into cylinders or pipework.

A flashback arrestor serves to prevent reverse flow of oxygen into fuel lines and fuel into oxygen lines.

The flame arrestor usually contains an element which may consist of narrow passages through a wire mesh or metal foam. When a flame enters the element, it is quickly cooled by the cold surface of the element and the flame is extinguished. The flame arrestor may contain a pressure or temperature actuated cut-off valve and may then be known as a flashback arrestor.

It is strongly recommended that arrestors with cut-off valves are fitted to the pressure regulator outlet of all acetylene cylinders and acetylene distribution systems. It is highly advisable to fit them to the oxygen outlet. And other fuel gas outlets. They can be fitted to the blowpipe but this offers no protection from a fire arising from a leaking hose.(Fig 1, 2)

Fig 1

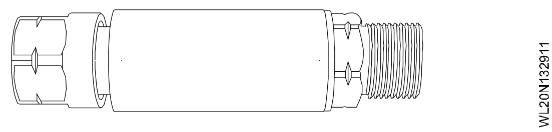
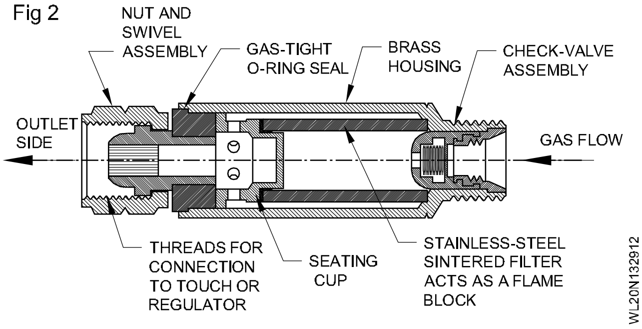


Fig 2



Oxygen gas properties & uses

Objective: At the end of this lesson, you shall be able to
- **explain the composition and properties of oxygen gas.**

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.

Uses of oxygen gas

- It plays a main role in respiration.
- It is used in oxy-acetylene welding & cutting.
- It is used for artificial respiration in hospitals.
- Common uses of oxygen includes production of steel, plastics, textiles, rocket propellant, oxygen therapy, life support systems in aircraft, submarines, spaceflight, etc.

Charging process of oxygen & acetylene gases

Objective: At the end of this lesson you shall be able to
- **describe the charging process of oxygen and acetylene gases.**

Charging of gas in oxygen cylinder: The oxygen cylinders are filled with oxygen gas under a pressure of 120-150kg/cm2.The cylinders are tested regularly and periodically. They are annealed to relieve stresses caused during 'on the job' handling. They are periodically cleaned using caustic solution.

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 litres 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.

Method of charging DA gas cylinder: The storage of acetylene gas in its gaseous form under pressure above 1kg/cm2 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 corn stalk
- fullers earth
- lime silica
- specially prepared charcoal
- fibre asbestos.

The hydrocarbon liquid named acetone is then changed 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.15kg/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 25volumes 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/cm2 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 acetylenes gas cylinders and colour coding different gas cylinder

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

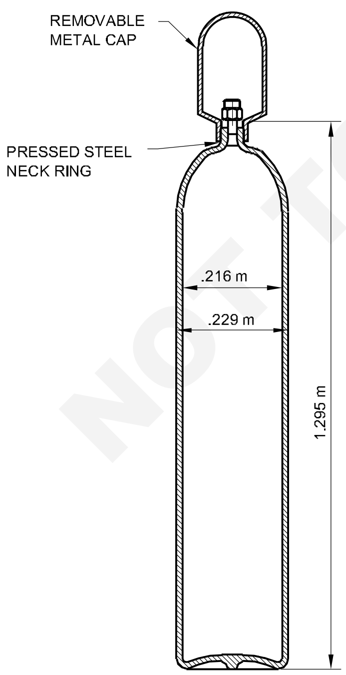
Types and identifications of gas cylinders: Gas cylinders are called by names of the gas they are holding. (Table 1)

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

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.

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)

Fig 1



CONSTRUCTIONAL FEATURE OF OXYGEN GAS CYLINDER

WLN133311

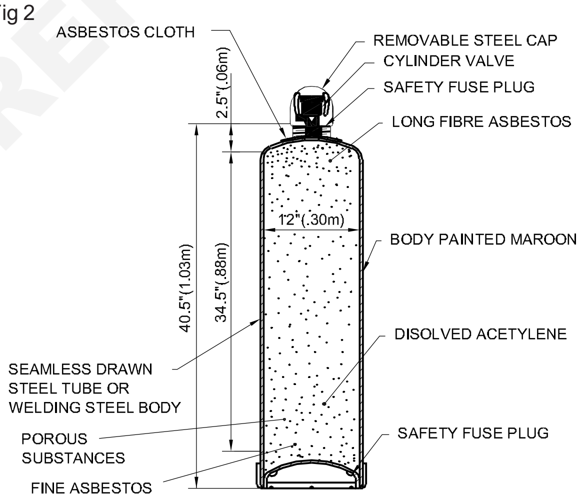
The cylinder body is painted black.

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

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

Constructional features (Fig 2): 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 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 2

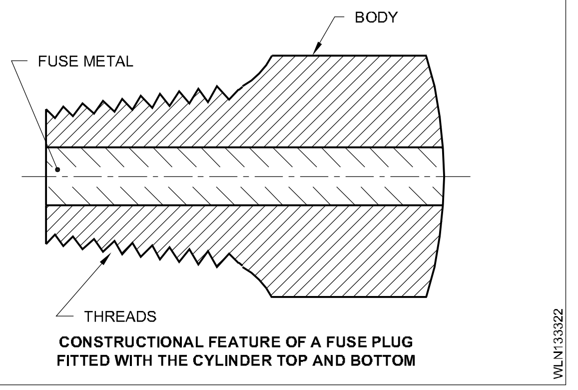


CONSTRUCTIONAL FEATURES OF A DISSOLVED ACETYLENE GAS CYLINDER

WLN133321

The base of the DA cylinder (Curved inside) is fitted with fuse plugs which will melt at a temperature of app. **100/// C** (Fig 3). 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 3



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

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

Welding gas regulators, uses of single and double stage gas regulators

Objectives: At the end of this lesson you shall be able to
- **identify the types of regulators and its parts**
- **describe the working principle of a single and double stage regulator.**

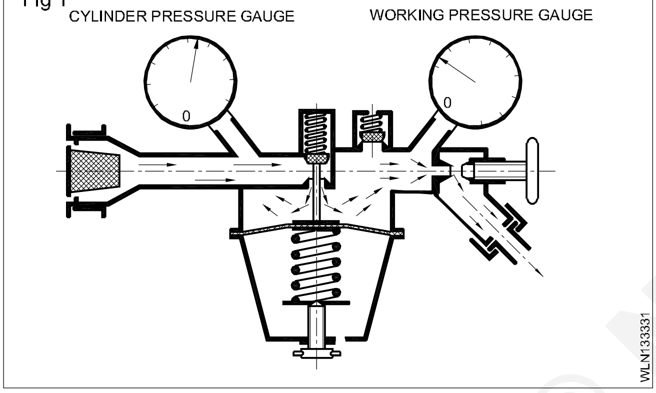
Types of regulators

- 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)

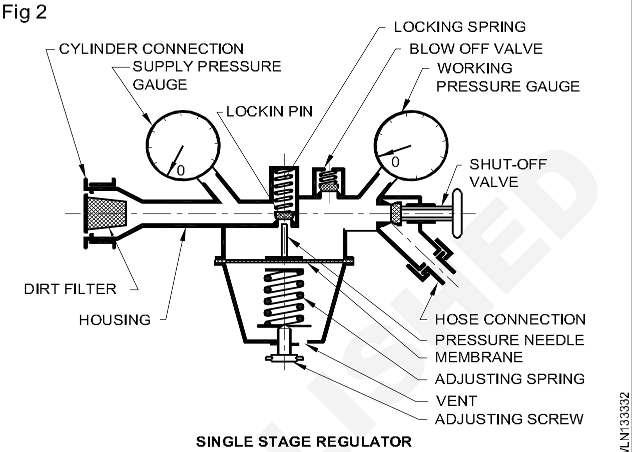
Fig 1



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)

Fig 2



SINGLE STAGE REGULATOR

Welding regulator (double stage)

Working principle: The two-stage regulator 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.

Oxy-acetylene gas welding system (low pressure and high pressure)

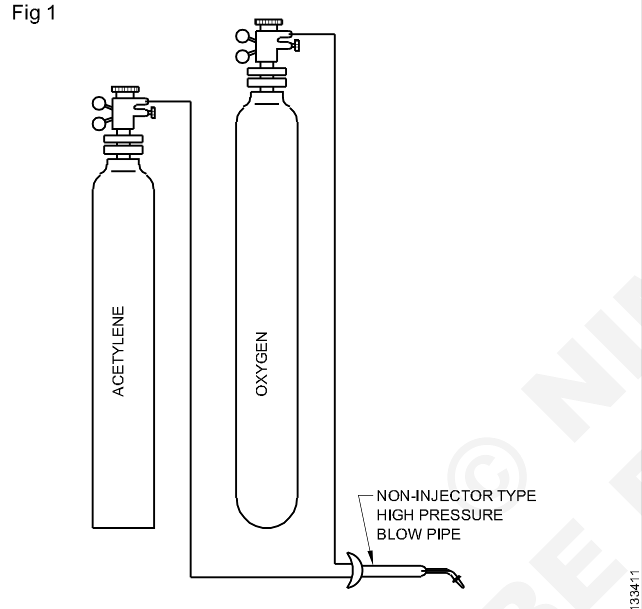
Objective: At the end of this lesson you shall be able to
- **explain low pressure and the high pressure systems of oxy-acetylene plants.**

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.

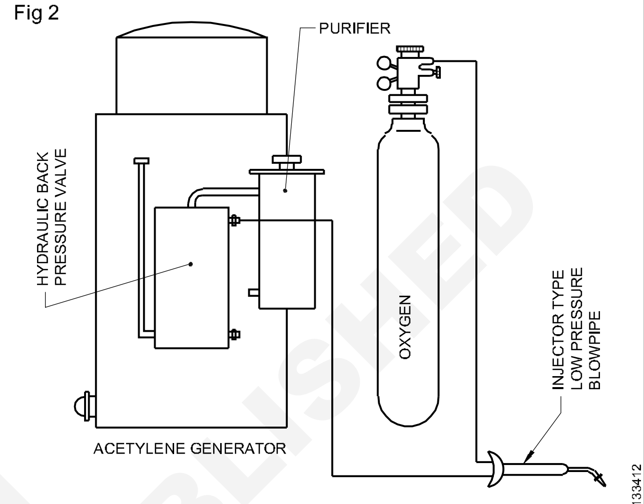
A low pressure plant utilizes acetylene under low pressure (0.017 kg/cm^2) produced by the acetylene generator only. (Fig 2)

> **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.

Advantages of high pressure system: Safe working and less chances of accidents. The pressure adjustment of gases in this system is easy and accurate, hence working efficiency is more. The gases being in cylinder are perfectly under control. The D.A cylinder is portable and can be taken easily from one place to another place.

The D.A cylinder can be fitted with a regulator quickly and easily, thus saving time. Both injector and non-injector type blowpipes can be used. No license is required for keeping the D.A cylinder.

Difference between gas welding and gas cutting blow pipe

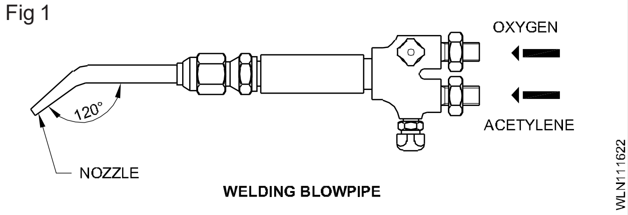
Scan QR code for this exercise

Objective: At the end of this lesson you shall be able to
- **identify the difference between gas welding & cutting blow pipe.**

Difference between cutting blow pipe and welding blow pipe:A cutting blow pipe has two control valves(oxygen and acetylene)to control the preheating flame and one lever type control valve to control the high pressure pure oxygen for making the cut.

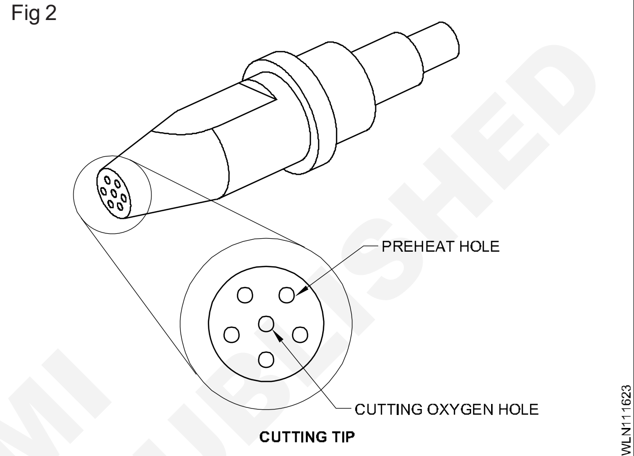
A welding blowpipe has only two control valves to control the heating flame. (Fig 1)

Fig 1



The nozzle of the cutting blowpipe has one hole in the centre for cutting oxygen and a number of holes around the circle for the preheating flame.(Fig 2)

Fig 2



Gas welding technique right ward & left ward

Objectives: At the end of this lesson you shall be able to
- **name the different gas welding techniques used in gas welding**
- **explain the leftward & rightwards techniques**
- **state the application of rightward & leftward techniques.**

There are two welding techniques on oxy-acetylene welding process. They are:

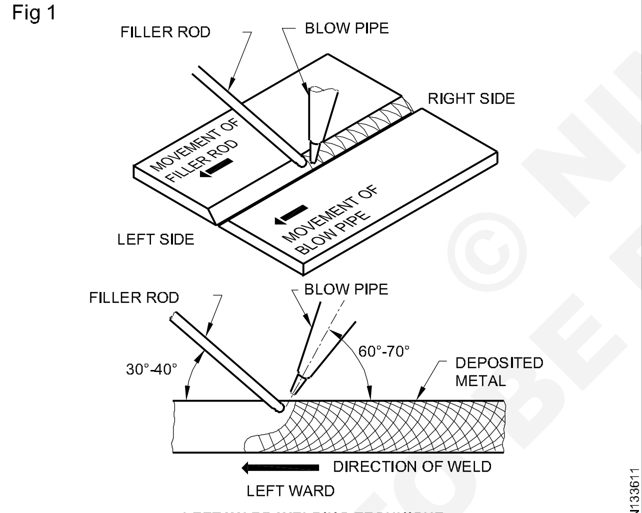
1 Leftward welding technique (Forehand technique)

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.

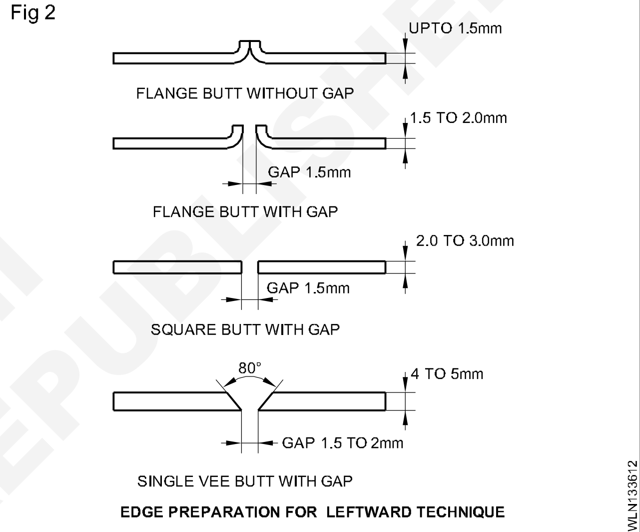
The filler rod is added in the (Weld) molten pool by a piston like motion and not melted off by the flame itself.

> **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.**

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.

Gas welding technique

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)

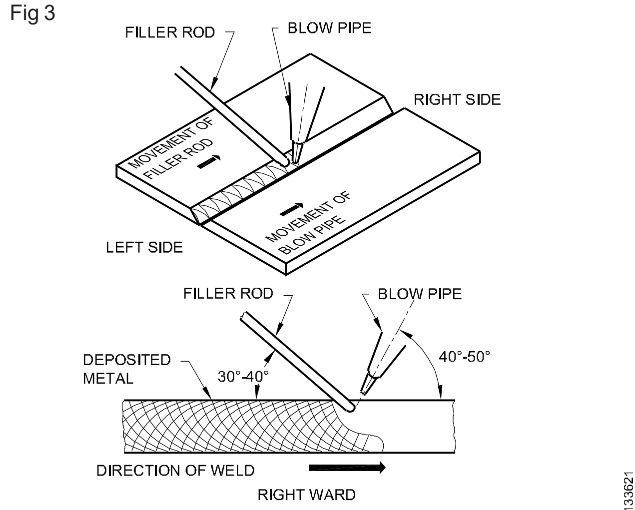


Fig 3 FEATURE OF RIGHTWARD WELDING TECHNIQUE

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)

For butt joints the edges are prepared.

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.

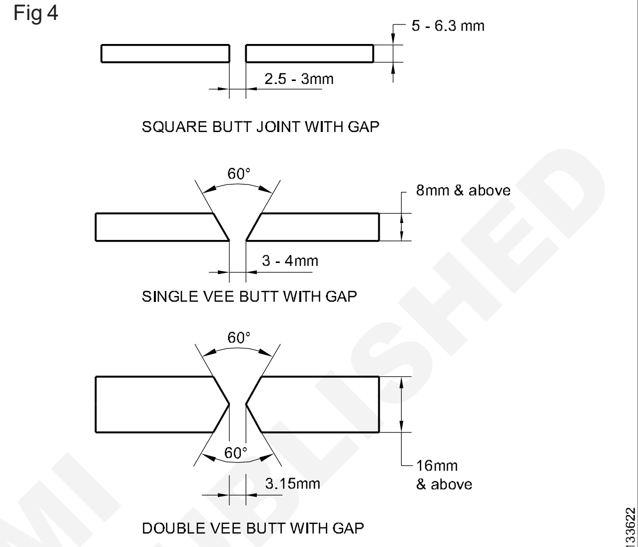


Fig 4 EDGE PREPARATION FOR RIGHTWARD WELDING

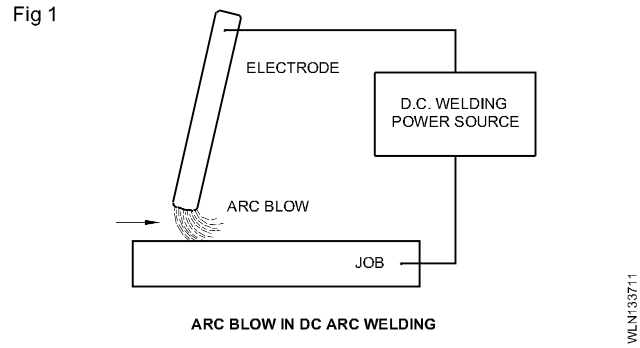
We can have a better view of the molten pool giving a better control of the weld which results in more penetration. The oxidation effect on the motion metal is minimized as the reducing zone of the flame provides continuous coverage.

Arc blow causes and methods of controlling

Objectives : At the end of this lesson you shall be able to
- **explain the effects of arc blow**
- **describe the 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)

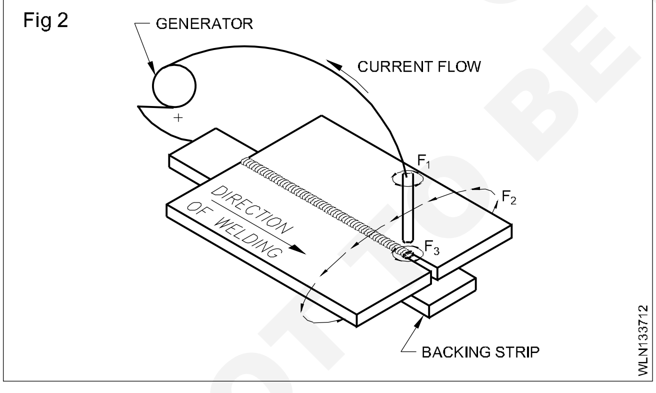
Fig 1



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)

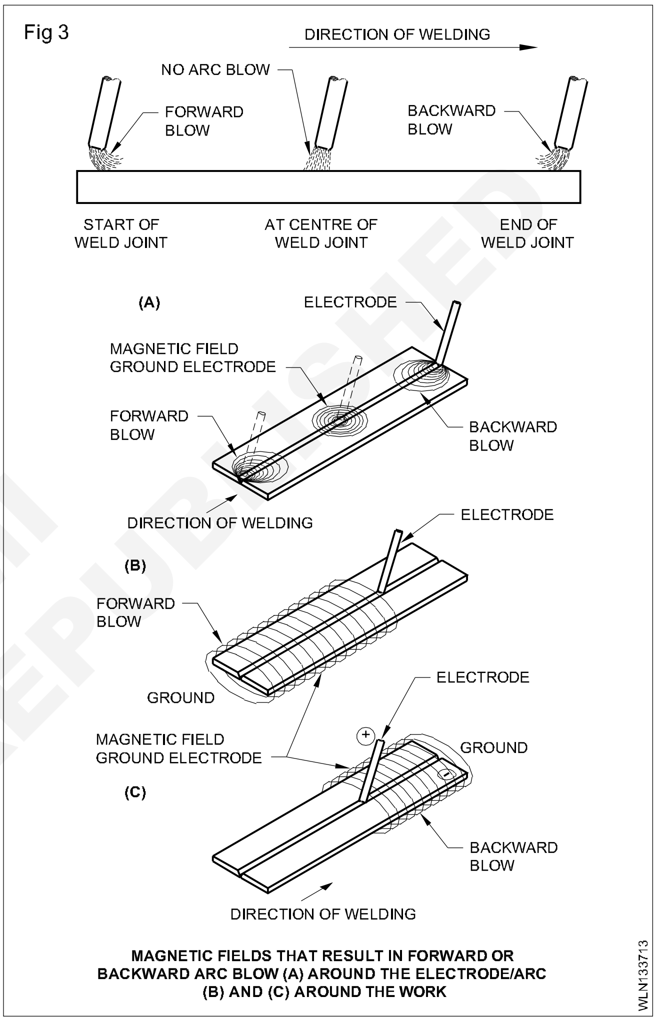
Fig 2



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

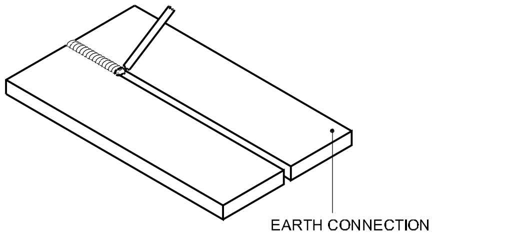
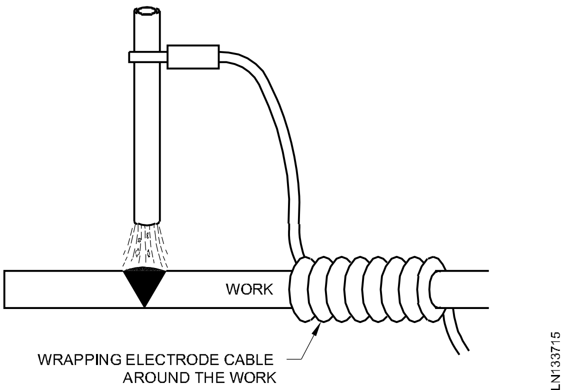


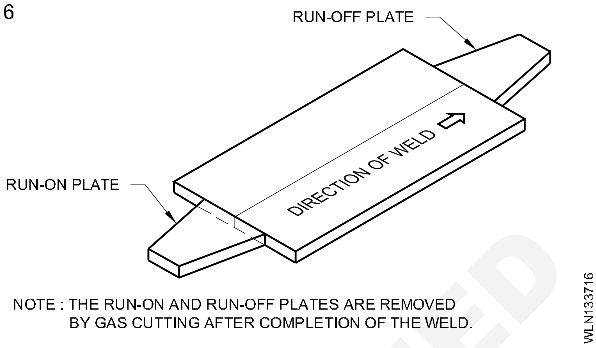
Fig 5



- 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



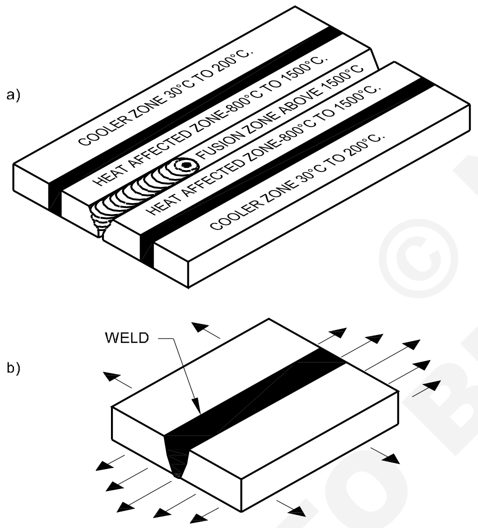
Distortion in arc & gas welding and methods employed to minimise distortion

Scan QR code for this exercise

Objectives : At the end of this lesson you shall be able to
- **explain the causes of distortion**
- **name the types of distortion**
- **explain the methods of preventing and correcting distortion.**

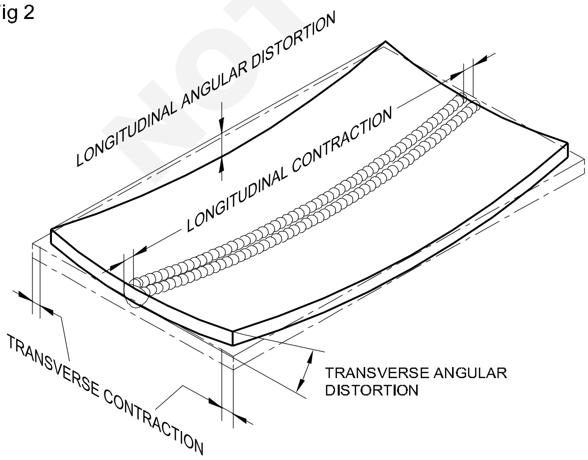
Causes of distortion: In arc welding, the temperature at different areas of the joint are different. (Fig 1a). The expansions in these areas are also different depending on the temperature (Fig 1b). In the same way after welding, different areas of the joint contract differently, But in a solid body (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

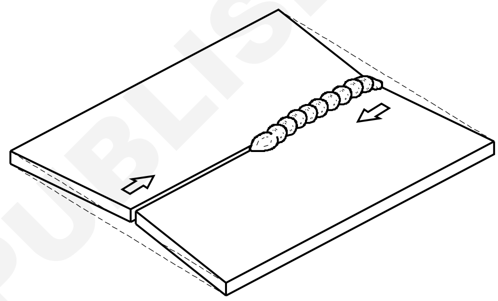
Types of distortion

The 3 types of distortion are:

- longitudinal distortion
- transverse distortion
- angular distortion.

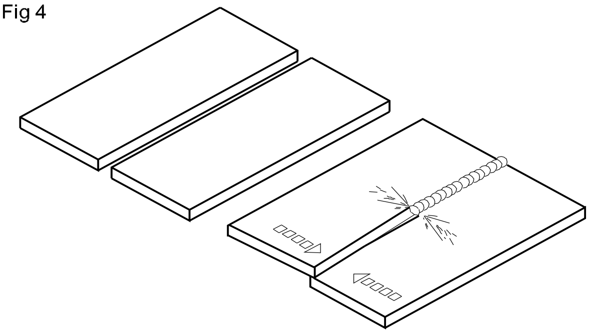
The Figs 3,4 & 5 illustrate the different types of distortion.

Fig 3



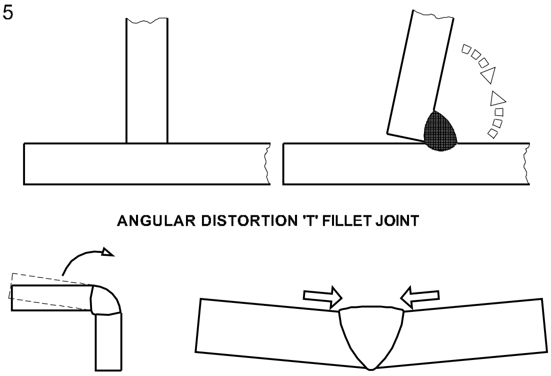
LONGITUDINAL DISTORTION

Fig 4



TRANSVERSE DISTORTION

Fig 5



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.

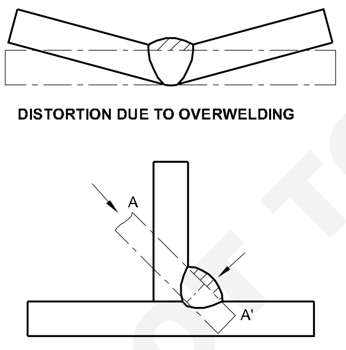
- Reducing the effective shrinkage force.
- Making the shrinkage forces to reduce distortion.
- Balancing the shrinkage force with another shrinkage force.

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



DISTORTION DUE TO OVERWELDING

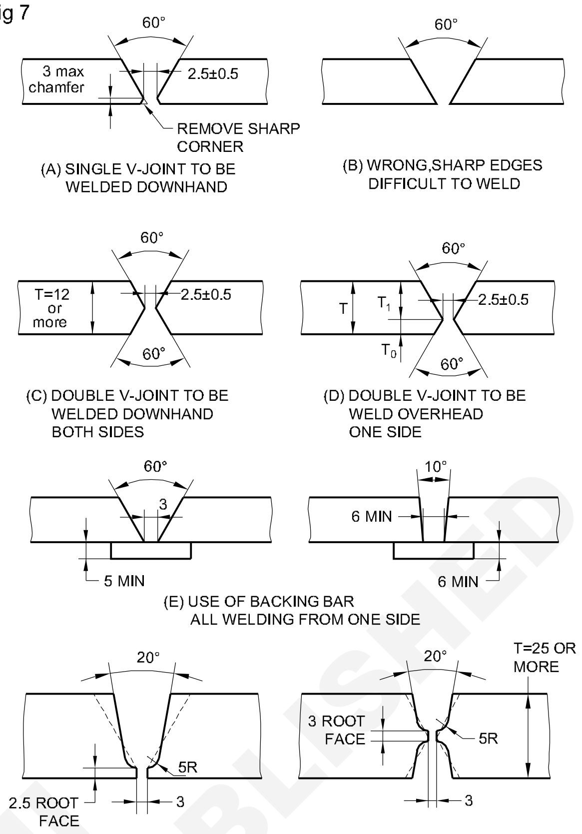
EXCESS WELD METAL ABOVE THE LINE A A' OF CONVENTIONAL FILLET WELD

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)

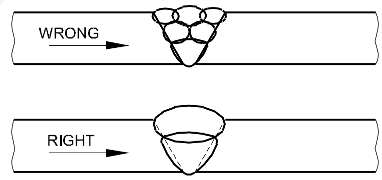
Use of deep fillet weld: Place the weld as possible to the neutral axis by using the deep fillet method. This will reduce the leverage of pulling the plates out of alignment. (Fig 9)

Fig 7



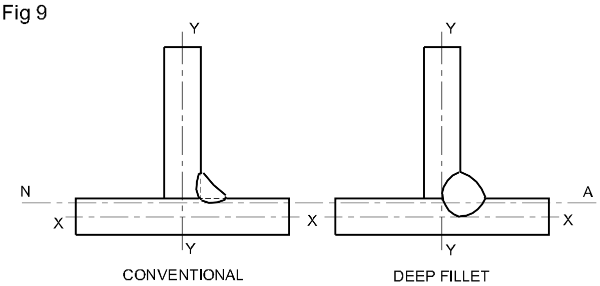
PREPARATION OF PLATES FOR BUTT WELDING

Fig 8



COMPARISION OF PASSES OF WELD

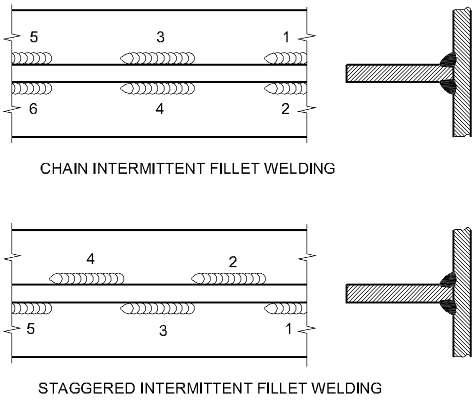
Fig 9



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

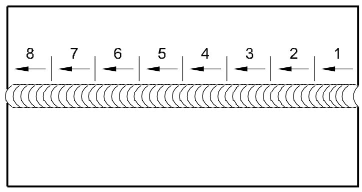


INTERMITTENT WELDING

WLN13381A

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



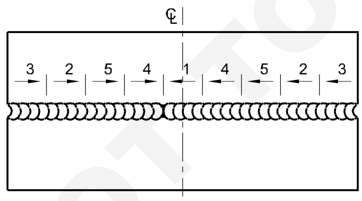
BACK STEP WELDING METHOD

WLN13381B

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

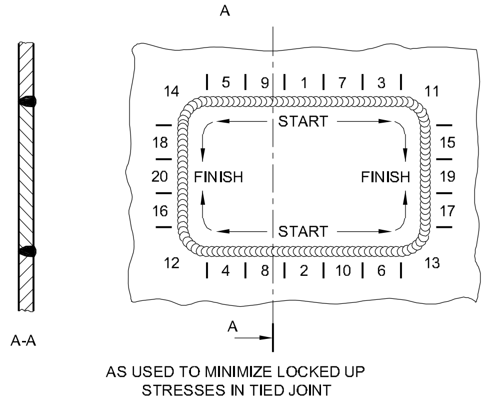


PLANNED WANDERING METHOD

WLN13381C

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



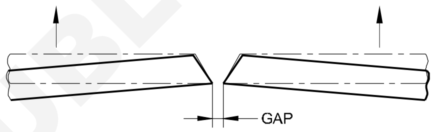
SKIP WELDING

WLN13381D

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)

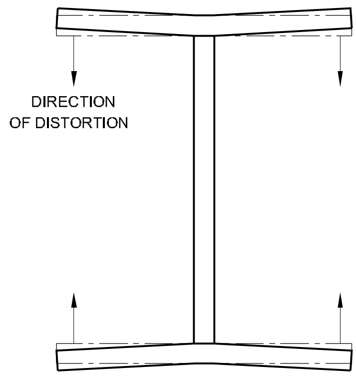
Fig 14



PRE-SETTING TO COMPENSATE FOR ANGULAR DISTORTION

WLN13381E

Fig 15

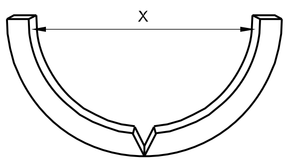


PRE-CAMBERING TO COMPENSATE FOR ANGULAR DISTORTION

WLN13381F

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



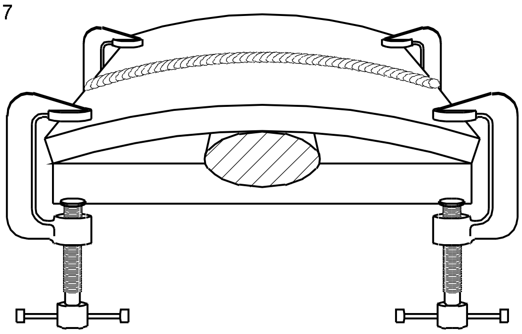
X = DIAMETER + SHRINKAGE ALLOWANCE

SPACING OF PARTS TO ALLOW FOR SHRINKAGE

WLN13381G

Pre-bending: Shrinkage forces may be put to work in many cases by pre-bending. (Fig 17)

Fig 17

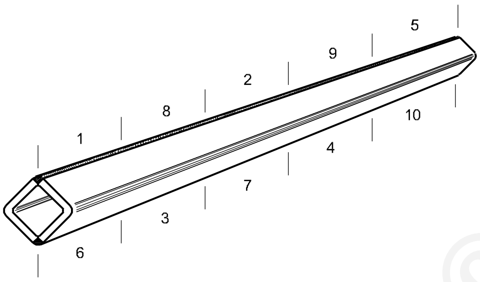


PRE-BENDING

Methods of balancing of one shrinkage force with another shrinkage force

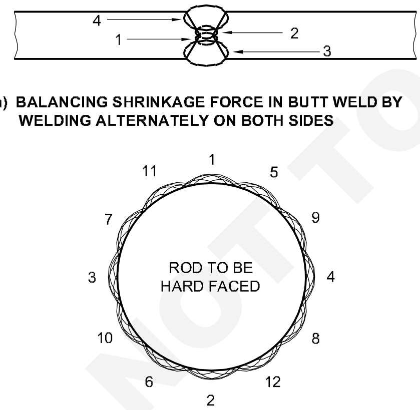
Use of proper welding sequence: This places the weld metal at different points about the structure. In this method, welds are made from each side alternately so that when a second run of weld metal shrinks it will counteract the shrinkage forces of the first weld. (Figs 18, 19 a and 19b)

Fig 18



AS USED WHEN FABRICATING SQUARE SECTIONS FROM ANGLES OR CHANNELS

Fig 19

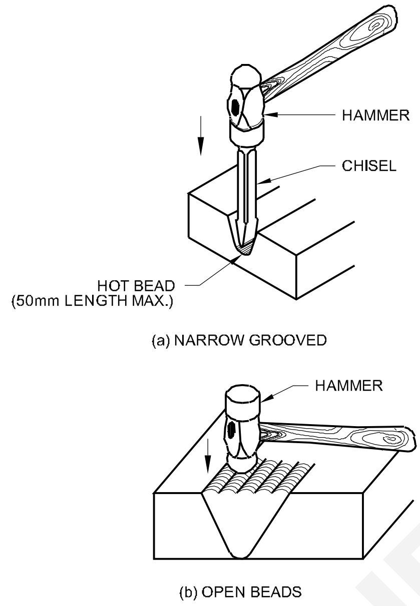


a) BALANCING SHRINKAGE FORCE IN BUTT WELD BY WELDING ALTERNATELY ON BOTH SIDES

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.

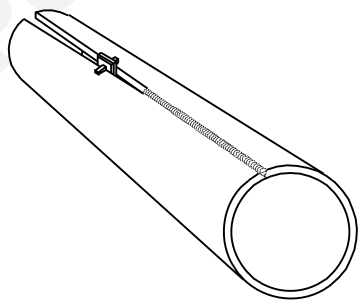
Fig 20



PEENING

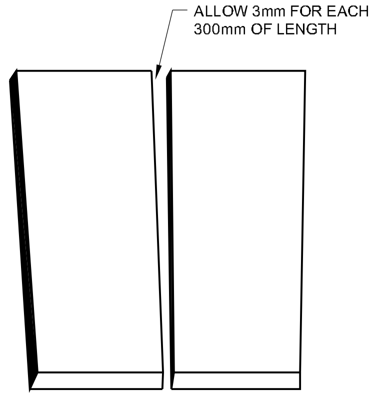
Divergence allowance: As there is a tendency of the plates to extend & converge along the seam during welding, this technique is used to diverge the plates from the point where welding commences by placing a wedge or an alignment clamp between the plates ahead of the weld. (Fig 21& 22)

Fig 21



DIVERGENCE ALLOWANCE

Fig 22



PROVIDE SPACE BETWEEN THE EDGES TO BE WELDED

DIVERGING ALLOWANCE

Arc welding defects causes and remedies

Scan QR code for this exercise

Objectives: At the end of this lesson you shall be able to
- **name different weld defects in arc welding**
- **describe the defects and rectify the welded joints**
- **state the 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

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.

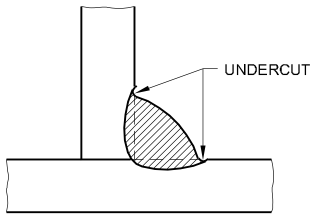
A remedy can be

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)

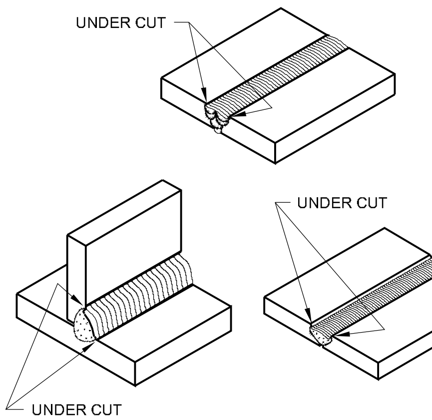
Fig 1



TEE-JOINT FILLET WELD

WLN133911

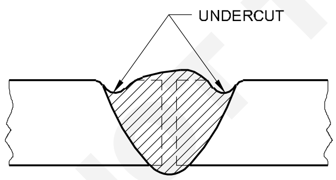
Fig 2



A SCHEMATIC DIAGRAM OF UNDERCUTS IN FILLET AND BUTT WELDS.

WLN133912

Fig 3



SQUARE-BUTT WELD

WLN133913

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

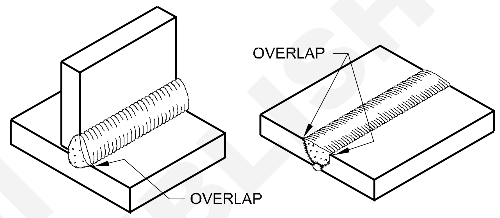
b Corrective action

- 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

WLN133914

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 under-cut.

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)

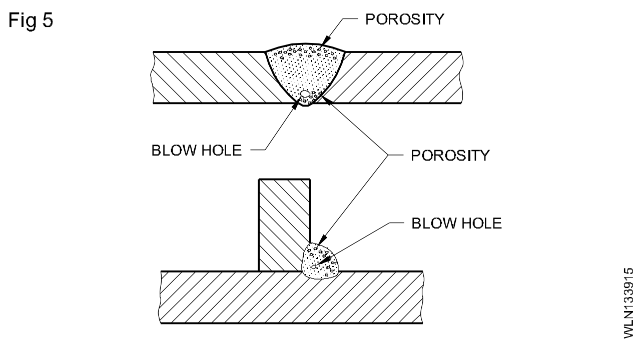


Fig 5

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)

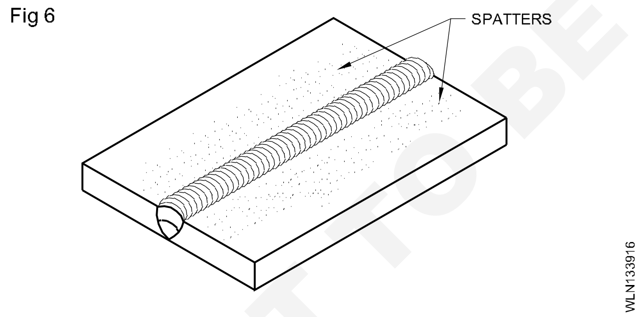


Fig 6

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)

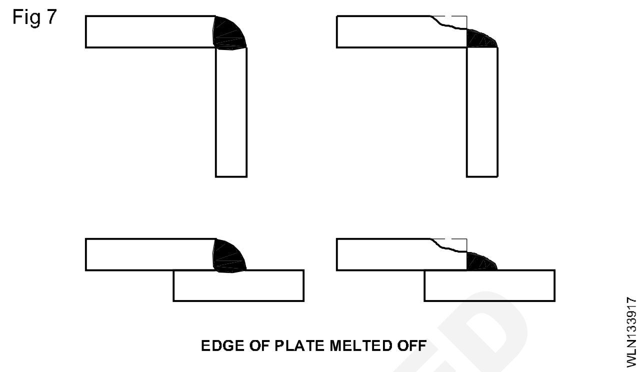


Fig 7

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)

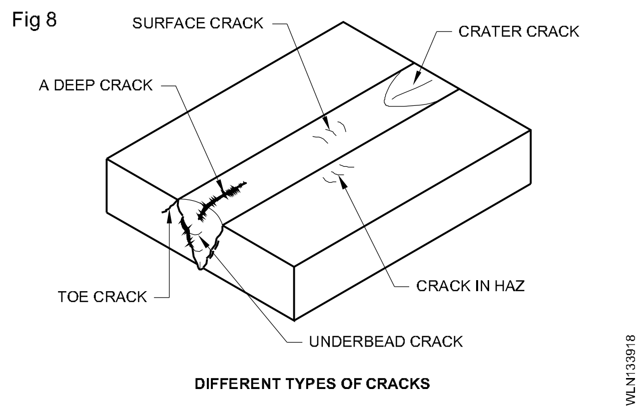


Fig 8

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

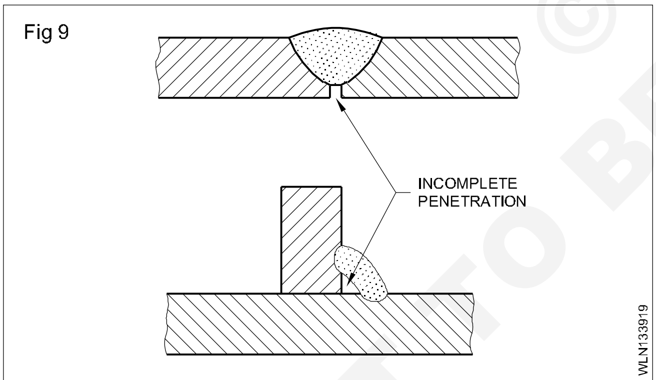
– For all external cracks to a smaller depth, take a V groove using a diamond point chisel upto the depth of the crack and re-weld (with preheating if necessary) using low hydrogen electrode. Cool the job slowly.

– 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)

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.

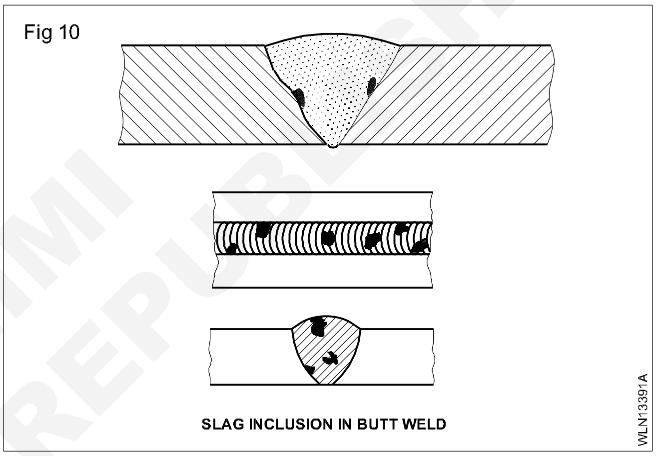
– Correct current setting is required.

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)

Fig 10



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.

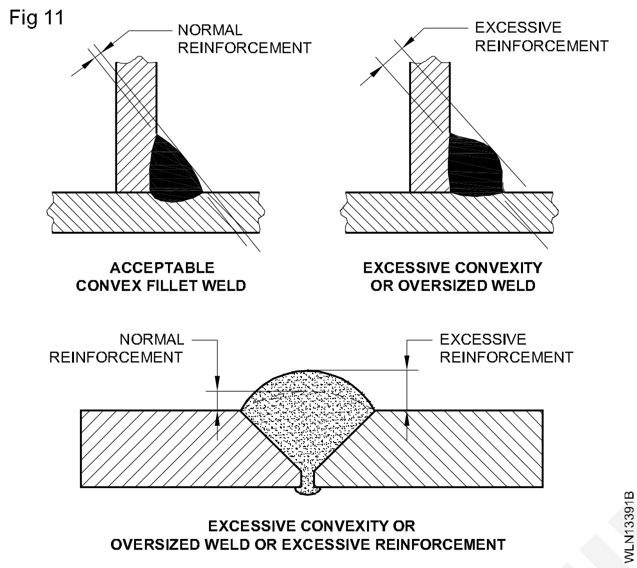
b Corrective actions

- 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.

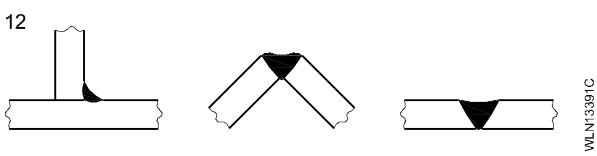
Fig 11



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)

Fig 12



Causes

- Incorrect bead profile due to improper weaving of electrode.
- 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 type of pipe joints, position & procedure

Scan QR code for this exercise

Objectives: At the end of this lesson you shall be able to
- **identify the various types of pipe joints, describe the specification of pipes**
- **describe the different position of pipe welding**
- **explain the pipe welding procedure.**

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.

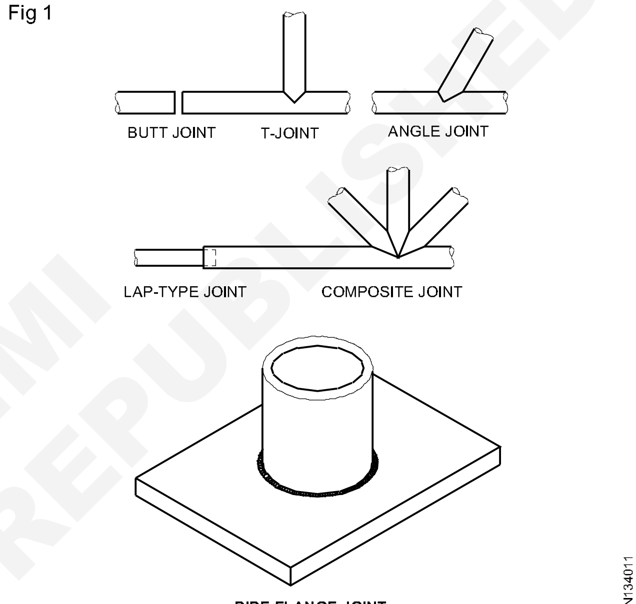
– Metallic arc welding
– Gas metal arc welding
– Tungsten inert gas welding
– Submerged arc welding
– Carbon arc welding

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

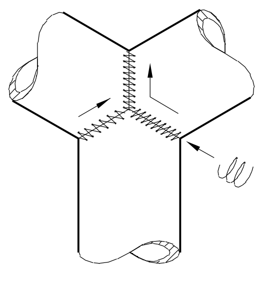
1 Butt joint
2 'T' joint
3 Lap joint (Fig 1)
4 Angle joint

Fig 1



5 composite joint
6 Pipe flange joint
7 Y joint (Fig 2)

Fig 2

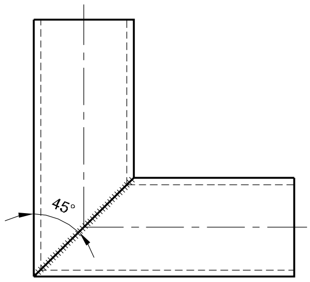


8 Elbow joint (Fig 3)

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.

Fig 3

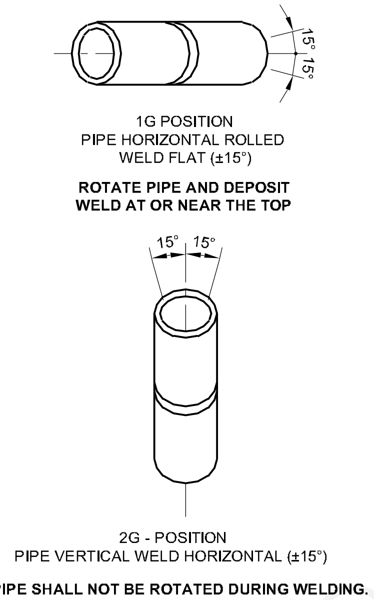


ELBOW JOINT

WLN134013

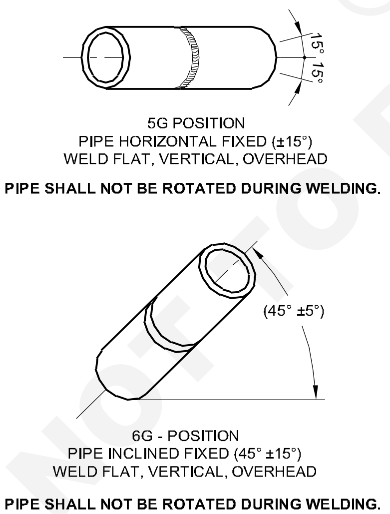
Pipes welding positions (Figs 4&5)

Fig 4



WLN134014

Fig 5



WLN134015

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.

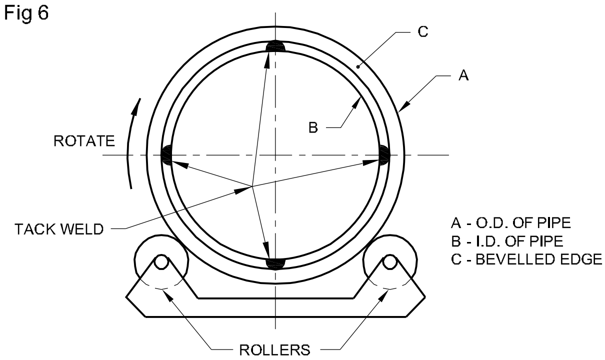
Setting the pipes for welding: Tack weld together with 4 small equally spaced tacks. The gap should be equal to the root face dimension plus 0.75 mm. Support the tacked assembly on V blocks or rollers so that the assembly can be rolled or rotated with the free hand.

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.

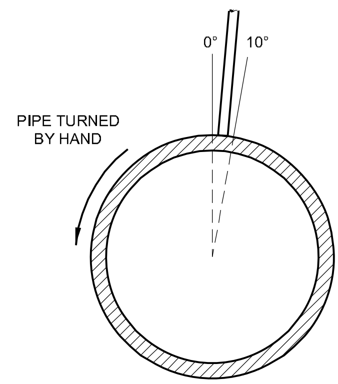
Rotate the assembly as welding proceeds. (Fig 6) keeping the welding arc within an area between vertical and 10° from the vertical in the direction of welding Fig 7. (Use a helmet type screen).

Fig 6



WLN134016

Fig 7



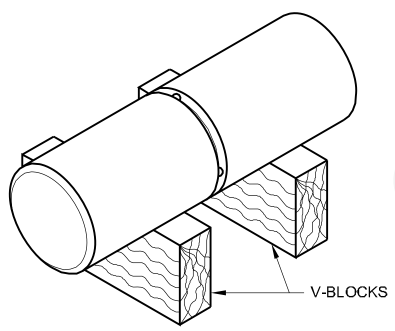
WLN134017

- 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.

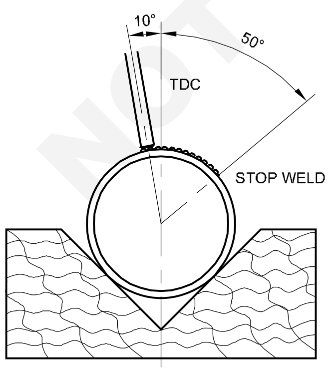
- The edges of the pipe are beveled to 35 to 40° angle with a root gap of 2.5 mm.
- Tack the pipe as before and support the assembly on two 'V' blocks. (Fig 8)

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)

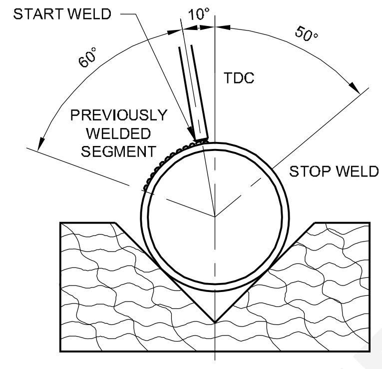
Fig 9



WELDING FIRST SEGMENT

- When a segment equivalent to 60° has been welded, terminate/stop the weld run. Avoid the formation of a crater.
- 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)

Fig 10



WELDING SECOND SEGMENT

- 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.

Pipe welding by arc in fixed positions

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.

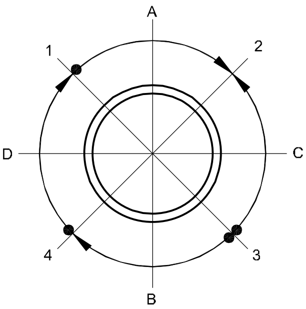
The other pipe welding positions in which the pipes are fixed during welding are 2G and 6G positions. If the axis of the fixed pipes to be welded are vertical then this position is called 2G position. If the axis of the fixed pipes in inclined at 45° to both horizontal and vertical planes, then the welding 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 11)

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.

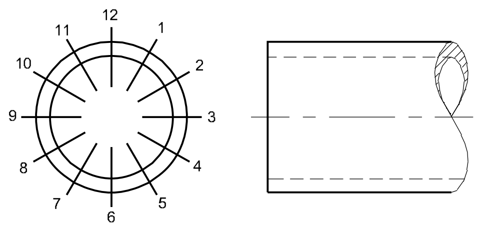
Fig 11



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 12)

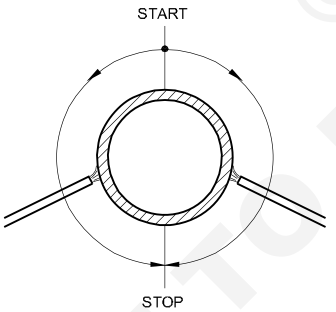
Fig 12



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 13). This method is called down hill method and is normally used for thin walled pipes with wall thickness of 3 to 4 mm.

Fig 13



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 14). 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 15)

In the 6G position welding is usually done by using one of the methods i.e. uphill or downhill welding. (Fig 16)

Fig 14

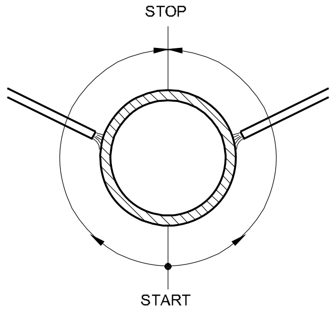
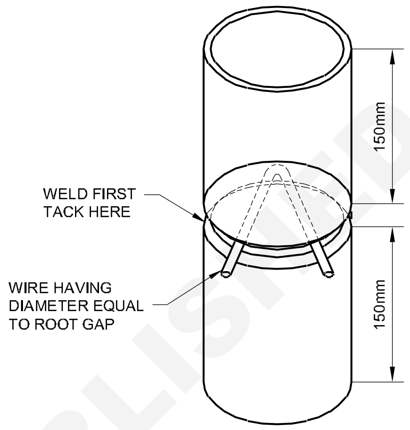
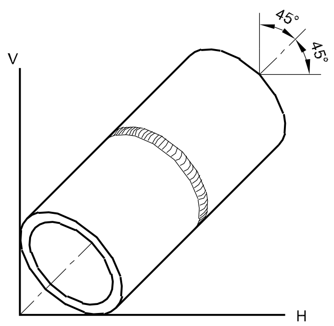


Fig 15



USE OF BEND WIRE OF SPACER TO SET ROOT GAP

Fig 16



POSITION 6 G

Use electrodes specially manufactured for pipe welding to get good penetration, appearance and strength, (low hydrogen electrodes, deep penetration electrodes etc.)

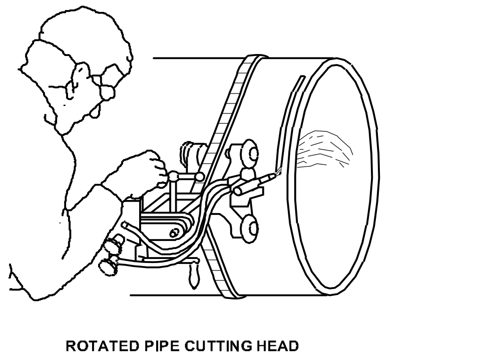
Welding procedure of M.S. pipe butt joint by arc in fixed (5G) position.

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 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.

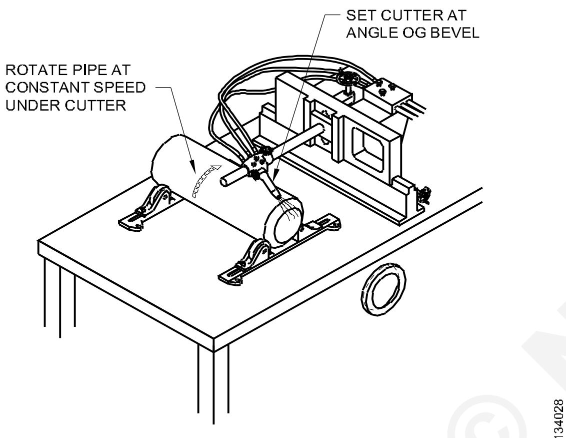
Edge preparation: The pipe ends are beveled by flame cutting or machining in the shop (Figs 17 & 18) The including angle is 75° the root face and root gap are 2.5 mm to 3 mm. All traces of oxide from and other contaminations must be removed before starting the weld. (Fig 19)

Fig 17



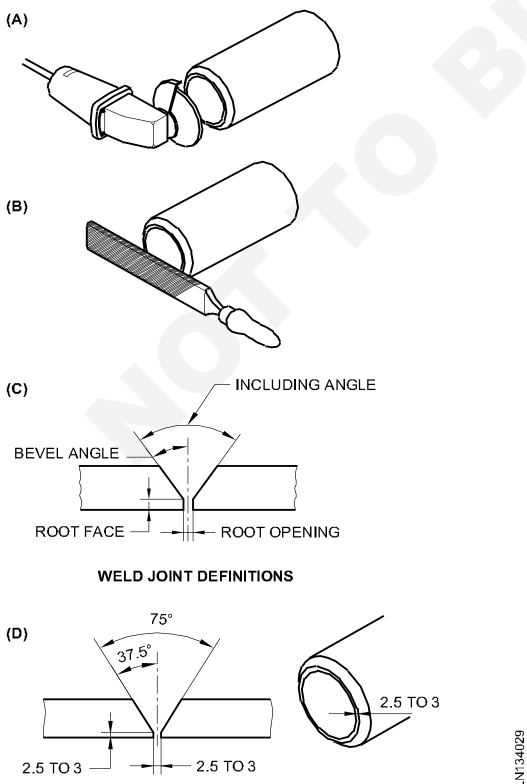
ROTATED PIPE CUTTING HEAD

Fig 18



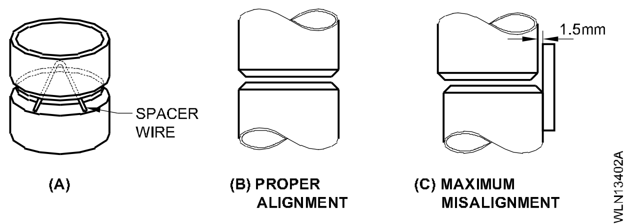
CUTTING BEVEL ON PIPE

Fig 19



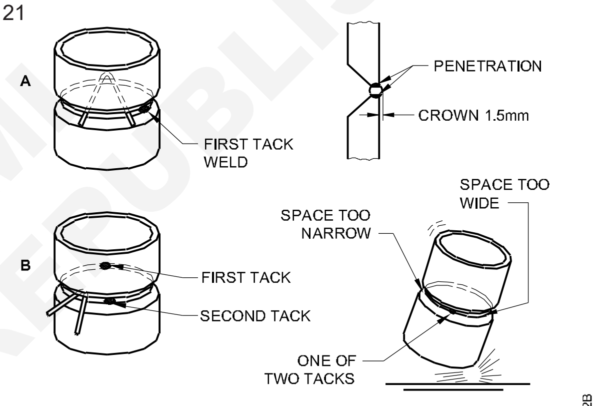
Setting of pipe: Pipe to be joined together must be accurately aligned prior to welding. The inside surface of the pipe must be blended together smoothly as in the outer surface. Maintain the root opening 2.5 mm, use a M.S. angle and strength bar for checking the alignment of the pipe. (Fig 20)

Fig 20



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 21)

Fig 21



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 22. The keyhole is an essential part in the welding of the root pass. (Fig 23) It should be

about $\sqrt{1\frac{1}{3}}$ of the diameter of the electrode. Maintain

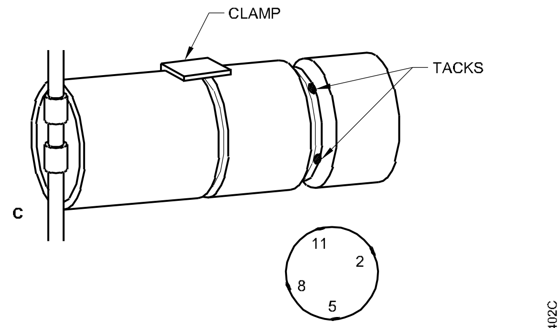
the electrode angle as shown in Fig 24 Weld the root pass on side 2 of the pipe joint. (Fig 24)

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.

Fig 22



PIPE CLAMPED IN PLACE AFTER TACK WELD.

Fig 23

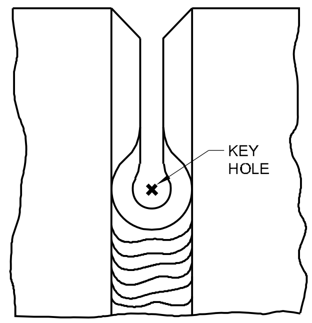
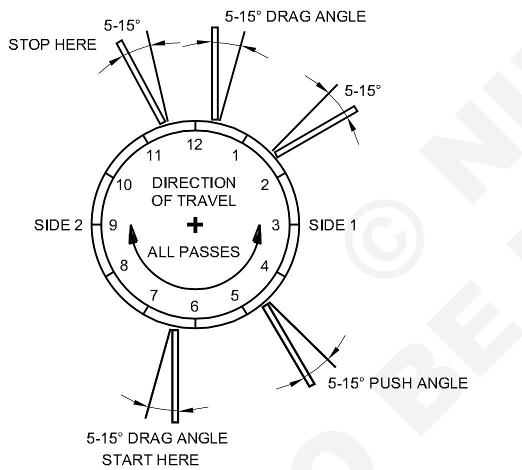


Fig 24

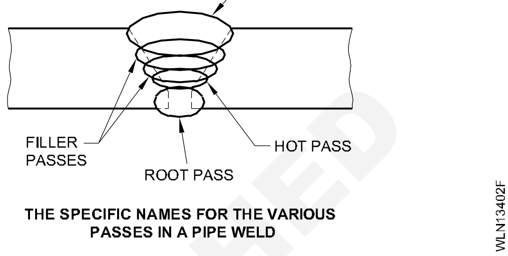


EECTRODE DRAG AND PUSH ANGLES.

The names of each pass is given in Fig 25. 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 24. 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 25)

Fig 25



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.

Difference between plate welding and pipe welding

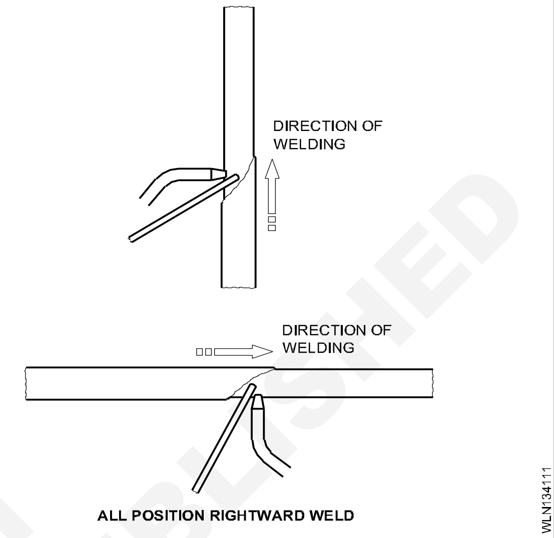
Objective: At the end of this lesson you shall be able to
- **explain the differences between plate welding and pipe welding.**

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



Metal thickness and related techniques

Position	Material thickness range	Method
Flat	Not exceeding 5 mm Exceeding 5 mm	Leftward Rightward
Horizontal-vertical	1 mm to 5 mm 5 mm and above	Leftward All-position Rightward
Vertical (single operator)	1 mm to 5 mm 5 mm and above	Leftward All position rightward
Vertical (two operators-technique)	5 mm and above	Leftward
Overhead	1 mm to 5 mm 5 mm and above	Leftward All-position rightward.

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.

Position	Method
At the top of the pipe, flat position.	Leftward or rightward
At the flank of a set on branch when both pipe axes are in horizontal flat position.	Leftward or rightward
The weld is made along the vertical sides of the pipe.	Leftward or rightward or all-position rightward
The weld at the bottom of a pipe is made in the overhead position.	Leftward or rightward or all-position rightward

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.

The leftward, rightward or all-position rightward techniques are used as appropriate on sections of 5 mm and above.

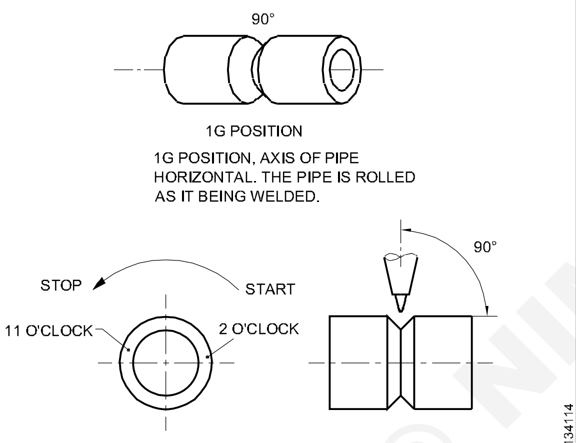
Differences between plate welding and pipe welding

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 2) 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 3)

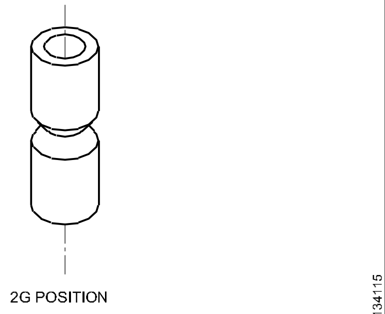
In plate welding the sealing run can easily be deposited when needed. In pipe welding the sealing run cannot be deposited in small pipes. Sealing run can be deposited only when the pipe has so large a diameter as to allow the welder to enter into the pipe.

Fig 2



WELDING PIPE IN THE 1G POSITION

Fig 3

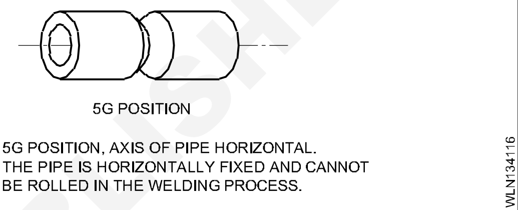


2G POSITION, AXIS OF PIPE VERTICAL

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 4)

Fig 4



5G POSITION, AXIS OF PIPE HORIZONTAL.
THE PIPE IS HORIZONTALLY FIXED AND CANNOT
BE ROLLED IN THE WELDING PROCESS.

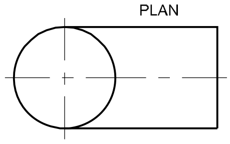
Pipe development for elbow, tee, 'Y' joint & branch joint

Objective: At the end of this lesson you shall be able to
- **state the pipe development for elbow, Tee, 'Y' and Branch joint.**

Develop the pattern for a 90° elbow of equal diameter pipes by parallel line method:

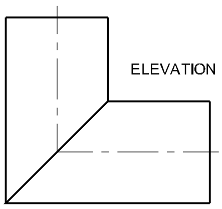
Draw plan as shown in Fig 1.

Fig 1



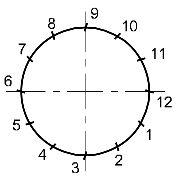
Below this, draw the front elevation as shown in Fig 2.

Fig 2



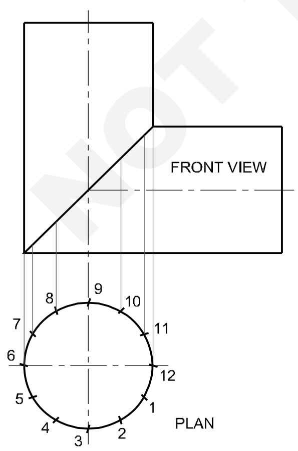
Divide the circle in the plan into twelve equal parts and number the points 0 to 12 as shown in Fig 3.

Fig 3



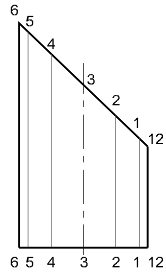
Draw the perpendicular line from these points towards the front view and number 1 to 12 as shown in Fig 4.

Fig 4



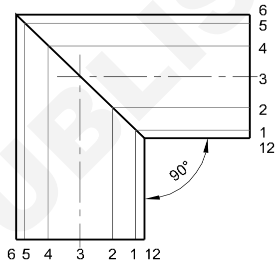
Now you find that the vertical lines are cutting at six different points top and bottom in the elevation line. Number them as shown in Fig 5.

Fig 5



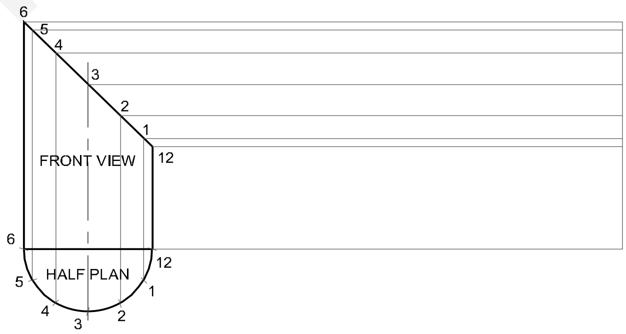
Draw horizontal parallel lines from each point and number them as shown in Fig 6.

Fig 6



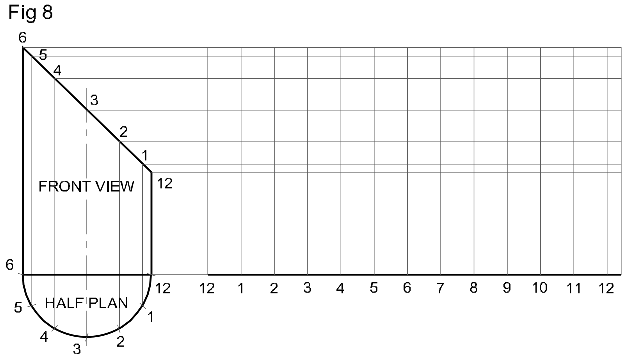
Extend the front elevation base line as shown in Fig 7.

Fig 7



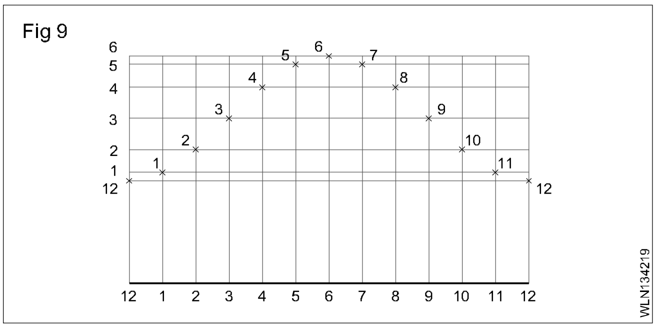
Take the distance equal to one division of plan and mark twelve times on base line by a compass and draw perpendicular lines from each point as shown in Fig 8.

Fig 8



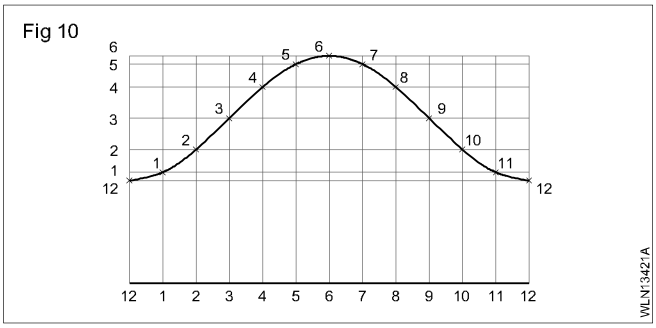
Now you find that each horizontal line and corresponding vertical line meet at a point. Number the points as 1 to 12 as shown in Fig 9.

Fig 9



Join these points by free hand curve as shown in Fig 10.

Fig 10

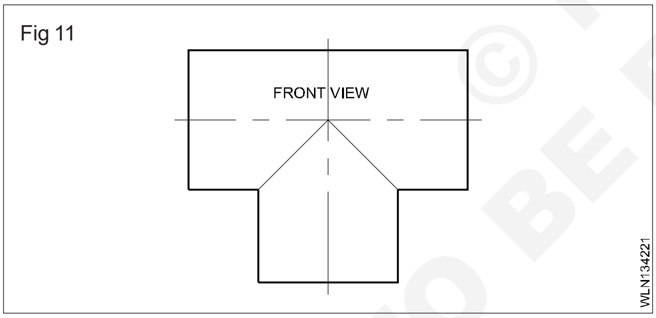


Development of a pipe "T" joint

Develop the pattern for a 90° "T" pipe of equal diameter by parallel line method:

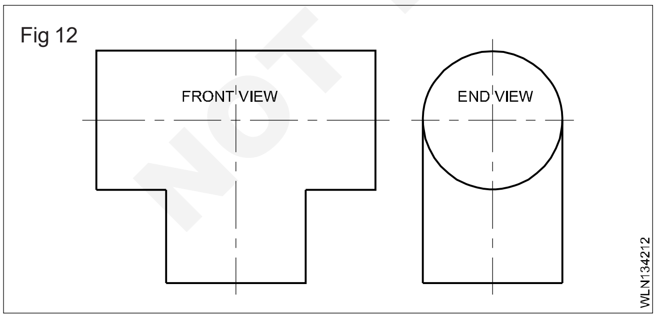
Draw the front view as shown in Fig 11.

Fig 11



Draw the side view as shown in Fig 12.

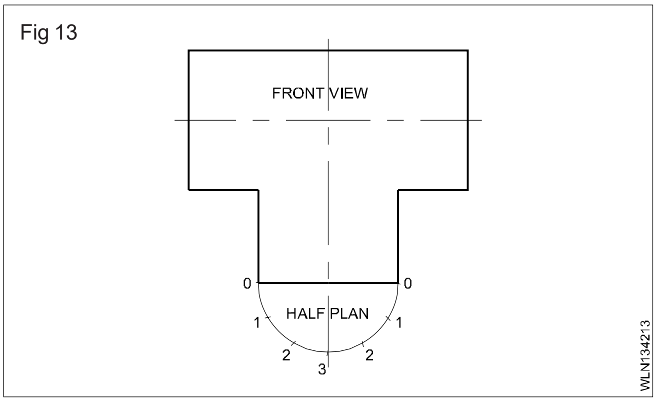
Fig 12



Draw a semi-circle on the base line of the front elevation. (Fig 3)

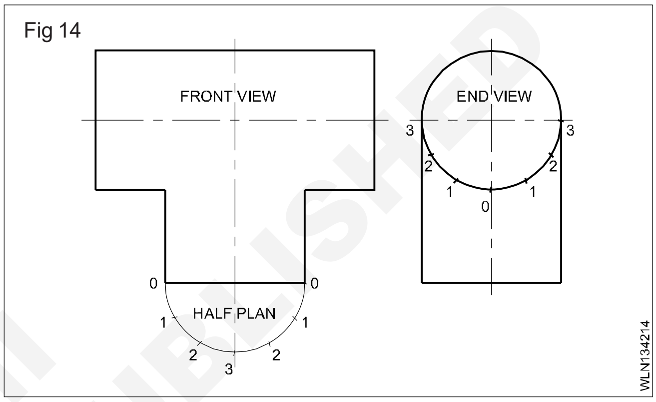
Divide the semi-circle into six equal parts and number them as 0, 1, 2, 3, 2, 1, 0. (Fig 13)

Fig 13



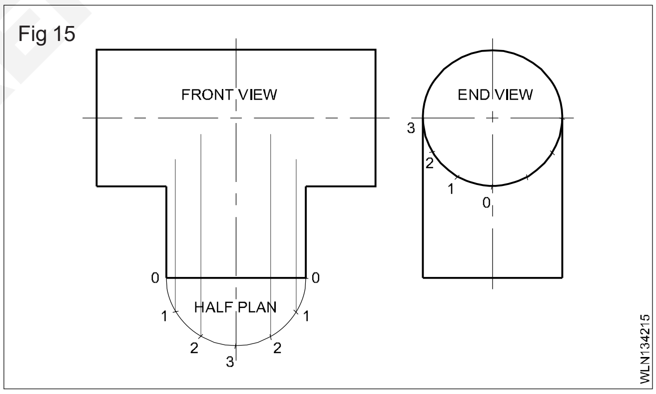
Divide a semi-circle in side view into six equal parts and number as 3, 2, 1, 0, 1, 2, 3 as shown in Fig 14.

Fig 14



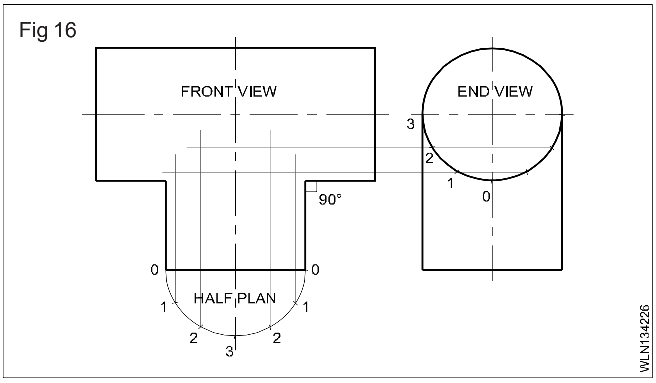
Draw the perpendicular lines from each point of the semi-circle of the view as shown in Fig 15.

Fig 15



Draw horizontal lines from the side view towards the front view as shown in Fig 16.

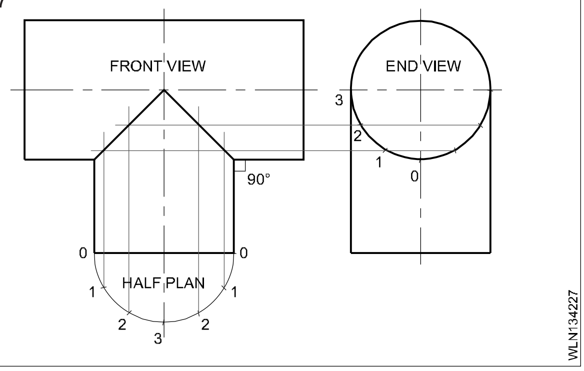
Fig 16



Now the vertical lines of the front view and the horizontal lines of side meet at their respective points.

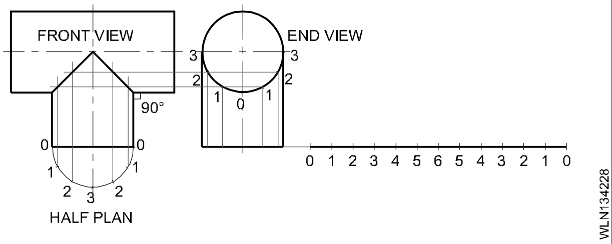
Join these points to get the line of intersection of "T" pipe as shown in Fig 17.

Fig 17



Extend the base line of the side view and mark the end point as 0. (Fig 18)

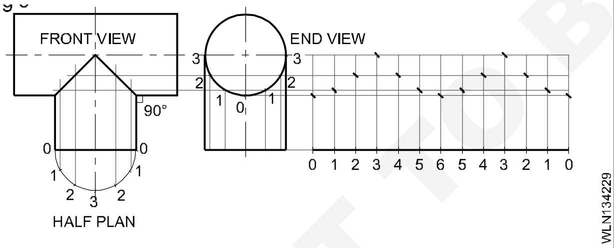
Fig 18



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.

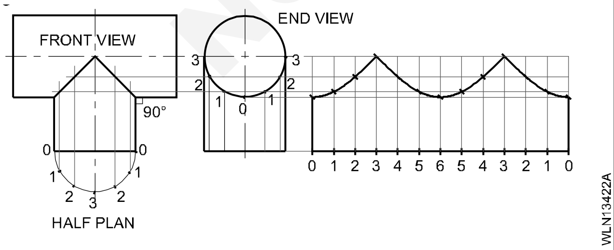
Draw perpendicular lines from these points and draw horizontal lines from the points on the line of intersection of "T". These line meet at their respective points. (Fig 19)

Fig 19



Join these points by free hand curve. (Fig 20)

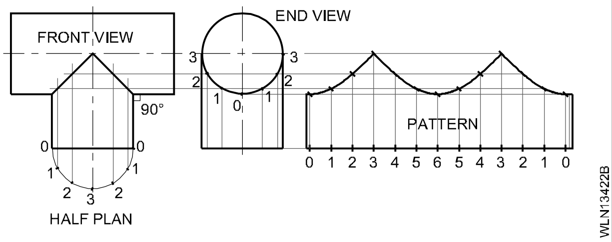
Fig 20



Provide locked grooved joint allowance as shown in Fig 21.

Check the pattern once again and cut. Thus you get the pattern for branch pipe.

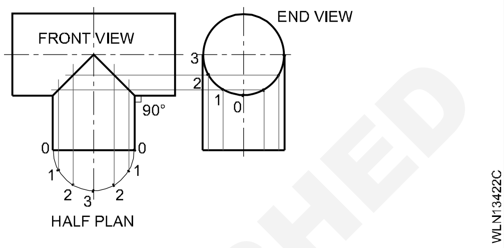
Fig 21



For main pipe, develop and layout the pattern as follows:

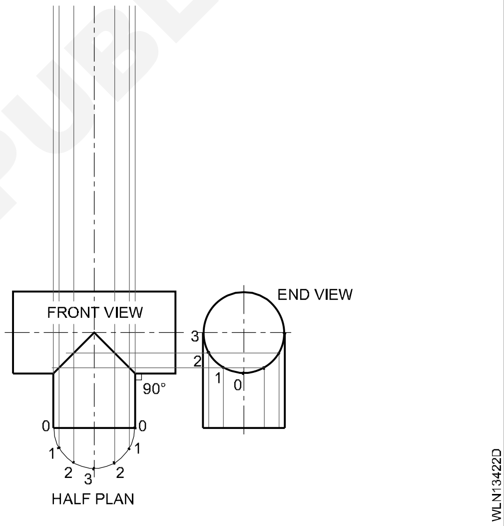
Draw the front view and end view. (Fig 22)

Fig 22



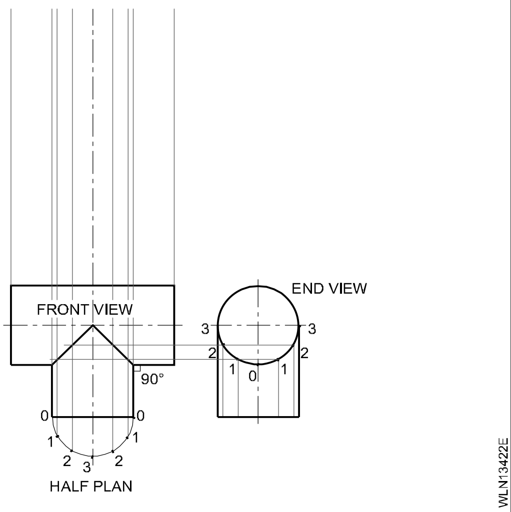
Extend the vertical lines 0, 1, 2, 3, 1, 0 of branch pipe from the front view as shown in Fig 23.

Fig 23



Extend the two extreme end vertical lines of the main pipe from the front view as shown in Fig 24.

Fig 24



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 25)

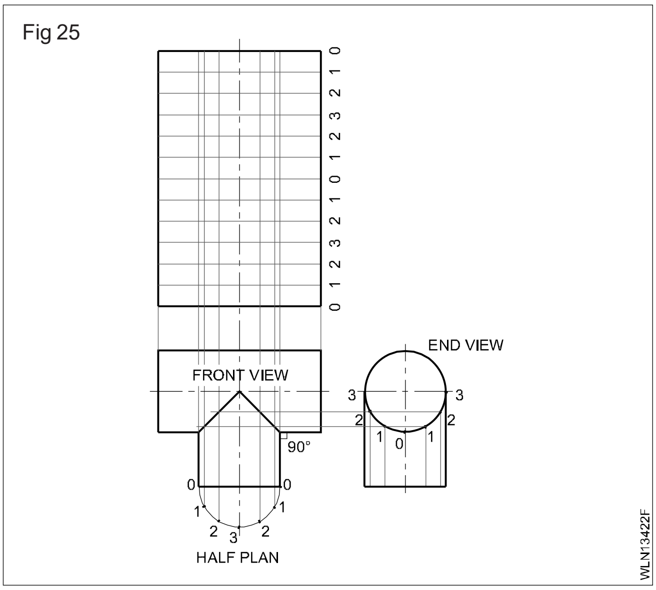


Fig 25

Now these horizontal lines meet the vertical lines at their respective points as shown in Fig 26.

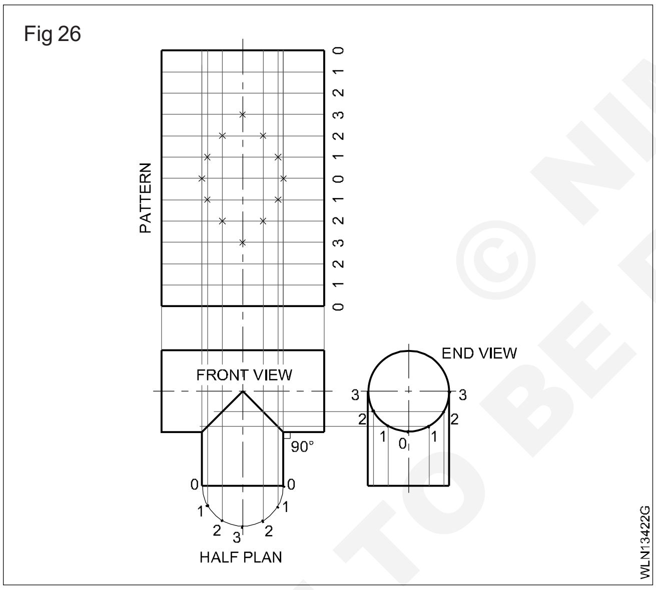


Fig 26

Join these points by free hand curve and get the pattern for the main pipe. (Fig 27)

Provide the locked grooved joint allowances as shown in Fig 27.

Pipe development for "Y" joint

Development of "Y" joint pipes intersecting at 120°: Draw the development of intersecting cylinders of dia. 30 mm at 120°. (Fig 28)

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 28b)

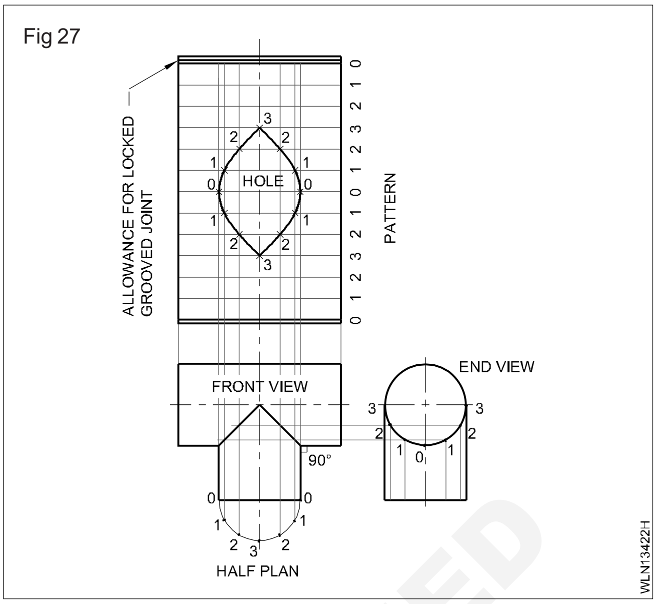


Fig 27

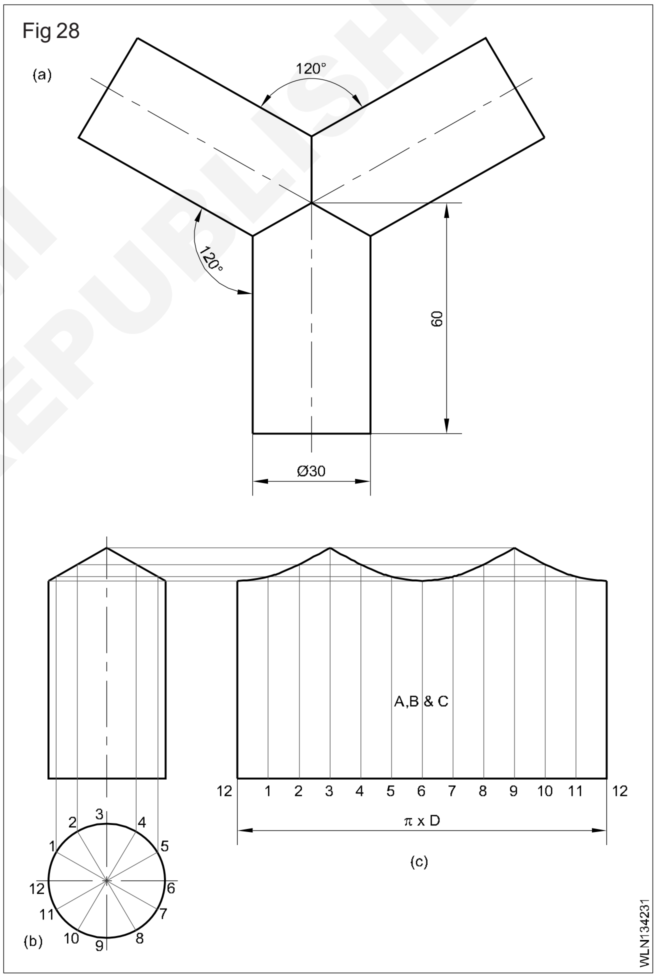


Fig 28

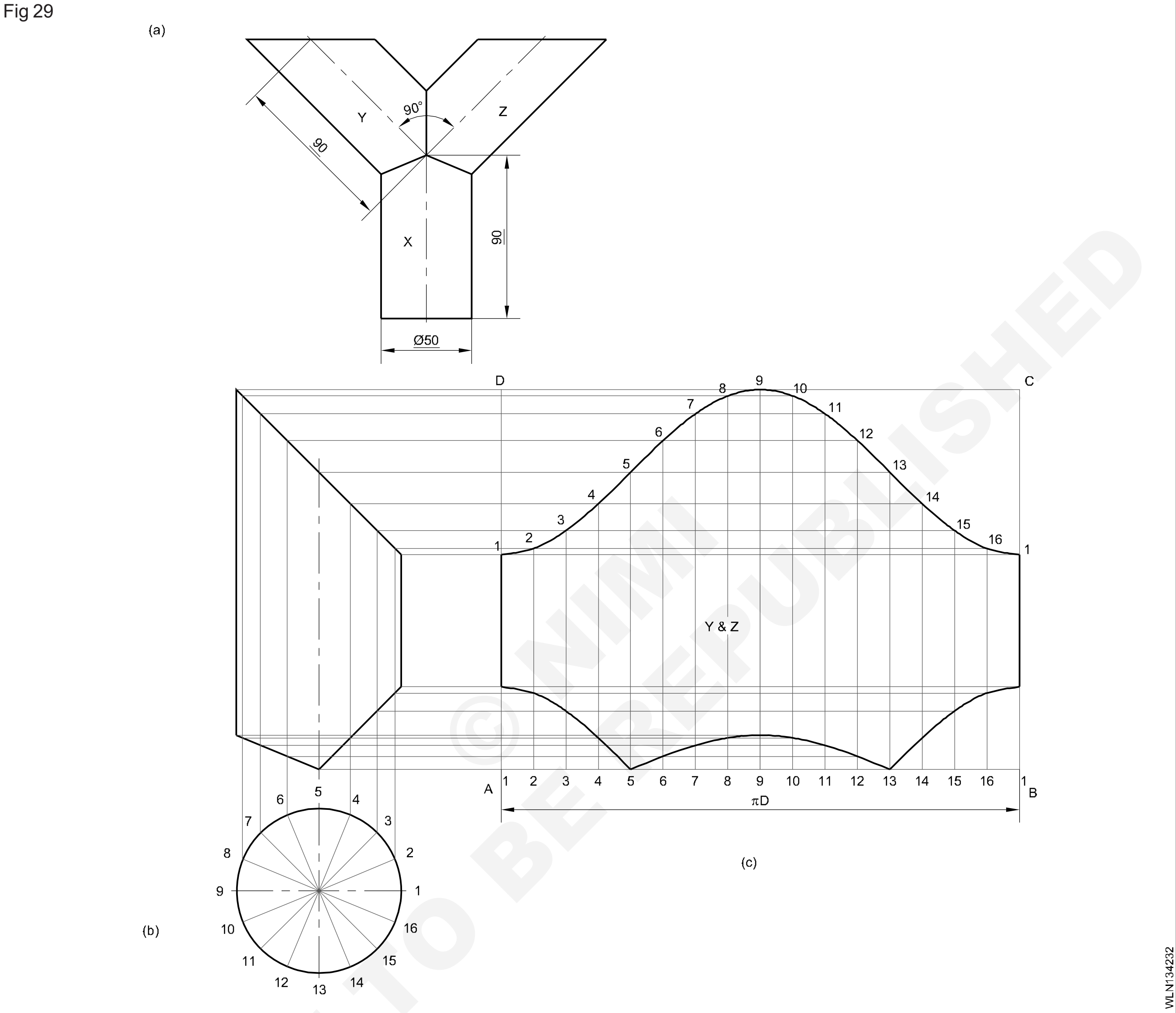
- Draw the vertical projectors from the plan to front view to meet the line of intersection.
- Draw horizontal projectors from these points on to the development.
- Mark the intersecting points and join with a smooth curve to complete the required development.

Development of 'Y' joint branching at 90°: Three cylindrical pipes of X, Y, Z form a 'Y' piece. (Fig 29) 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 29.

Fig 29



Development of 45° and 90° branch pipe

Procedure for development of 45° branch pipe: Refer Fig 30. 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'.

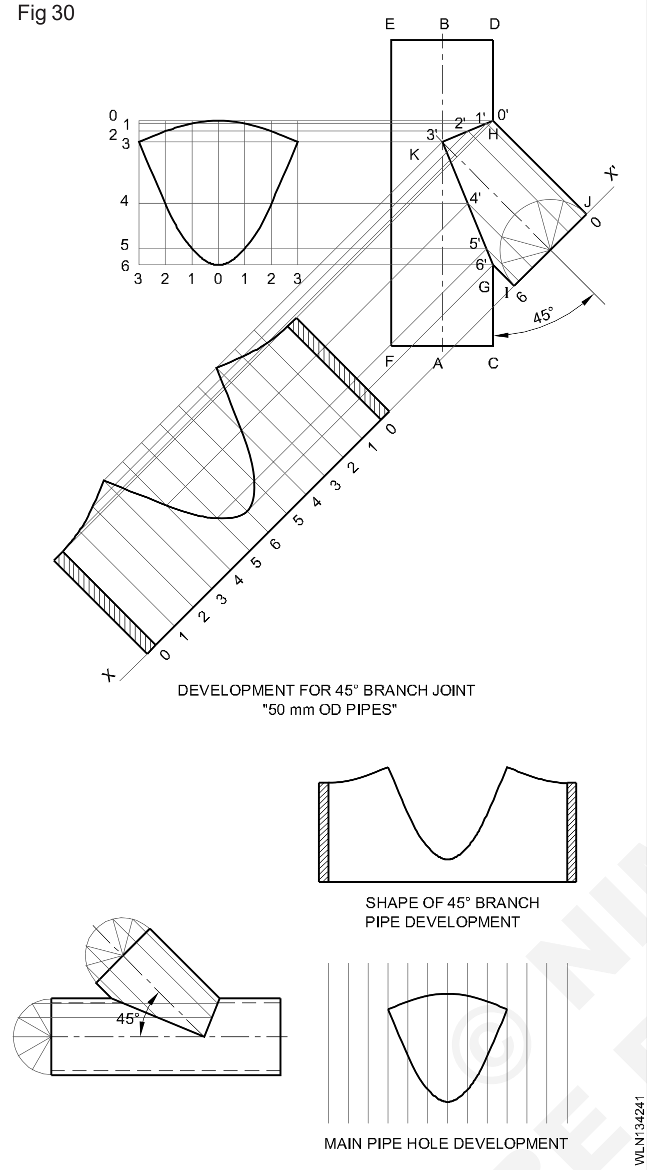
Draw a center line for the branch pipe. This line will cut the main pipe's center line AB at K.

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 30



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 30)

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.

Brief use of manifold system

Objectives: At the end of this lesson you shall be able to
- **state the manifold system and its types**
- **describe the construction, advantages and disadvantages 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.

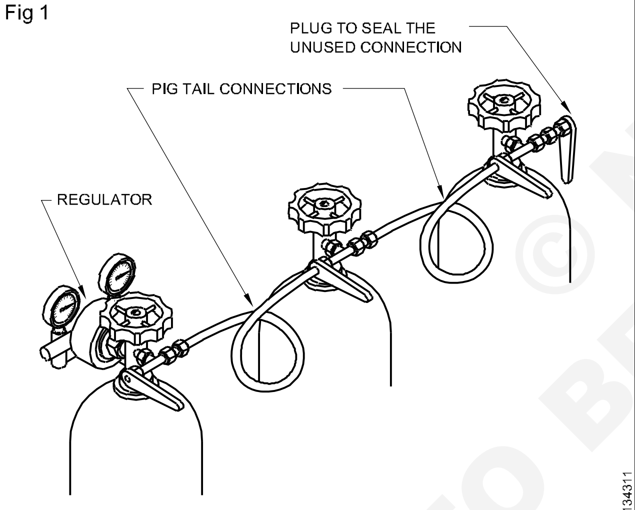
Types

– 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.

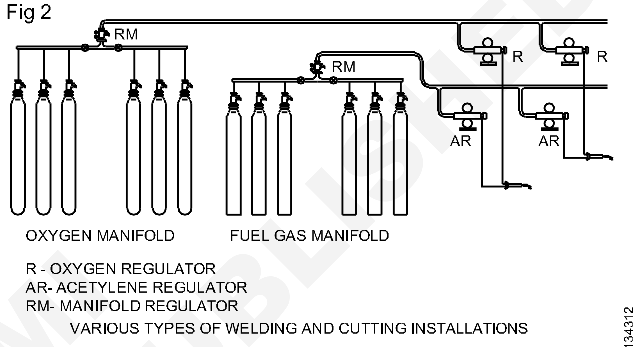
Fig 1



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 specification & size

Objectives: At the end of this lesson you shall be able to
- **name the types of filler rods and there sizes**
- **state the necessity of filler rods**
- **describe the selection of filler and its care and maintenance.**

Filler rod and its necessity: Pieces of wires or rods of standard diameter and length used as filler metal in the joint during gas welding process are called filler rods or welding rods.

To obtain best results, high quality filler rods should be used.

The actual cost of welding rods, is very small compared with cost of job, labor, gases and flux.

Good quality filler rods are necessary to:

- reduce oxidation (effect of oxygen)
- Control the mechanical properties of the deposited metal
- Metal caused by fusion.

While welding, a cavity or depression will be formed at the joints of thin section metals. For heavy/thick plates a groove is prepared at the joint. This groove is necessary to get better fusion of the full thickness of the metal, so as to get a uniform strength at the joint. This groove formed has to be filled with metal. For this purpose a filler rod is necessary. Each metal requires a suitable filler rod.

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.

Different types of filler rods used in gas welding

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.

Care and maintenance

Filler rods should be stored in clean, dry condition to prevent deterioration.

Do not mix different types of filler rods.

Ensure that packages and their labels are in order for easy and correct selection.

Where it is not practicable to store filler rods under heated conditions, an absorbent for moisture such as silica-gel may be used in the storage area.

Ensure the rod is free from contamination such as rust, scale, oil, grease and moisture.

Ensure the rod is reasonably straight to assist manipulation during welding.

Each metal requires a suitable filler rod. Refer to IS : 1278 - 1972 and IS : 2927 - 1975 attached. (Table 1: Filler metals and fluxes for gas welding.)

Gas welding fluxes types and function

Objectives: At the end of this lesson you shall be able to
- **describe the flux and its function in gas welding**
- **name 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.

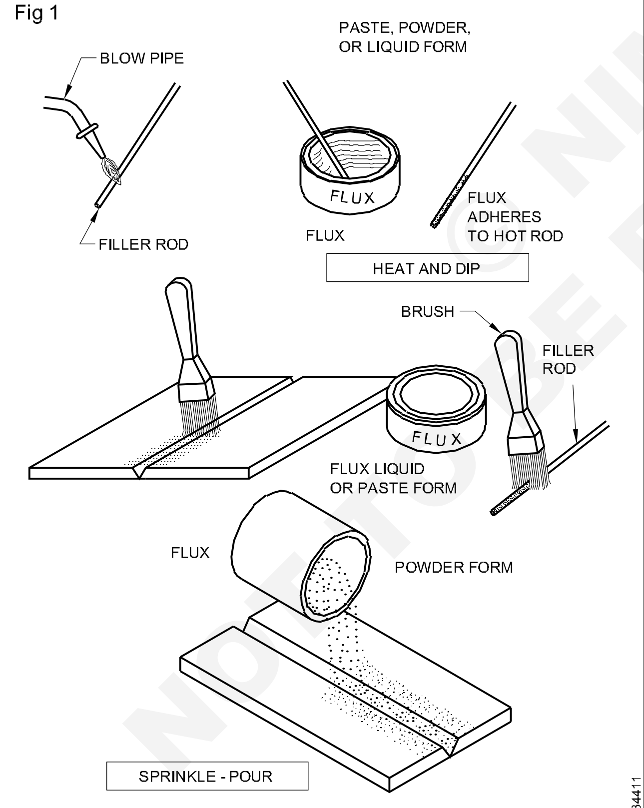
The function of flux in gas welding: To dissolve oxides and to prevent impurities and other inclusion that could affect the weld quality.

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.

Fig 1



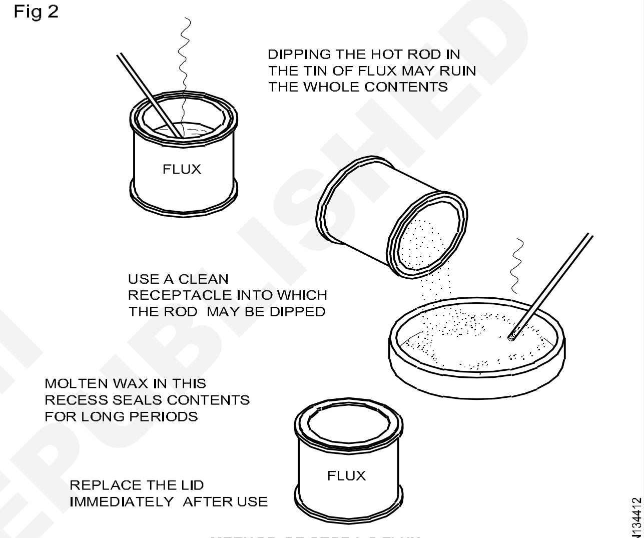
METHOD OF APPLICATION

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 2



METHOD OF STORING FLUX

Removal of flux residues: After welding or brazing is over, it is essential to remove the flux residues. Fluxes in general are chemically active. Therefore, flux residues, if not properly removed, may lead to corrosion of parent metal and weld deposit.

Some hints for removal of flux residues are given below:

– Aluminium and aluminium alloys - As soon as possible after welding, wash the joints in warm water and brush vigorously. When conditions allow, follow up by a rapid dip in a 5 percent solution of nitric acid; wash again, using hot water to assist drying.

Types

- Borax
- copper silver alloy
- Zinc chloride
- Potassium chloride
- Aluminium flux powder
- Cos tiron flux
- Sodium carbonate
- Potassium carbonate
- Sodium nitrate
- Sodium bicarbonate

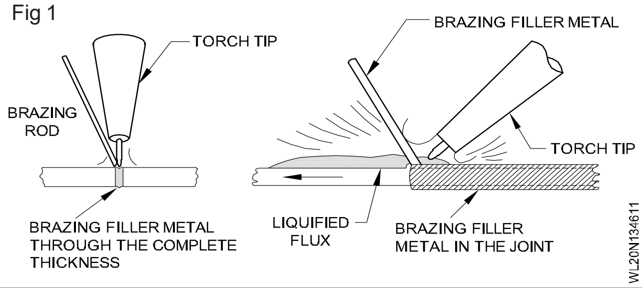
Gas brazing, soldering, principles, types, flux & uses

Objectives: At the end of this lesson you shall be able to
- **define the brazing & soldering methods**
- **describe the types of brazing and soldering.**
- **describe the fluxes used in brazing and soldering**
- **mention the application of brazing and soldering**

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.

Brazing principle: Brazing or soldering, the flier alloy flows between two closely adjacent surfaces by capillary action. (Fig 1)

Fig 1



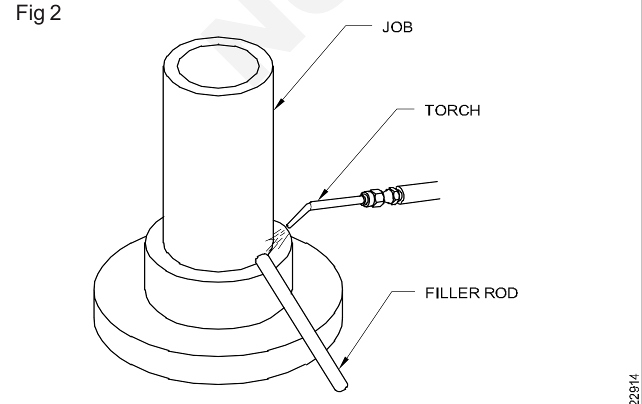
Steps involved in brazing

- 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 0.08mm)
- Apply the flux in paste from (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, fluoroborates, boric acid, wetting agents and water. So suitable flux combination is selected based on metal being used.

Various methods of brazing

Torch brazing: The base metal is heated to the requires temperature by the application of the oxy - acetylene flame (Fig 2).

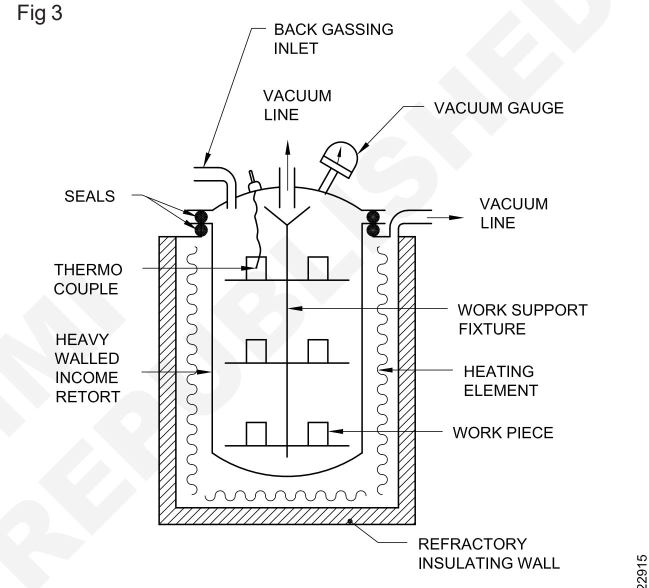
Fig 2



TORCH BRAZING

Furnace brazing: The parts to be brazed are aligned with the brazing material placed in the joints. The assembly is kept in the furnace. The temperature is controlled to provide uniform heating. (Fig 3)

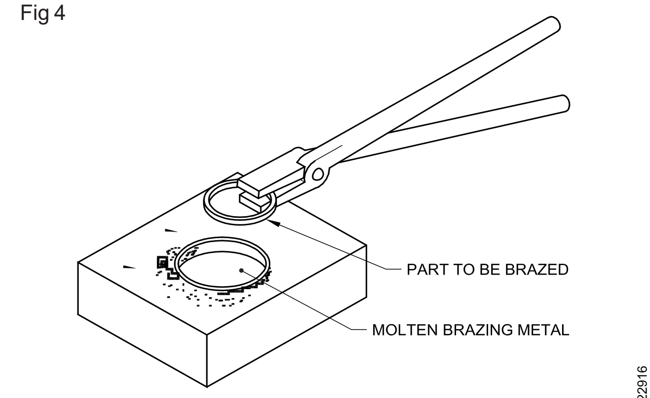
Fig 3



VACUUM FURNACE FOR BRAZING

Dip brazing: The parts to be brazed are submerged in a molten metal or chemical bath (Fig 4) of brazing filler metal.

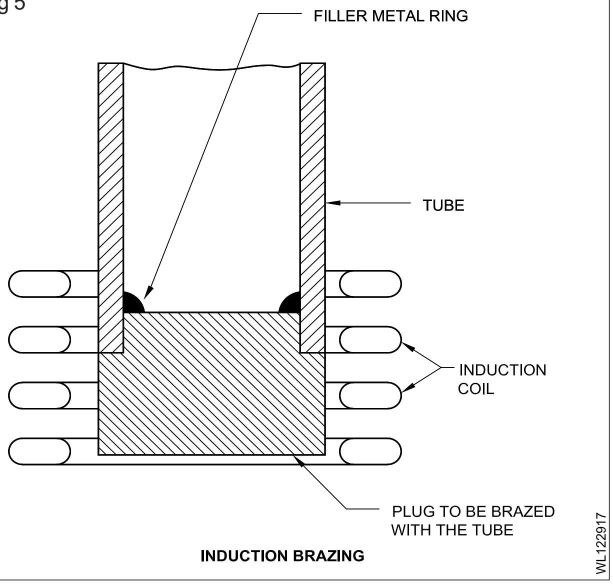
Fig 4



DIP BRAZING PROCESS

Induction brazing: The parts to be brazed are heated to the melting points of the brazing material by means of a high frequency electric current. This is done by encircling the joints with a water cooled induction coil. (Fig 5)

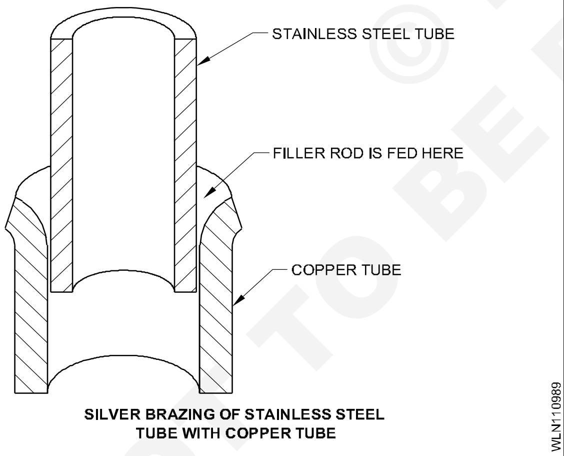
Fig 5



INDUCTION BRAZING

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 joints. 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 points 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 points to be remembered while silver soldering are.

- The joint must the thoroughly cleaned both mechanically and chemically.
- Fit the joint closely / tightly without any gap and support the joint.
- Apply proper flux at the joint and on the filler rod.

Heat the joint to the brazing temperature depending on the composition on the silver brazing filler rod.

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.

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

Clean the joint thoroughly to remove all residual flux.

Brazing fluxes: Fused borax is the general purpose flux for most metals. It is applied on the form of a paste made by mixing with water.

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

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

Advantages of brazing

- The completed joint requires little or no finishing.
- The relatively low temperature at which the joint is made minimize distortion.
- 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 mechanized.
- The process is economical owing to the above advantages.

Disadvantages of brazing:

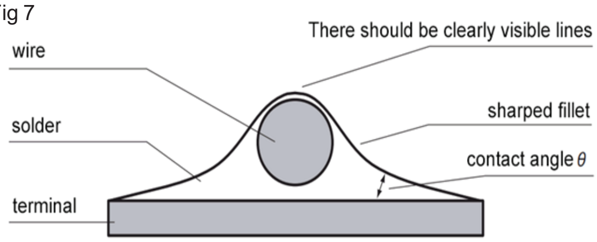
- If the joints is exposed corrosive media, the filler metal used may not have the required corrosive resistance.
- All the brazing alloys loose strength at an elevated temperature.
- The colour of the brazing alloy which ranges from silver white to copper red may not match the base metal very closely.

Application of Brazing

- Brazing is used for the fastening of pipe fitting, carbide tips on tools, heat exchanges, electrical
Joining automobile radiator cores.
- It can joint cast material to wrought metals, dissimilar parts, radiators, axles, etc.
- It is used to join parts of the bicycle such as frame an rims

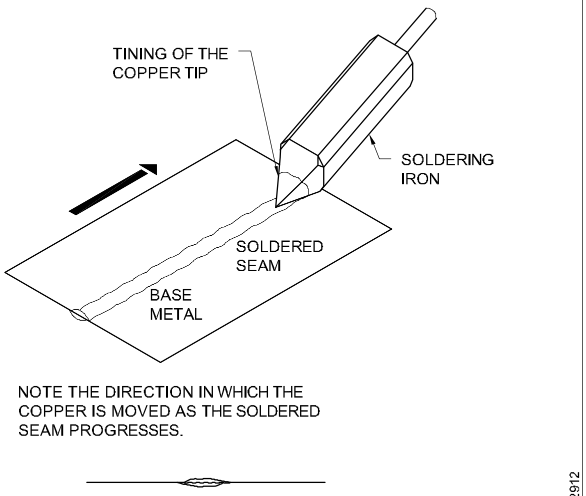
Soldering : Soldering is the process by which metals are joined with the help of another alloy called solder without heating the base metal to be joined. The melting point of the solder is lower than that of the materials being joined. (Fig 7)

Fig 7



Soldering principle: Soldering iron is used to heat the metal (base material) of the part to be soldered. The solder is then melted on to the metal by wetting and capillary action to create on alloy of the metal and solder at the connection surface. (Fig 8)

Fig 8



SOLDERING WITH A SOLDERING IRON

Types of soldering

Soft soldering: The filler metal used in soldering have a melting point below 427°C.

The alloys used for soft soldering are:

- tin-lead (for general purpose soldering)
- tin-lead-antimony
- tin-lead-cadmium.

The process is referred to as 'soft soldering'. The heat required for 'soft soldering' is supplied by a soldering iron, whose copper tip is heated either by a forge or electrically.

Composition of soft solder

Usually soft solder is an alloy of lead and tin in different ratios depending on the base metals soldered and the purpose of soldering.

Soft solders are available in different shapes and forms such as stick, bar, paste, tape or wire etc.\

Hard solder: These are alloys of copper, tin, silver, zinc, cadmium and phosphorus and are used for soldering heavy metals. Brass or silver is the bonding metal used in this process, and requires a blowtorch to achieve the temperatures at which the solder metals. (Fig 9)

Fig 9

Basic operations in soldering: The parts to be soldered are fitted closely.

Paint, rust, dirt or thick oxides are removed by filing, scraping or by using emery paper or steel wool.

The surface to be soldered are coated with flux to remove the films of oxide. (Fig 2)

The solder is applied with a copper soldering bit.(Figs 3a,b and c)The joining takes place due to "sweating" of the joint by the hot and tinned copper tip of the soldering iron.

The two sheets to be soldered are adhering to each other due to sweating and bonding of the timed area.

The excess solder present on the surface is removed and the joint is allowed to cool.

The solder is applied with a copper soldering bit. (Figs 3a b and C). The joining takes place due to "sweating" of the joint by the hot and tinned copper tip of the soldering iron.

The Two sheets to be soldered are adhering to each other due to sweating and bonding of the tinned area.

The excess solder present on the surfaces is removed and the joints is allowed to cool.

Types of fluxes

Corrosive: In this type the solution contains inorganic substances like zinc chloride, ammonium chloride, hydrochloric acid. This type of flux leaves a corrosive deposit on the base metal surface which must be thoroughly washed off after soldering. This type of flux is not used on electrical works or where the joint cannot be effectively washed.

Non-corrosive: These are flux based on resin. These leave a non-corrosive residue. They are used on electrical works, instruments like pressure gauges, and parts where washing is difficult.

Suitable fluxes for various materials

- Steel-zinc chloride
- Zinc and galvanized iron-hydrochloric acid
- Tin-zinc chloride
- Lead-tallow resin
- Brass, copper, bronze-zinc chloride, resin.

Soldering flux: 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 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.

Advantages

- It is simple, low cost, flexible, economical and user friendly.
- Can be operated at low temperature.
- Base metal does not melt.
- Any metals, non-metals can be joined by this process.
- Less time required to join.
- The life of solder will be more.
- Soldered joints can be dismantled.
- This can be easily operated.
- Low process temperature.
- Low amount of power is required.
- Thin wall part may be joined.
- Easily automated process.
- No thermal distortion and residual stresses in the join parts.

Disadvantages

- Cannot be used at high temperature.
- Strength if the joint is less.
- Can not join heavy sections.
- Suitable for only small parts.
- Chance to toxic components at fluxes.
- Careful removal of flux residuals is required.
- Large sections can not be joined.
- Skilled labor is required.

Application

- General sheet metal applications
- Used in galvanized iron sheets
- Soldering brass, copper and jewelers
- Joining automobile radiator cores
- Used in plumbing and fitting works.
  leak repair in containers
- In expensive vacuum tubes are solders to from a sealant and insulated having part in metal.

Following Table shows the nature and type of flux used in soldering.

Metal to be soldered	Inorganic flux	Organic flux	Remarks
Aluminium Aluminium-bronze			Commercially prepared flux and solder required
Brass	Killed spirits Sal ammoniac	Resin Tallow	Commercial flux available
Cadmium	Killed sprits	Resin	commercial flux available
Copper	Killed sprits sal-ammoniac	Resin	Commercial flux available
Gold		Resin	
Lead	Killed Spirits	Tallow Resin	
Monel			Commercial flux required
Nickel	Killed spirits	Resin	commercial flux available
Silver		Resin	commercial flux available
Stainless steel	Phosphoric acid		commercial flux available
Steel	Killed spirits		
Tin	Killed spirits		commercial flux available
Tin -bronze	Killed spirits	Resin	
Tin-lead			
Tin-zinc	Killed spirits	Resin	
zinc	Muriatic acid		

Gas welding defects - causes and remedies

Objectives: At the end of this lesson you shall be able to
- **define various weld defects**
- **identify the faults in gas welding**
- **explain the defects causes and remedies.**

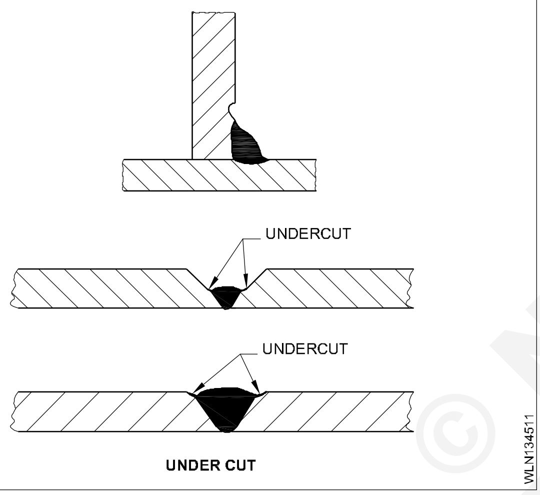
Definition

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.

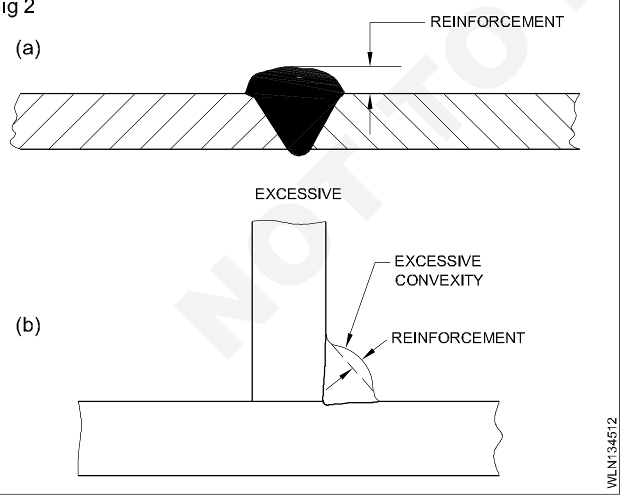
Undercut: A groove or channel formed along the toe of the weld on one side or on both sides. (Fig 1)

Fig 1



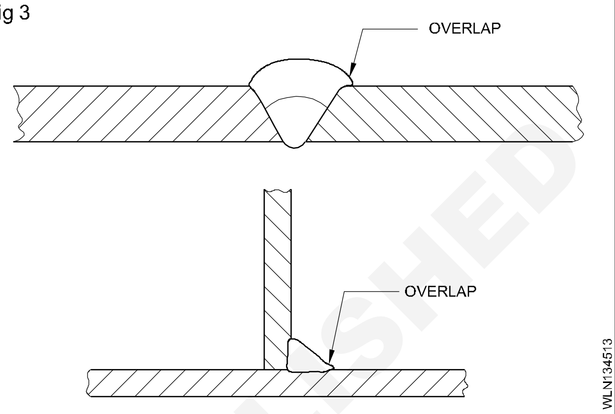
Excessive convexity: Too much weld metal added to the joint so that there is excessive weld reinforcement. (Fig 2)

Fig 2



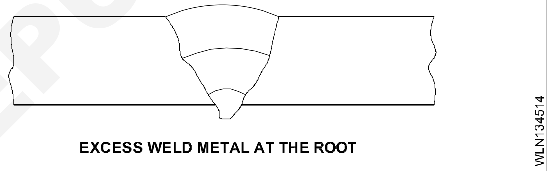
Overlap: Metal flowing into the surface of the base metal without fusing it. (Fig 3)

Fig 3



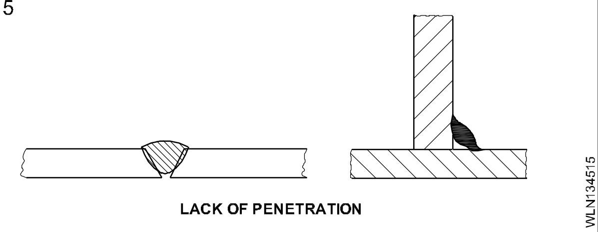
Excessive penetration: Depth of fusion at the root of the grooved joint is more than the required amount. (Fig 4)

Fig 4



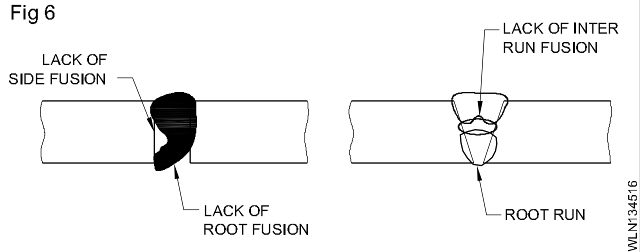
Lack of penetration: Required amount of penetration is not achieved, i.e. fusion does not take place up to the root of the weld. (Fig 5)

Fig 5



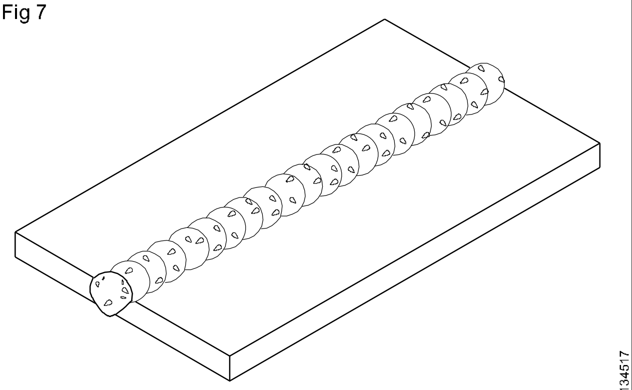
Lack of fusion: If there is no melting of the edges of the base metal at the root face or on the side face or between the weld runs, then it is called lack of fusion. (Fig 6)

Fig 6



Porosity: Number of pinholes formed on the surface of the deposited metal. (Fig 7)

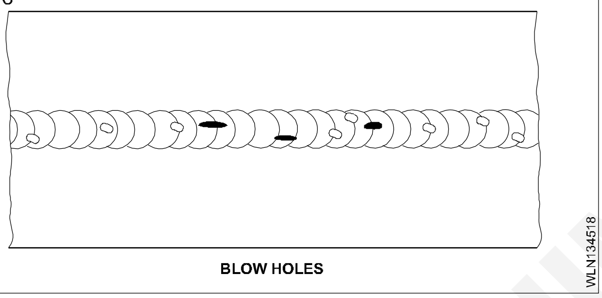
Fig 7



POROSITY

Blow-holes: These are similar to pinholes but have a greater diameter. (Fig 8)

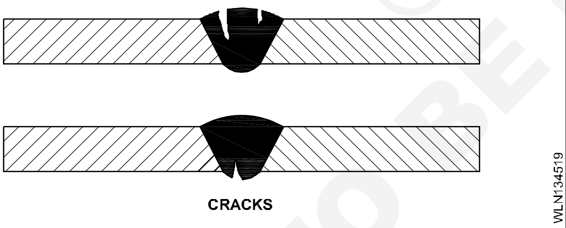
Fig 8



BLOW HOLES

Cracks: A discontinuity in the base metal or weld metal or both. (Fig 9)

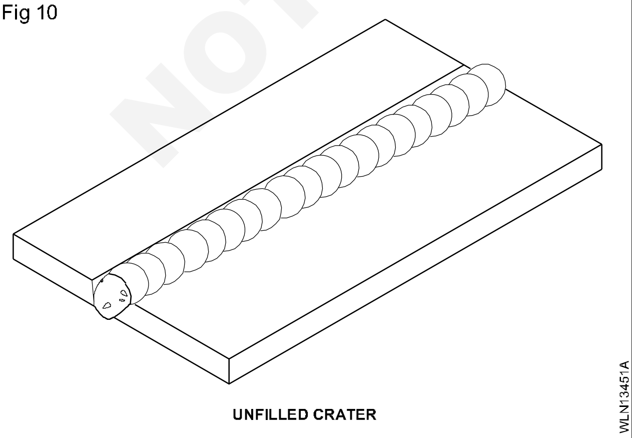
Fig 9



CRACKS

Unfilled crater: A depression formed at the end of the weld. (Fig 10)

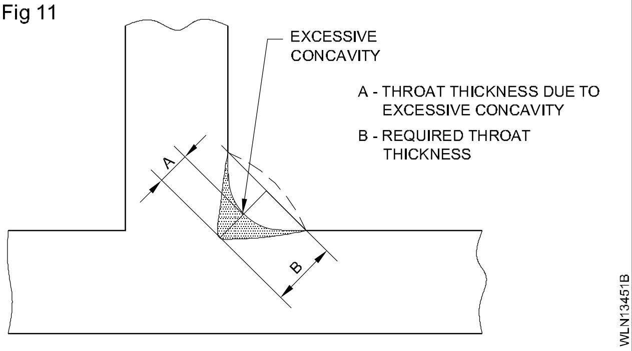
Fig 10



UNFILLED CRATER

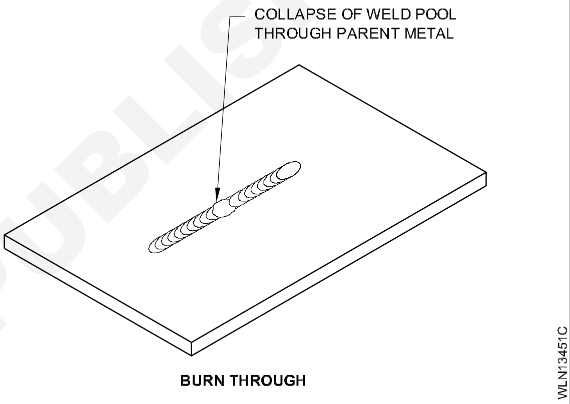
Excessive concavity/insufficient throat thickness: Enough weld metal is not added to the joint so that there is insufficient throat thickness. (Fig 11)

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

Weld defects - causes and remedies

Welding defects: Possible causes and remedies

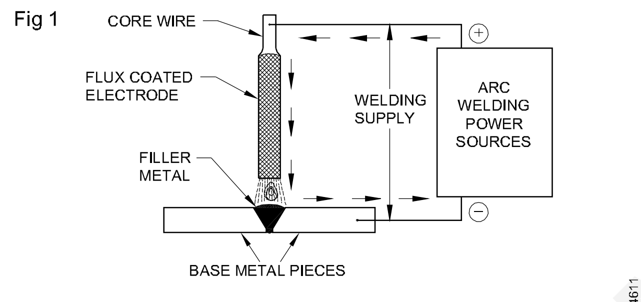
	Defect	Possible causes	Appropriate remedies
1	Fillet weld with insufficient throat thickness.	Incorrect angle of filler rod and blowpipe.	Maintain filler rod and blowpipe at the appropriate angles.
2	Excessive concavity in butt weld profile. rod too small.	Excess heat build-up with too fast a speed of travel or filler speed of travel.	Use the appropriate size nozzle and filler rod with the correct
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.
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 prepara -tion of material before welding. Avoid draughts and use appropriate heat treatment.
13	Surface porosity and gaseous intrusions.	Use of incorrect filler rod and techniq -ue. 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 at flux coating factor, size specifications of electrode coding of electrode as per AIS, AWS

Objectives: At the end of this lesson you shall be able to
- **identify the arc welding electrode**
- **name the types of electrodes and coating factor**
- **state the functions of flux coating.**

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

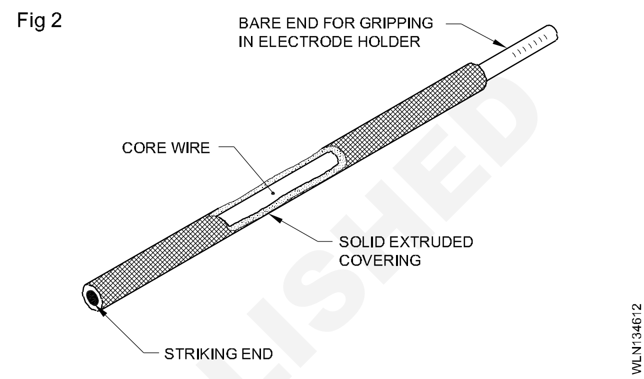
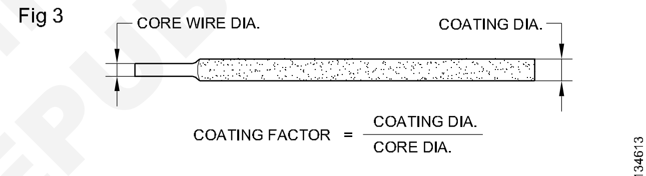


Fig 3



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.

Sizes of Mild Steel Electrodes

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.

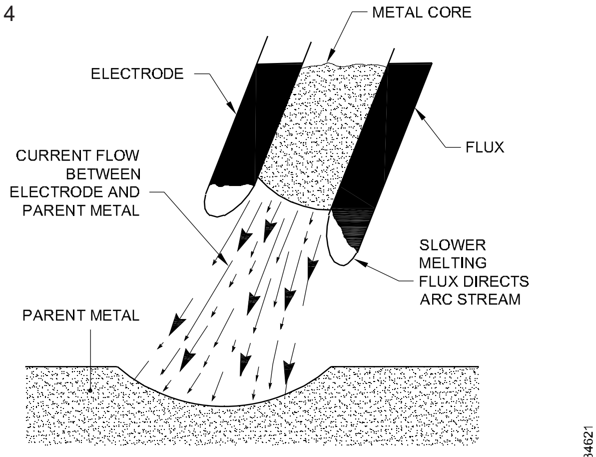
Functions of an electrode in shielded metal arc welding: The two main functions of an electrode in SMAW are: (Fig 4)

– 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 4



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:

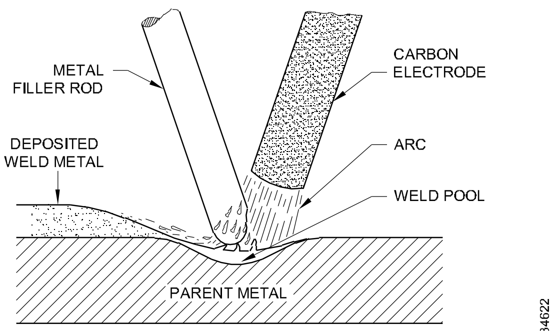
Carbon electrodes

Bare electrodes

Flux coated electrodes

Carbon electrodes are used in the carbon arc welding process (Fig 5). 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.

Fig 5

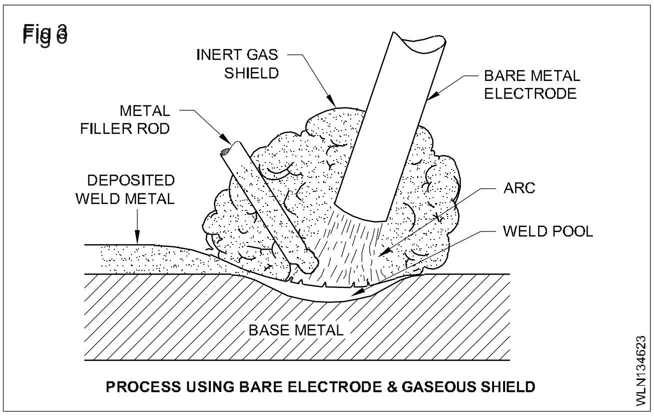


CARBON ARC PROCESS

Normally the carbon arc has very little use of welding. Its main application is in cutting and gouging operations.

Bare electrodes are also used in some arc welding processes (Fig 6). 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.

Fig 6

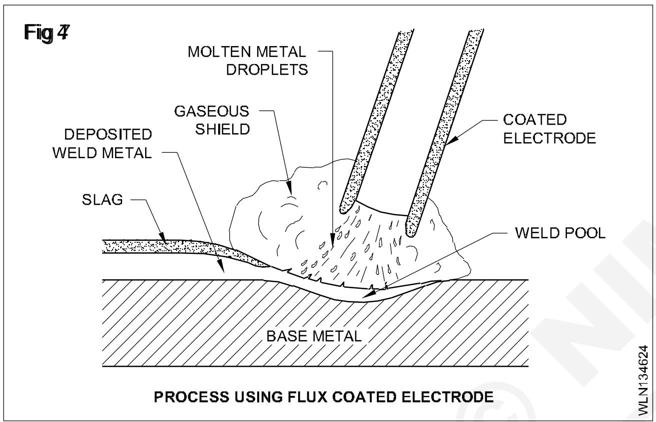


PROCESS USING BARE ELECTRODE & GASEOUS SHIELD

Flux coated electrodes are used in the manual metal arc welding process for welding ferrous and non-ferrous metals. (Fig 7)

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 7



PROCESS USING FLUX COATED ELECTRODE

Coding of Electrodes as per BIS, AWS

Necessity of coding electrodes: Electrodes with different flux covering gives different properties to the weld metal. Also electrodes are manufactured suitable for welding with AC or DC machines and in different positions. These conditions and properties of the weld metal can be interpreted by the coding of electrodes as per Indian Standards.

The chart shown at the end of this lesson gives the specification of a particular electrode and also shows what each digit and letter in the code represents. By referring to this chart any one can know whether an electrode with a given specification can be used for welding a particular job or not.

Classification of electrodes shall be indicated by the IS: 814-1991 coding system of letters and numerals to indicate the specified properties or characteristics of the electrode.

Main coding: It consists of the following letters and numerals and shall be followed in the order stated:

a a prefix letter 'E' shall indicate a covered electrode for manual metal arc welding, manufactured by extrusion process;

b a letter indicating the type of covering;

c first digit indicating the ultimate tensile strength in combination with the yield stress of the weld metal deposit;

d second digit indicating the percentage elongation in combination with the impact values of the weld metal deposited;

e third digit indicating welding position(s) in which the electrode may be used and

f fourth digit indicating the current condition in which the electrode is to be used.

Additional coding: The following letters indicating the additional properties of the electrodes may be used, if required:

a letters H_1, H_2, H_3 indicating hydrogen controlled electrodes.

b letters J, K and L indicating increased metal recovery as 'Effective Electrode Efficiency' as per IS: 13043:91.

J = 110 - 129 percent;

K = 130 - 149 percent; and

L = 150 percent and above.

c letter 'X' indicating the radiographic quality.

Different standards used in coding of electrodes

They are:

1 I.S. (814 - 1991)

2 A.W.S.

3 B.S.

INDIAN SYSTEM OF CODING OF ELECTRODES ACCORDING TO IS: 814-1991

Type of covering: The type of covering shall be indicated by the following letters.

A - Acid

B - Basic

C - Cellulosic

R - Rutile

RR - Rutile, heavy coated

S - Any other type not mentioned above

Strength characteristics: The combination of the ultimate tensile strength and the yield strength of the weld metal deposited shall be indicated by the digits 4 and 5. (See Table 1)

Table 1
Designation of strength characteristics
(Clauses 5.2 and 5.3)

Designating digit	Ultimate tensile strength N/mm^2	Yield strength Min N/mm^2
4	410-510	330
5	510-610	360

Table 2

Combination of percentage elongation and impact strength		
(Clause 5.3)		
Designation digit	**Percentage elongation (Min) on 5.65/So**	**Impact strength in joules (Min)/at °C**
(For tensile range 410-510 N/mm²)		
0	No elongation and impact requirements	
1	20	47J/+27°C
2	22	47J/+0°C
3	24	47J/-20°C
4	24	27J/-30°C
(For tensile range 510-610 N/mm²)		
0	No elongation and impact requirements	
1	18	47J/+27°C
2	18	47J/+0°C
3	20	47J/-20°C
4	20	27J/-30°C
5	20	27J/-40°C
6	20	27J/-46°C

Elongation and impact properties: The combination of percentage elongation and impact properties of all weld metal deposited for the two tensile ranges (See Table 1).

Welding position: The welding position or positions on which the electrodes can be used as recommended by the manufacturer shall be indicated by the appropriate designating digits as follows.

1 All positions

2 All positions except vertical down

3 Flat butt weld, flat fillet weld and horizontal/vertical fillet weld

4 Flat butt weld and flat fillet weld

5 Vertical down, flat butt, flat fillet and horizontal and vertical fillet weld

6 Any other position or combination of positions nit classified above

Where an electrode is coded as suitable for vertical and overhead position it may be considered that sizes larger than 4 mm are not normally used for welding in these positions.

An electrode shall not be coated as suitable for particular welding position unless it is possible to use it satisfactorily in the position to comply with test requirements of this code.

Welding current and voltage conditions: The welding current and open circuit voltage conditions on which the electrodes can be operated as recommended by the manufacturer shall be indicated by the appropriate designating digits as given in Table 3.

For the purpose of coating an electrode, for any of the current conditions under 5.5 shall be size 4 mm or 5 mm and shall be capable of being operated at the condition satisfactorily within the current range recommended by the manufacturer.

Hydrogen controlled electrodes: The letters H_1, H_2 and H_3 shall be included in the classification as a suffix for those electrodes which will give diffusible hydrogen per 100 gm when determined in accordance with the reference method given in IS:1806:1986 as given below.

H_1 - up to 15 ml diffusible hydrogen

H_2 - up to 10 ml diffusible hydrogen

H_3 - up to 5 ml diffusible hydrogen

Table 3

Welding current and voltage conditions

(Clause 5.5)

Digit	Direct current: recommended electrode polarity	Alternating current: open circuit voltage, V, Min
0	–	Not recommended
1	+ or –	50
2	–	50
3	+	50
4	+ or –	70
5	–	70
6	+	70
7	+ or –	90
8	–	90
9	+	90

1 Symbol 0 reserved for electrodes used exclusively on direct current,

2 Positive polarity +, Negative polarity –.

The frequency of the alternating current is assumed to be 50 or 60 Hz. The open circuit voltage necessary when electrode are used on direct current is closely related to the dynamic characteristics of the welding power source. Consequently no indication of the minimum open circuit voltage for direct current is given.

Increased metal recovery: The letters J, K and L shall be included in the classification as a suffix for those electrodes which have appreciable quantities of metal powder in their coating and give increased metal recovery with respect to that of core wire melted, in accordance to the range given in 5.0.2 (b).

The metal recovery shall be determined as 'Effective Electrode Efficiency (E_E) as per the method given in IS 13043:1991.

Radiographic quality electrodes: The letter 'X' shall be included in the classification as a suffix for those electrodes which deposit radiographic quality welds.

Example 1

The classification for the electrode EB 5426H1JX

E B 5 4 2 6 H_1 J X

- E — Covered electrode
- B — Type of covering (Basic)
- 5 — Strength characteristics (UTS = 510–610 N/mm² and YS = 360 N/mm² min.)
- 4 — Elongation and impact properties (Elongation = 20% min. and IMPACT = 27 J min. at – 30°C)
- 2 — Welding position (all positions except vertical down)
- 6 — Welding current and voltage condition (D + and A 70)
- H_1 — Hydrogen controlled electrodes (15 ml max.)
- J — Increased metal recovery (110 – 129%)
- X — Radiographic quality electrode

Example 2

The classification for the electrode ER 4211

E R 4 2 1 1

- E — Covered electrode
- R — Type of covering (Rutile)
- 4 — Strength characteristics (UTS = 410 – 510 N/mm² and YS = 330 N/mm² min.)
- 2 — Elongation and impact properties (Elongation = 22% min. and impact = 47 J min. at 0°C)
- 1 — Welding position (all positions)
- 1 — Welding current and voltage conditions (D ± and A 50)

AWS codification of carbon and low alloy steel coated electrodes

Chart - 1 shows details of AWS coding of an electrode.

In the chart, E stands for electrode. It means that it is a stick electrode.

The first two digits are very important. They designate the minimum tensile strength of the weld metal that the electrode will produce.

The third digit indicates the welding positions.

The last digit the code indicates the kind of flux coating used.

BS codification of carbon steel and low alloy steel covered electrodes (BS 639 : 1976 equivalent to ISO 2560)

As shown chart 2, E stands for covered MMA electrodes.

The first two digit indicated tensile strength and yield stress.

The next two digits indicate elongation and impact strength.

The letter after the first 4 digits indicates the type of covering.

The first 3 digits after the letter indicating the type of covering shows electrode efficiency.

The fourth digit after the letter indicating type of covering shows the welding position.

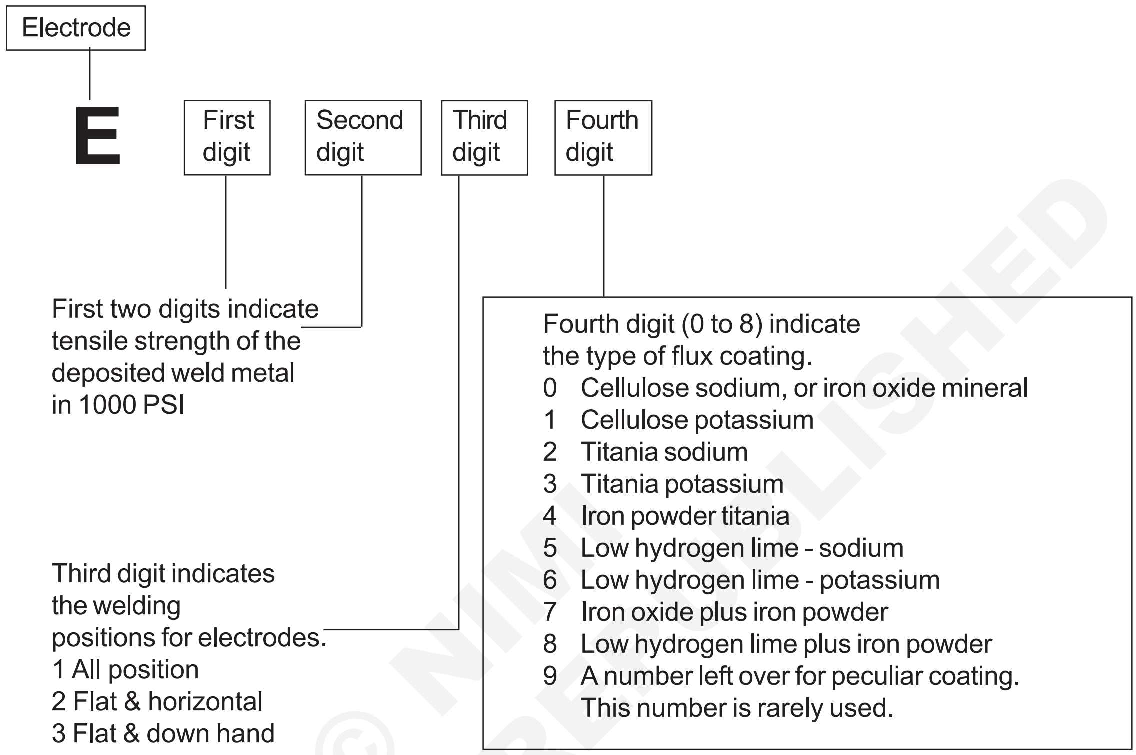
The fifth digit after the letter indicating type of covering indicates current and voltage.

In the case of rutile covered electrodes, the digits indicating the electrode efficiency after the letter indicating type of covering will not be given as shown in chart 1.

Chart 2 shows an electrode coding with electrode efficiency.

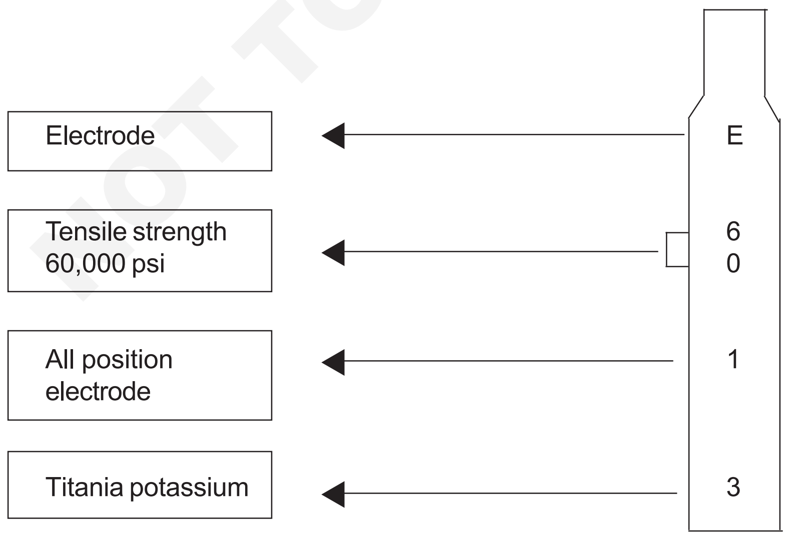
CHART 1

AWS CODIFICATION OF CARBON STEEL AND LOW-ALLOY STEEL COATED ELECTRODES

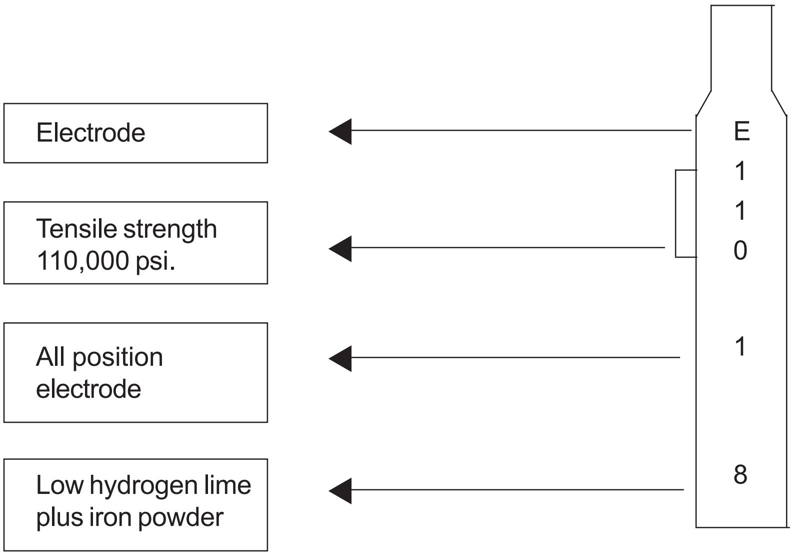


FOUR DIGITS CODIFICATION

EXAMPLE : AWS – E 6013.



FIVE DIGITS CODIFICATION



*To get the tensile strength of the weld in p.s.i., the number given here should be multiplied by 1000.

CHART 2 (BS 639 : 1976 equivalent to ISO 2560)

COVERING ④

- A Acid (iron oxide)
- AR Acid (rutile)
- B Basic
- C Cellulosic
- O Oxidising
- R Rutile (medium coated)
- RR Rutile (heavy coated)
- S Other types

ELECTRODE EFFICIENCY ⑤

% recovery to nearest 10% (> 110)

(H) ⑧

Indicates hydrogen controlled (> 15mg/100g)

STRENGTH ②

Electrode designation	Tensile strength N/mm^2	Minimum yield stress. N/mm^2
E43	430.550	330
E51	510.650	360

Example (b)	**E**	**51**	**33**	**B**	**160**	**2**	**0**	**(H)**
	1	2	3	4	5	6	7	8

PROCESS ①

Covered MMA electrode

WELDING POSITION ⑥

- 1 All positions
- 2 All positions except vertical down
- 3 Flat and, for fillet welds, horizontal vertical
- 4 Flat
- 5 Flat, vertical down and, flat fillet welds, horizontal vertical
- 6 Any position or combination of positions not classified above.

ELONGATION (3)

First Digit	Minimum elongation, %		Temperature for impact value of 28J, °C
	E43	E51	
0	Not specified		Not specified
1	20	18	+20
2	22	18	0
3	24	20	-20
4	24	20	-30
5	24	20	-40

IMPACT (3)

Second Digit	Minimum elongation, %		Impact properties		
			Impact value, J		Tempera-ture °C
	E43	E51	E43	E51	
0	Not specified		Not specified		
1	22	22	47	47	+20
2	22	22	47	47	0
(3)	22	22	47	47	-20
4	Not relevant	18	Not relevant	41	-30
6		18		47	-50

CURRENT / VOLTAGE (7)

Code	Direct current	Alternating current
	Recommended electrode polarity	Minimum open circuit voltage, V.
0	Polarity as recommended by manu-facturer	Not suitable for use on A C
1	+ or -	50
2	-	50
3	+	50
4	+ or -	70
5	-	70
6	+	70
7	+ or -	90
8	-	90
9	+	90

Example (1) Covered electrode for manual metal arc welding having a rutile covering of medium thickness and depositing weld metal with the following minimum mechanical properties. (BS 639)

Tensile Strength : 500 N/mm^2

Elongation: 23 %

Impact strength: 71 J at + 20°C, 37 J at 0°C, 20 J at -20°C.

It may be used for welding in all positions. It welds satisfactorily on alternating current with a minimum open-circuit voltage of 50 V and on direct current with positive polarity.

The complete classification for the electrode would therefore E 43 21 R 1 3

and the compulsory part would be E 43 21R 13.

Covered electrode for manual metal arc welding — E

Tensile strength — 43

Elongation and impact strength — 21

Covering — R

Welding positions — 1

Current and voltage — 3

Example (2) An electrode for manual metal arc welding having a basic covering, with a high efficiency and depositing weld metal containing 8 ml of diffusible hydrogen per 100 g of deposited weld metal with the following minimum mechanical properties.

Yield stress: 380 N/mm^2

Tensile strength: 560 N/mm^2

Elongation: 22%

Impact strength: 47 J at -20°C

} Also a minimum elongation of 20% with an impact value of 28 J at -20°C

Nominal efficiency: 158%

It may be used for welding in all positions except vertical down, direct current only.

The complete classification for the electrode would, therefore, be E 51 33 B 160 2 0 (H)

and the compulsory part would be E 51 33 B 16020(H)

Covered electrode for manual metal arc welding — E

Tensile strength and yield stress — 51

Elongation and impact strength — 33

Covering — B

Efficiency — 160

Welding positions — 2

Current and voltage — 0

Hydrogen controlled — (H)

Effects of moisture pick up storage and baking of electrodes

Scan QR code for this exercise

Objectives: At the end of this lesson you shall be able to
- **identify the effect of moisture pick up**
- **describe the storage & baking electrodes.**

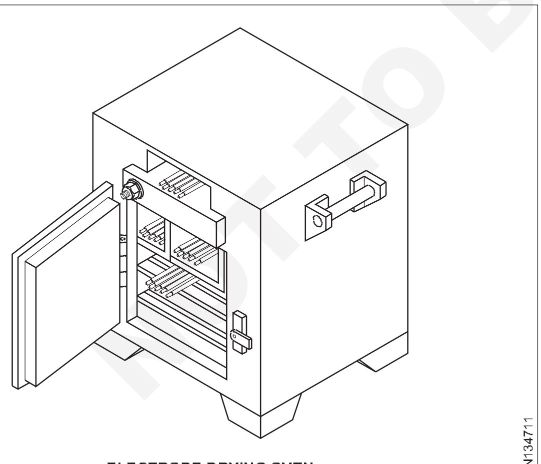
Storage of electrodes: The efficiency of an electrode is affected if the covering becomes damp.

- 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 OVEN

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.**

Weldability of metals, importance of preheating, post-heating and maintenance of inter-pass temperature

Objectives: At the end of this lesson you shall be able to
- **state the weldability of metals**
- **describe the importance of pre-heating and post-heating.**

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.

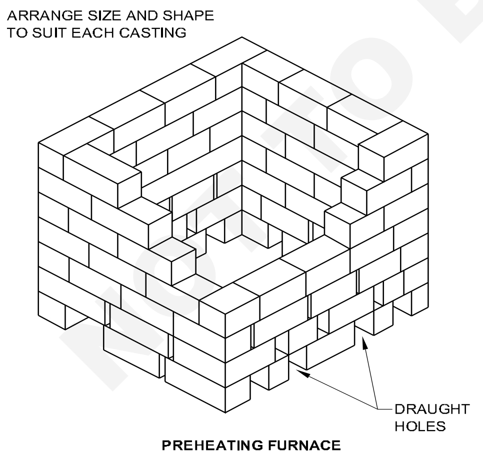
Preheating: Heating the job before welding operation is known as 'preheating'. The purpose of preheating of the cast iron job is to reduce cracking due to distortion. The rate of cooling, and gas consumption etc. are also reduced.

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

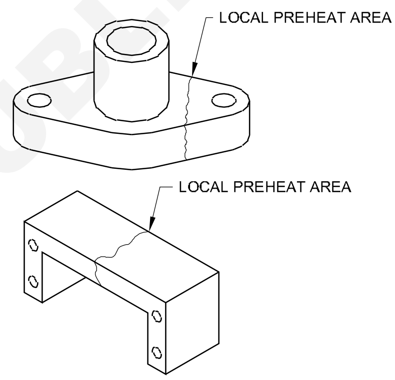
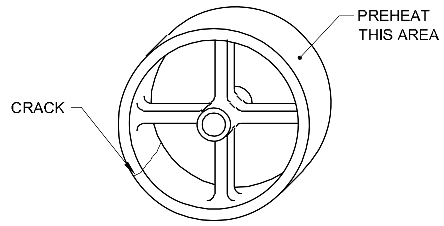


Fig 3



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)

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)

Fig 4

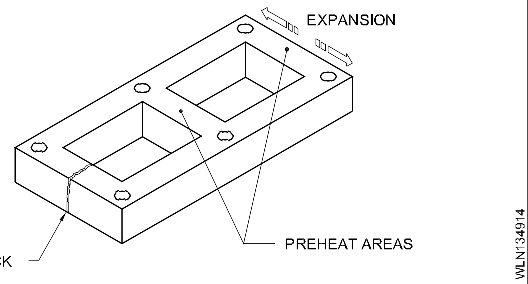
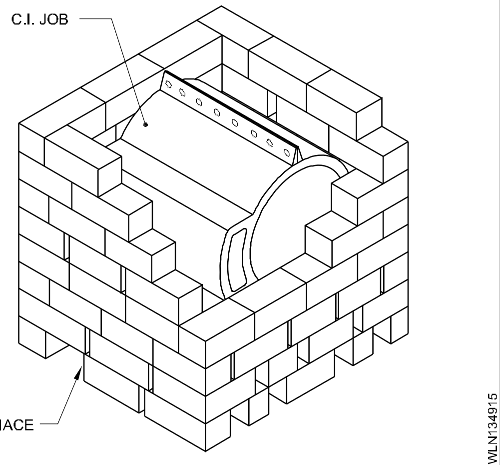


Fig 5



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 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.

Welding of low carbon steel, medium and high carbon steel and alloy steel

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**
- **describe the method of welding low, medium and high 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.

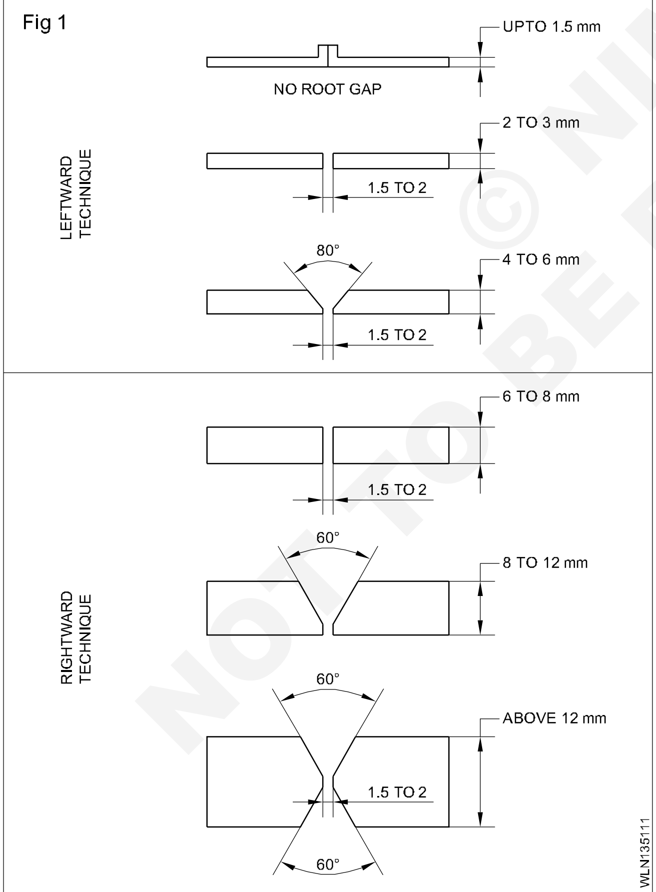
Carbon steels are classified according to the percentage of carbon they contain. They are referred to as low, medium and high carbon steels.

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 Machin able 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.

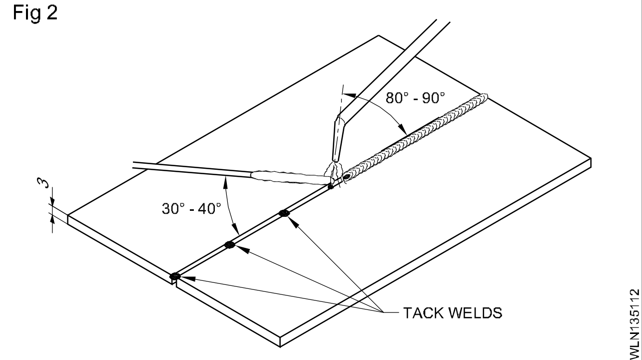
Welding procedure

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.

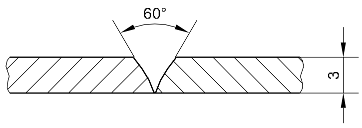
Keep the tip of the inner cone of the flame within 1 to 1.5 mm of the molten puddle, and hold the blowpipe at an angle of 80-90° to the work. (Fig 2)

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.

Fig 3



WLN135113

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.

> **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

When the steel is mixed with other metals like linoleum, manganese tungsten etc., it is called an alloy steel. Alloy steel has properties of its ingredients.

Types of Alloy Steel

Two types of alloy steel are:

A Low alloy steel

B High alloy steel

A Low Alloy steel: Besides carbon other metals are in lesser quantity. Its tensile strength is more. The welding can work on it. This can also be hardened and tempered. It is used in manufacturing various parts of an aeroplane and cam shaft etc.

B High Alloy Steel: Besides carbon it has a high percentage of the metals higher than low steel alloy. This is classified into following types:

a High Speed Steel: It is also called high tungsten alloy steel because it has more quantity of tungsten. According to the quantity of tungsten it is classified into three types:

1 Tungsten 22%, Chromium4%, Vanadium 1%

2 Tungsten 18%, Chromium 4%, Vanadium 1%

3 Tungsten 14%, Chromium 4%, Vanadium 1%

Cutting tools are made out of it because it is very hard but becomes soft at low critical temperature. This temperature is raised out of cutting process of tool, then the cutting tool becomes useless and is unfit for work. But due to high percentage of tungsten it keeps working upto high temperature. It is used for cutting tools, drills, cutters, reamers, hacksaw blades etc.

b Nickel Steel: In this 0.3% carbon and 0.25 to 0.35% nickel is present. Due to nickel its tensile strength, elastic limit and hardness is increased. It does not catch rust. Its cutting resistance increases 6 times more than plain carbon and steel due to 0.35% nickel present in it. This is used for making rivets, pipes, axle shafting, parts of buses and aeroplane. If 5% of cobalt is mixed with 30-35% nickel, it becomes invar steel. It is mainly used for making precious instruments.

c Vanadium Steel: It contains 1.5% carbon 12.5% tungsten, 4.5% chromium, 5% vanadium and 5% cobalt. Its elastic limit, tensile strength and ductility is more. It has strength to bear sharp jerks. It is mainly used to manufacture of tools.

d Manganese Steel: It is also called special high alloy steel. It contains 1.6 to 1.9% of manganese and 0.4 to 0.5% carbon. It is hard and less wear. It is not affected by magnet. It is used in grinders and rail points etc.

e Stainless Steel: Along with iron it contains 0.2 to 90.6% carbon, 12 to 18% chromium, 8% nickel and 2% molybdenum. It is used for making knives, scissors, utensils, parts of aeroplane, wires, pipes and gears etc.

Properties of stainless steel:

1 Higher corrosion resistance

2 Higher cryogenic toughness

3 Higher work hardening rate

4 Higher hot strength

5 Higher ductility

6 Higher strength and hardness

7 More attractive appearance

8 Lower maintenance

f Silicon Steel: It contains 14% of silicon. Its uses are multifarious according to the percentage of silicon. 0.5% to 1% silicon, 0.7 to 0.95% manganese mixture is used for construction work. 2.5 to 4% silicon content mixture is used for manufacturing electric motors, generators, laminations of transformers. In chemical industries 14% silicon content mixture is used.

g Cobalt Steel: High carbon steel contains 5 to 35% cobalt. Toughness and tenacity is high. It has magnetic property therefore used to make permanent magnets.

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

Manganese

Sulphur

Phosphorus

Silicon

Chromium

Nickel

Tungsten

Vanadium

Molybdenum

Effects:

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
- **identify classification of steel**
- **state the physical properties of stainless steel**
- **describe the weldabity and welding procedure of SS**
- **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-hard enable and magnetic. The other group is MARTENSITE, which is hard-enable 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 marten site 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.

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.

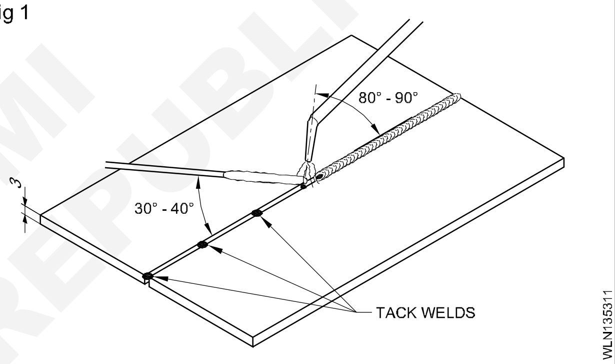
Welding procedure

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.

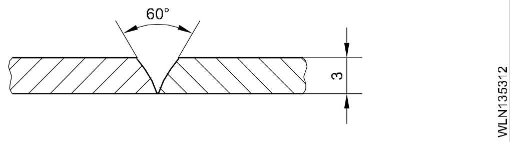
Keep the tip of the inner cone of the flame within 1 to 1.5 mm of the molten puddle, and hold the blowpipe at an angle of 80-90° to the work. (Fig 1)

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.

> **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 braz able. Austenitic 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.

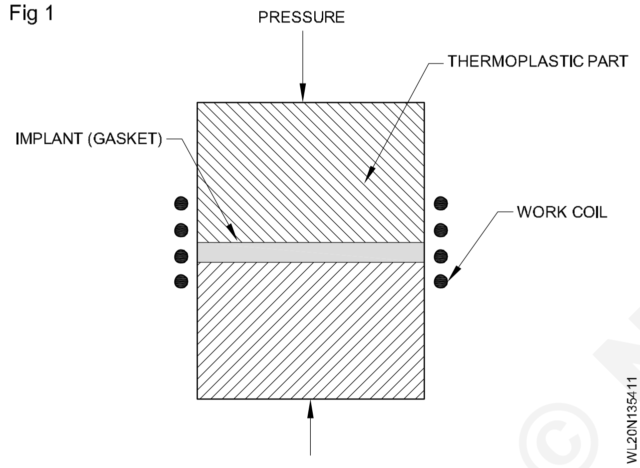
Induction welding, brazing of copper tubes

Objectives: At the end of this lesson you shall be able to
- **state the induction welding**
- **describe the brazing of copper tubes**

Induction welding is a type of welding that fuses two or more metals together using the resistive heat caused by changing electromagnetic fields, otherwise known as induction. During induction welding, a work piece is surrounded by conductive coils.

The changing magnetic field is typically induced through the use of an alternating current that runs through the conductive materials.

Fig 1



The use of copper brazing is for when greater joint strength is needed or for systems that operate at 350degrees or higher.

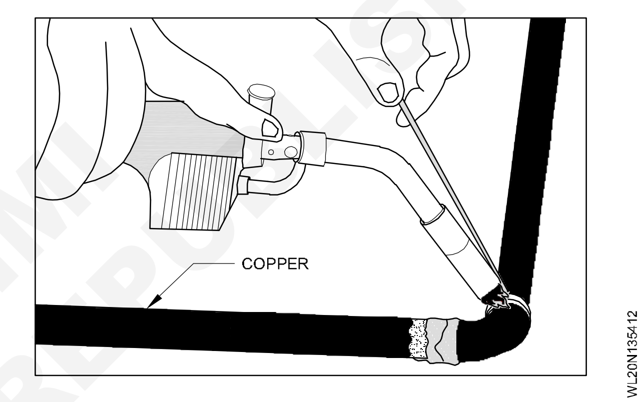
Typical uses include

- Fire protection
- Air-conditioning and refrigeration
- Fuel gas distribution
- Water supplies

Both oxygen-bearing and oxygen-free copper can be brazed to produce a joint with satisfactory.

The most common method of joining copper tubes is with the use of a socket-type, copper, or copper alloy fitting into which the tube sections are inserted and fastened by means of filler metal, using either a soldering or brazing process. This type of joint is known as a capillary or lap joint because the socket of the fitting overlaps the tube end and a space is formed between the tube and the fitting.

Fig 2



Brazing is a common fabrication process used for joining two or more metals. It is similar to the process of soldering, but it is done at higher temperatures. For best results, it must be performed with the appropriate brazing rod material based on the metals being brazed together.

Brass types properties and welding methods

Objectives: At the end of this lesson you shall be able to
- **state the composition and properties of brass**
- **describe the welding technique of brass.**

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.

Selection of nozzle, flame and flux: The main difficulty in welding of brass is the vapourisation of zinc, because the melting point of zinc is lower than that of brass. Due to the loss of zinc, below holes or porosity is produced in the weld and only copper is left over.

The strength is thereby reduced, and the weld gives a pitted appearance when polished.

Therefore excess burning of zinc should be controlled.

These 'zinc' problems are minimized by excess oxygen in the oxidising flame. The excess oxygen in the oxidising flame will convert zinc into zinc oxide whose melting point is more than that of zinc. So use of oxidising flame prevents evaporation of zinc. The flux helps to retain the zinc while solidification of weld metal occurs. The copper-zinc alloys, most of which are called BRASS, are more difficult to weld than copper. The zinc in the alloy produces irritating and destructive fumes or vapours during the welding process. Be sure to provide adequate ventilation and avoid inhaling zinc fumes.

For oxy-acetylene welding of brass, an oxidising flame is used and the nozzle is one size larger than the one used for welding mild steel plate of the same thickness. This will give a soft oxidising flame.

It is difficult to weld brass by electric arc process.

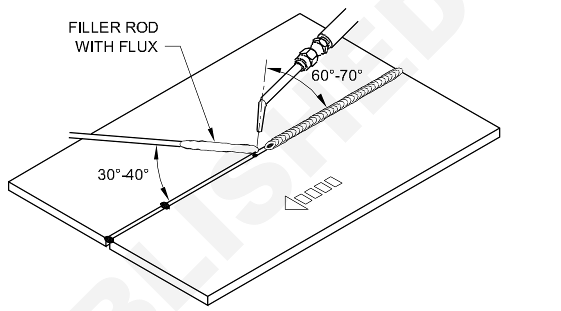
Flux is very important in welding brass. A fresh mixture of borax paste makes a good flux for brass welding.

The flux should be applied on the underside of the joint area and to the filler rod.

Edge preparation is as shown in Table 1.

Welding technique: Adopt leftward technique and keep the angle of the blowpipe at 60°-70° and the filler rod at 30°-40°. At the end of the joint reduce the blowpipe angle and withdraw entirely to reduce the heat input at the crater. (Fig 1)

Fig 1



Ensure complete removal of all traces of flux because the residual flux will react and reduce the strength of the joint.

> **Use a respirator and avoid inhaling zinc fumes during welding.**

Brass properties

- Brass often has a bright gold appearance, however, it can also be reddish-gold or silvery-white. A higher percentage of copper yields a rosy tone, while more zinc makes the alloy appear silver.
- 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 resist corrosion, including galvanic corrosion from salt-water.
- Brass is easy to cast.
- Brass is not ferromagnetic. Among other things, this makes it easier to separate from other metals for recycling.

Copper types properties

Objectives: At the end of this lesson you shall be able to
- **name the types of copper**
- **identify physical properties of copper and its alloys**
- **describe 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.

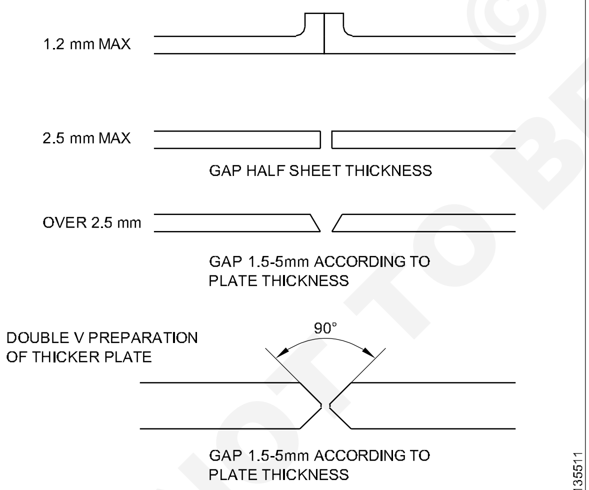
Melting point: 1083°C.

Density: 8.98 g/cm^3

Coefficient of linear expansion (ic): 0.000017 mm/mm/°C

Edges preparation (Fig 1)

Fig 1



PREPARATION OF COPPER PLATES FOR WELDING

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.

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

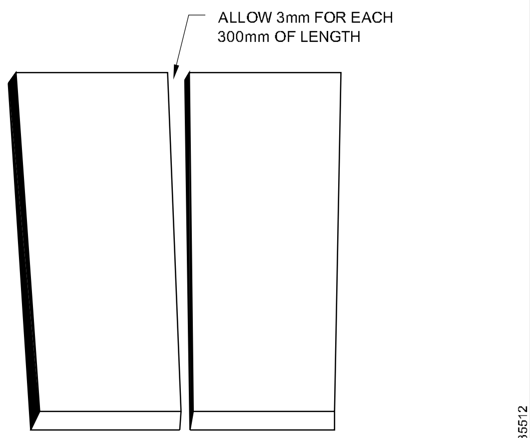
Too much oxygen will cause the formation of copper oxide and the weld will be brittle.

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.

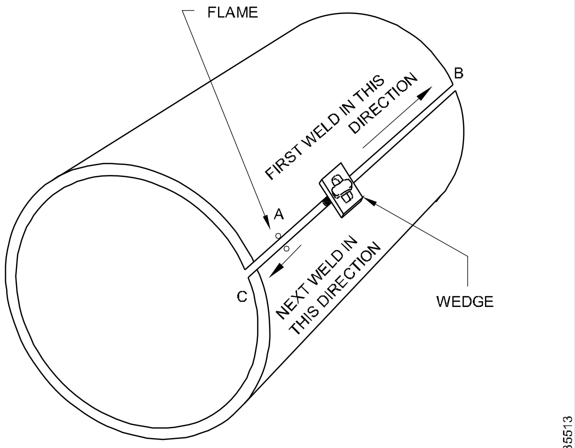
Preheat: Surface of the base metal is raised to a fairly high temperature 750°C (peacock neck blue colour) before the actual welding is started.

Fig 2



DIVERGENCE ALLOWANCE

Fig 3



WELDING LONG SEAM IN COPPER

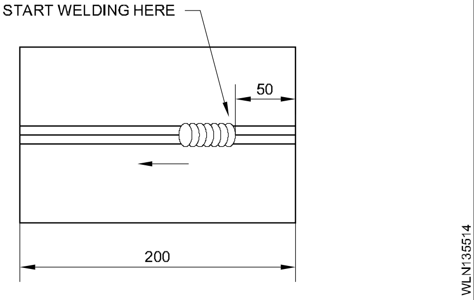
Welding technique: Adopt leftward technique up to 3.5 mm thickness and rightward technique for 4 mm thickness and above. Usually the welding starts from a point 40 to 50 mm away from the right end of the job and after welding till the left end turn the job by 180° and weld the balance non-welded portion. Always welding is done towards the open end of the joint. (Fig 4)

Control of distortion

Divergence allowance (as already stated in job setting) acts as an effective controlling distortion.

Chill plates or backing bar also prevents distortion.

Fig 4



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.

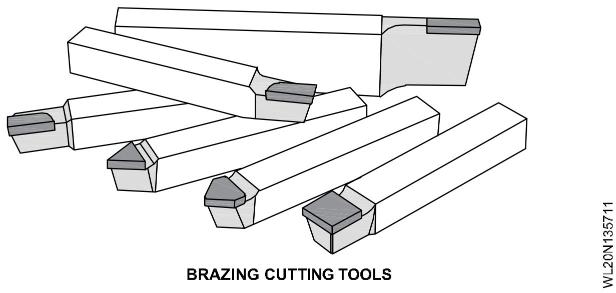
- Properties of copper alloys
- Excellent heat conductivity.
- Excellent electrical conductivity.
- Good corrosion resistance.
- Good machinability.
- Retention of mechanical and electrical properties at cryogenic temperatures.
- Non-magnetic.

Brazing cutting tools

Objective: At the end of this lesson you shall be able to
- **identify the brazing cutting tools**

Tipped with tungsten carbide segments, the brazed tools provide a cutting surface with the combined characteristics of compressive strength, extreme hot hardness at high temperatures, and resistance to abrasion, corrosion and thermal shock. (Fig 1)

Fig 1

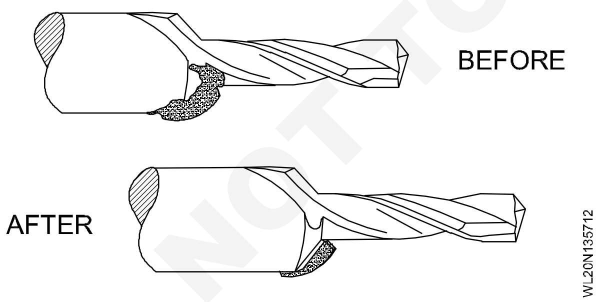


BRAZING CUTTING TOOLS

In order to make cutting tools stronger, manufacturers add a tungsten carbide insert into the surface of a tool steel bit. A pocket is machined out, the insert added, and then the insert and pocket are joined by the brazing process. This process can be messy and excess brazing material-usually an alloy filler-tends to smear around the tool steel, leaving a sloppy-looking part. The challenge of this application is similar to most selective cleaning applications: remove the unwanted material without impact to the part surface.

In this case, the goal is to remove any excess filler without damaging the carbide insert, darkening the part surface, or dulling the cutting features of the tool.(Fig 2)

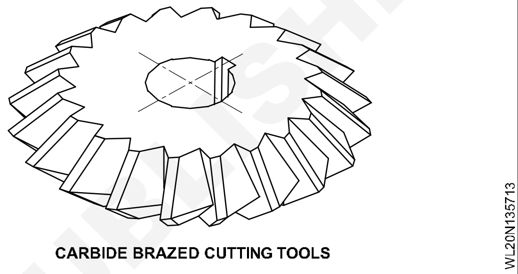
Fig 2



Tipped with tungsten carbide segments, the brazed tools provide a cutting surface with the combined characteristics of compressive strength, extreme hot hardness at high temperatures, and resistance to abrasion, corrosion and thermal shock. it's strongest characteristic-abrasion resistance-is 100 times greater than steel.it is the hardest known metal and is also three times more rigid than steel. Higher cutting speeds can be achieved.

Carbide brazed cutting tools (Fig 3)

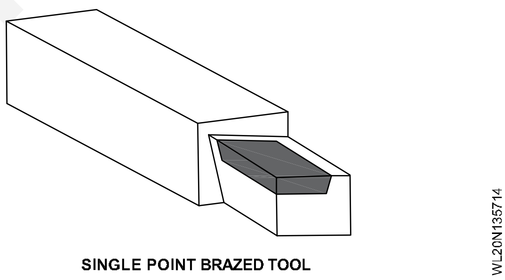
Fig 3



CARBIDE BRAZED CUTTING TOOLS

Single-point tooling highland (Fig 4)

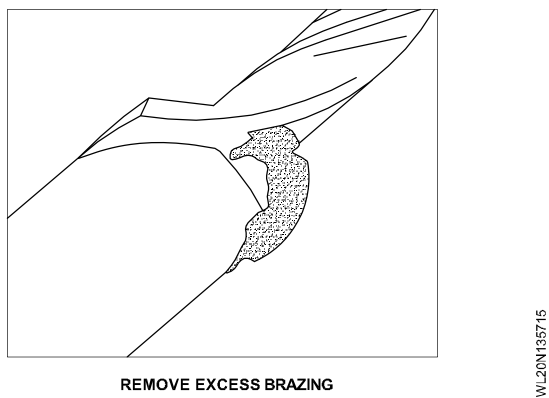
Fig 4



SINGLE POINT BRAZED TOOL

Remove excess brazing material from... (Fig 5)

Fig 5



REMOVE EXCESS BRAZING

Aluminium properties & weldability

Scan QR code for this exercise

Objectives: At the end of this lesson you shall be able to
- **state the properties of aluminium and its alloys**
- **describe the weldability and welding procedure of aluminium**
- **state the advantage and disadvantages of aluminium welding.**

Properties of aluminium and its alloys

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.

Difficulties in welding of aluminium by gas: 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)

Fig 1

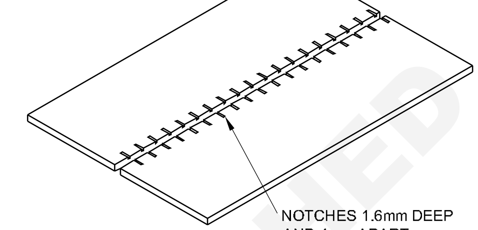
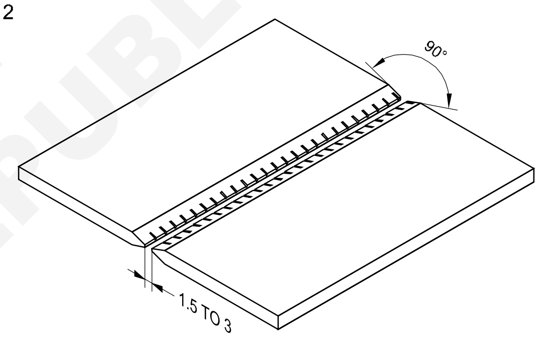


Fig 2



Preparation, pitch of tack, nozzle, size, filler rod etc. are given in Table 1 for butt joints.

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.

Arc cutting and gouging

Objectives: At the end of this lesson you shall be able to
- **describe the arc cutting and gouging processes**
- **state the advantages and applications of arc cutting and gouging.**

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)

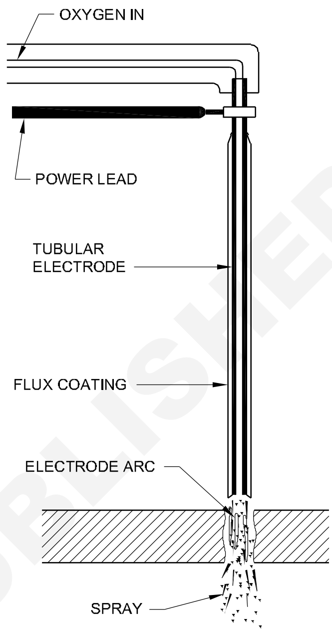
Metallic arc cutting and gouging electrodes: These electrodes are normally the same as welding electrodes or are sometime specially designed as cutting electrodes (Fig 2) at a current setting which is 20 to 50% higher than that normally used for a given size for welding. Although AC can be used, DC with 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.

Tungsten arc cutting electrode: This is an arc cutting electrode, which is used in TIG and plasma arc cutting processes.

Arc cutting and gouging procedure

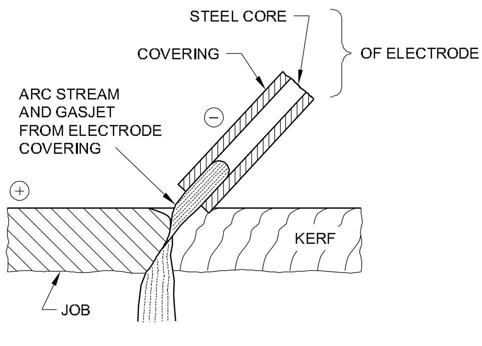
Arc cutting procedure: Prepare the piece as per the requirements. Clean the surface to be cut. Mark and punch the line. Position the job in flat.

Fig 1



SCHEMATIC OF OXYGEN ARC CUTTING ELECTRODE IN OPERATION

Fig 2



METAL ARC CUTTING

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.

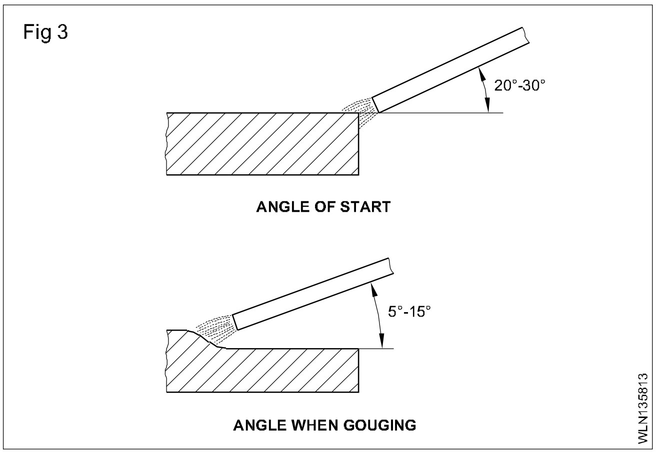
Arc gouging procedure: Prepare the piece as per the requirements. Clean the surface to be gouged. Mark and punch the line. Position the job in flat.

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)

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.

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 and its properties and welding methods

Objectives: At the end of this lesson you shall be able to
- **state the properties of cast iron and its types**
- **describe the 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.

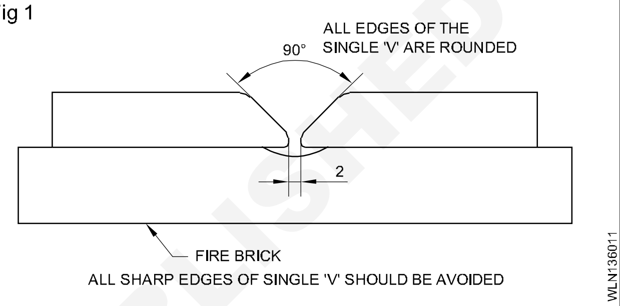
Nodular cast iron: It is also known as spheroidal graphite iron (SG iron). It is obtained by adding magnesium to the molten grey cast iron. The tensile strength and elongation of nodular iron is similar to that of steels which makes this iron a ductile material.

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).

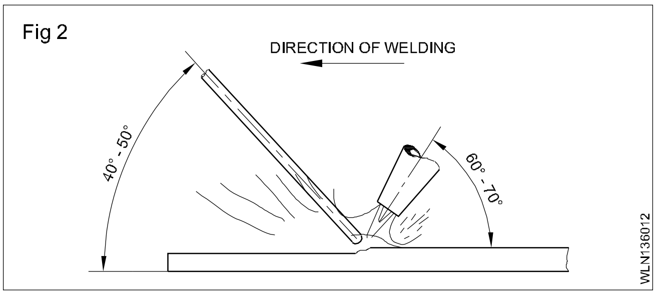
Flux: The flux should be of good quality to dissolve the oxides and prevent oxidation.

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)

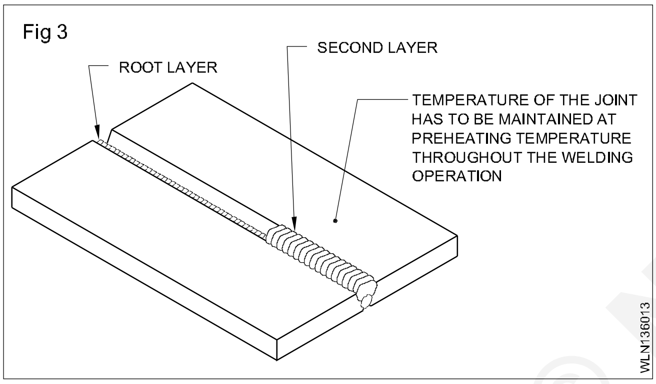
Fig 2



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)

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

– nature of joint to be made (i.e.), fusion welding or braze welding (non-fusion)

– welding technique to be used (leftward or rightward).

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.

Properties of cast iron

- It is having low cost.
- Very brittle.
- It is having high compressive strength and high wear resistance.
- It is having good casting characteristics.
- Cast iron melting point is lower than steel.
- It is having excellent machinability.
- Most cast irons are not malleable atg any temp.
- Cast iron has less ductility and cannot be rolled or drawn or worked easily at room temp.

Types of inspection method - classification of destructive and NDT methods

Objectives: At the end of this lesson you shall be able to
- **identify the types of tests**
- **describe the non-destructive and destructive test.**

Scan QR code for this exercise

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.

Non-destructive testing methods are classified as common testing and special testing methods.

Common non-destructive testing

- Visual inspection
- Leak or pressure test
- Stethoscope test(sound)

Special non-destructive test

- Magnetic particle test
- Liquid penetrant test
- Radiography (x-ray) test
- Gamma ray test
- Ultrasonic test

Visual inspection (non-destructive test): Visual inspection is observing the weld externally using simple hand tools and gauges to know whether there are 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 wielding 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.

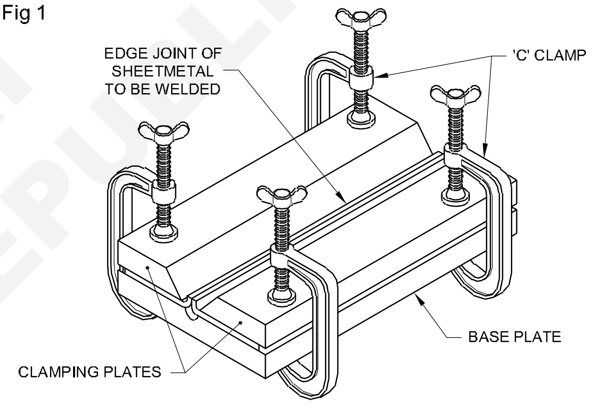
Polarity of the electrodes in the case of DC welding current.

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.

WLN216211

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.

The following factors are to be ensured.

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 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.

Stethoscope (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.

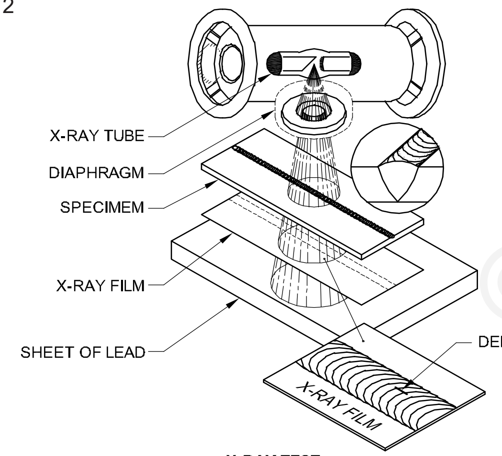
An ordinary physician's stethoscope and a hammer may be used to magnify and identify the sound.

Structural welds and welda in pressure vessel 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 2) 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 2



X-RAY TEST

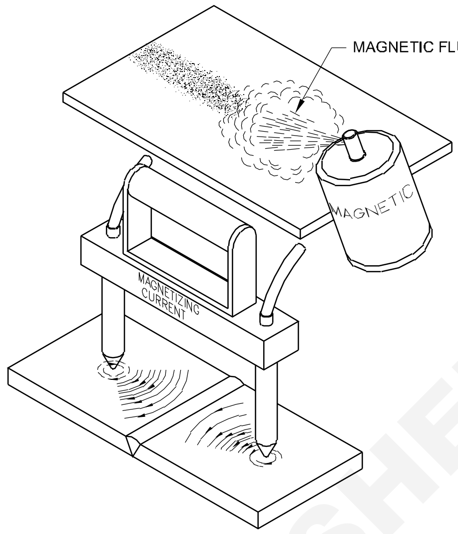
Gamma ray test: The short invisible rays given off by radium and radium compounds like cobalt 60 etc.are known as gamma rays.These rays penetrate greater thickness of steel than x-rays and the chief advantage of this process is portability.This test can be done at all places where electricity is not 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 6mm depth) defects in ferrous materials.

A liquid containing iron powder is first sprayed over the joint to be tested. When this test piece is magnetized, 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. (Fig 3 & 4)

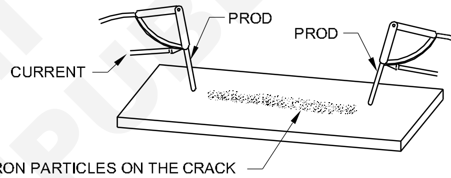
Liquid penetrant test: This test is based on the principle that coloured liquid dyes and fluorescent liquid penetrate into the cracks and are used to check for surface defects in metals, plastics, ceramics and glass. A solution of the coloured dye is sprayed on the clean welded joint and allowed to soak. Then the dye is washed off using a cleaner, and the surface dried with soft cloth.

Fig 3



MAGNETIC PARTICLE TEST

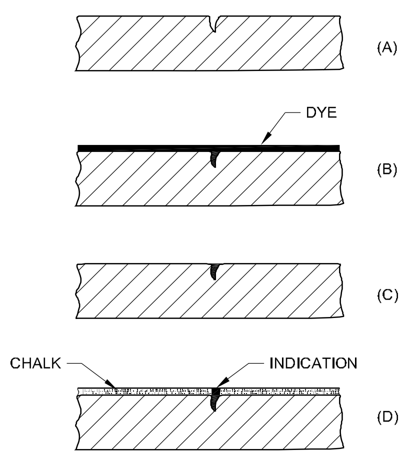
Fig 4



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 5)

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.

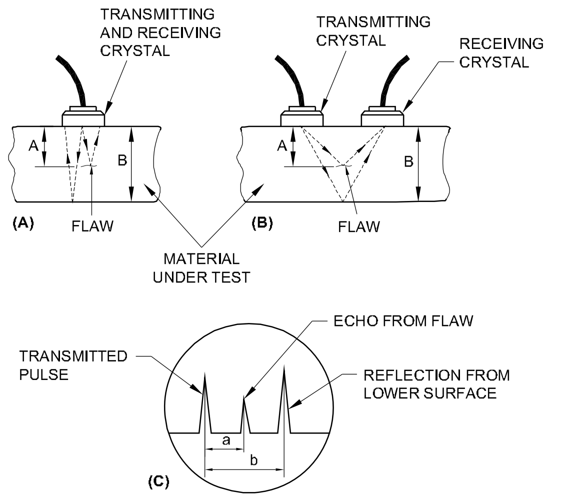
Fig 5



LIQUID PENETRANT TEST

A sound waves 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 7)

Fig 7



PRINCIPLE OF ULTRASONIC INSPECTION

Destructive test

Introduction: Welded joints are tested without damaging or destroying the welded structure under non-destructive testing methods which were explained earlier. Now to know the property of material used for welding and to know the strength of a weld joint and also to judge the skill of the welder, a destructive test is to be performed on a welded specimen which was destroyed during the testing. There are two main methods of destructive testing. They are:

- Workshop tests
- Laboratory tests

Workshop tests

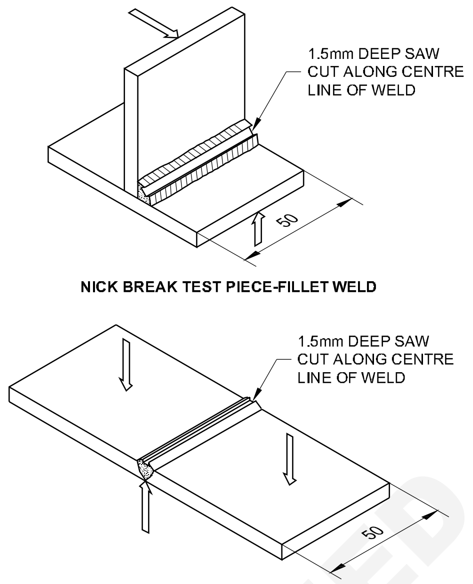
These are the tests that can be performed in the workshop

- Nick break test
- Free bend test in a vice
- Fillet fracture test (by using a bending bar)

Nick break test: In a nick break test a saw cut of about 1.5mm to 2mm depth is made along the centre line of the weld, and a hammer blow is given on the reverse of the joint as shown in the figure. (Fig 8). The joint will break along the saw cut and by observing the fractured surface, various defects like slag inclusions, lack of fusion, lack of penetration, etc. can be identified.

Free bend test: The welded joints are fixed on a vice and bend by applying forces by hammer/bending bar to determine the defect in the weld done by a trainee in a workshop. (Fig 9 & 10) The workshop tests are usually used to break open the weld in a workshop using a vice and hammer for visual inspection.

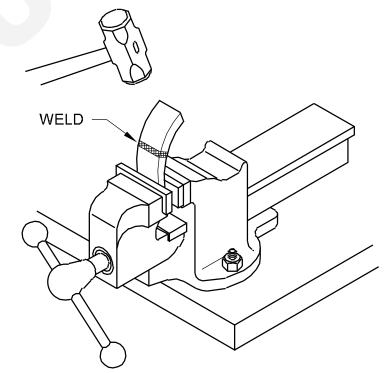
Fig 8



NICK BREAK TEST PIECE-BUTT WELD

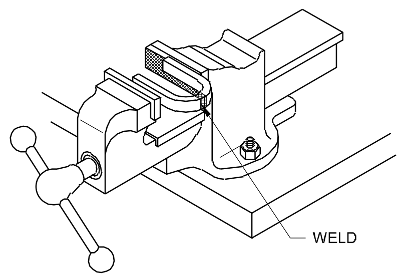
Advantages and limitations: The time taken to perform the test is less. Cost of testing is less. This test is useful for testing the welders in the beginning when the weld contains many defects. Does not give the actual strength of the joint. Cannot be used for testing the quality of weld consumables. (electrodes and filler rods)

Fig 9



THIS IS ONE WAY THE INITIAL BEND CAN BE MADE

Fig 10



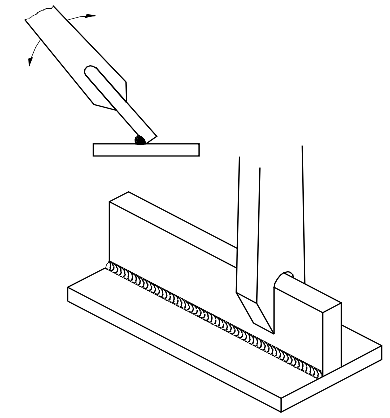
FOR THE FINAL BEND, THE SPECIMEN MUST BE BENT IN A VISE

Examination of fractured weld: The fractured weld may exhibit and show the following internal defects. (Figs 10, 11, 12 & 13)

- Lack of fusion
- Incomplete penetration

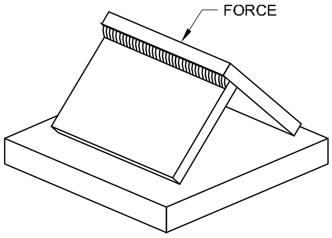
- Slag inclusions
- Blow-holes or porous weld

Fig 10



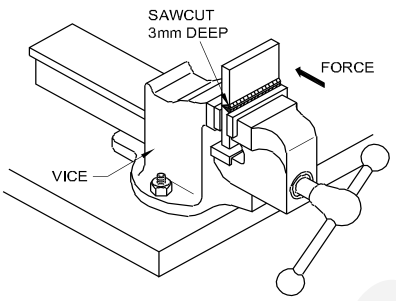
FILLET FRACTURE TEST USING BENDING BAR

Fig 11



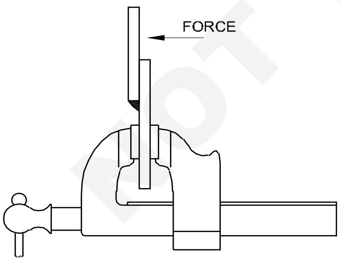
FILLET FRACTURE TEST USING HAMMER

Fig 12



FRACTURE TEST ON BUTT JOINT

Fig 13



FRACTURE TEST ON LAP FILLET

Laboratory tests

The laboratory test conducted on welds are the:

- Tensile test
- Guided bend test
- Impact test
- Fatigue test

Tensile test: A tensile test is conducted to know the tensile strength and ductility (i.e. elongation) of a weld.

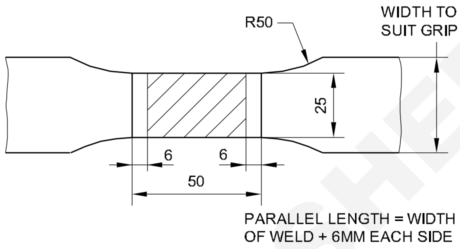
Two types of test specimens are prepared for the tensile test.

They are:

- Transverse tensile test specimen. (Fig 14)
- All-weld metal tensile specimen. (Figs 15 & 16)

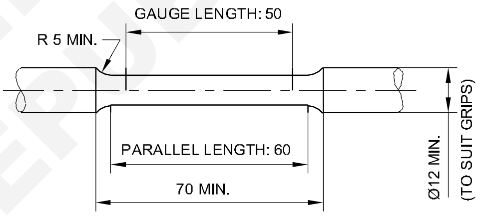
The tensile test gives the values of the tensile strength of

Fig 14



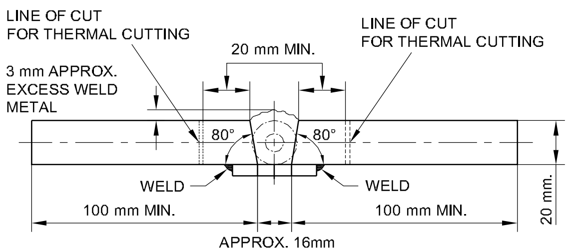
DIMENSIONS OF TRANSVERSE TENSILE TEST SPECIMEN

Fig 15



ALL-WELD METAL TENSION SPECIMEN

Fig 16



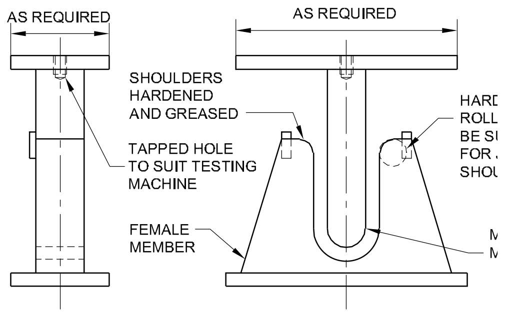
LOCATION OF ALL-WELD METAL TENSION SPECIMEN (END VIEW)

the weld and the percentage of elongation of the weld. This reveals the suitability of a joint welded with certain electrodes and base metals for a particular service condition.

Guided bend test: A guided bend test is one in which the specimen as in is bend to 180° through a bend testing jig as in Fig 17.

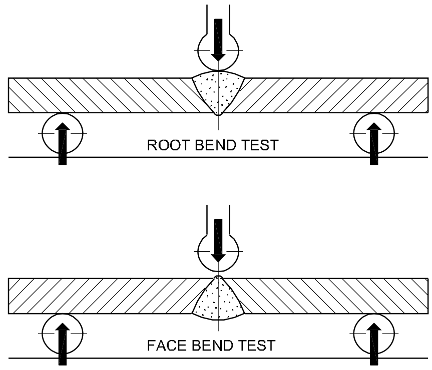
There are two types of specimens prepared for this-one for face bend and the other for root bend. (Fig 18) This test measures the ductility of the weld metal in a butt joint in a plate. This test shows most weld faults quite accurately and it is very fast. A sample specimen can be tested on destruction to determine (a) the physical condition of the weld and thus check on the weld procedure and (b) the welder's capability.

Fig 17



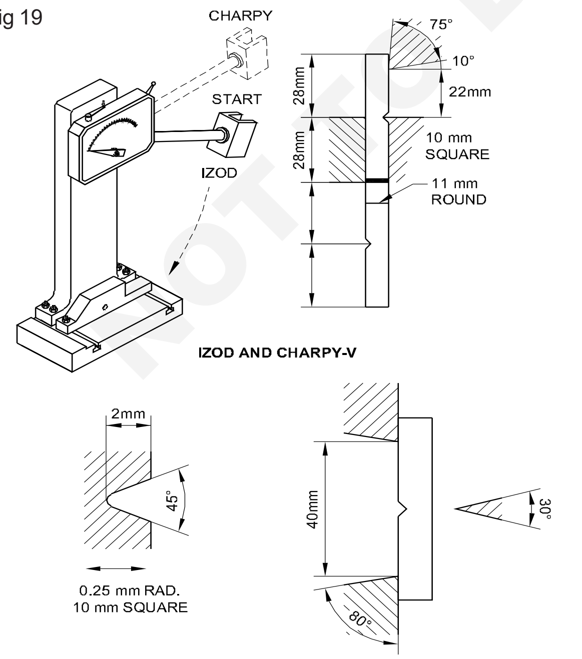
JIG FOR GUIDED BEND TEST

Fig 18



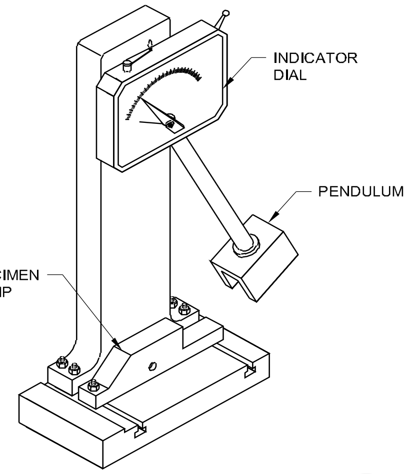
Impact test: Impact means application of a sudden force on an object. In an impact test of weld, a test specimen (Fig 19) is prepared from a test plate. This is further machined to have a V notch as in Fig 19. The test specimen with 10 mm square construction is used for chirpy V impact test and one with mm diameter circular cross-section is used for the izard impact test. Fig 20 shows an impact testing machine.

Fig 19



IZOD AND CHARPY - V MACHINE AND SPECIMENS IMPACT TEST

Fig 20



A CHARPY IMPACT TESTING MACHINE

IN THIS TESTER THE PENDULUM IS LIFTEDAND DROPED AGAINST THE TEST SPECIMEN WHICH IS HELD IN THE CLAMP. THE IMPACT FORCE IS REGISTERED BY THE DIAL INDICATOR.

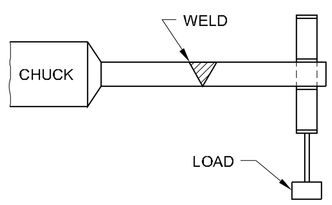
The impact test is used to determine the impact value of welds and base metals in welded products to be used at low temperatures up to - 40°C which are subjected to severe dynamic loading.

Fatigue test: When a welded joint is subjected to push and pull forces alternatively for a long period, it may fail due to the fatigue of the molecules. In this case the forces applied will rise to a maximum tension, decrease to zero, rise to a maximum compression and decrease again to zero. This cycle will be repeated which creates fatigue in the joint which will fail at much less loads than its maximum tension and compression strength.

The resistance to fatigue of a welded joint is tested by fixing the welded specimen in a chuck and rotated at a particular speed with a load hung at the other end as shown in Fig 21. Fatigue tests are extremely useful while testing welded shafts, cranks and other rotating parts which are subjected to varying alternating loads.

Fig 21

ILLUSTRATING PRINCIPLE OF WOHLER TEST



FATIGUE TEST

Welding economy and cost estimation

Objectives: At the end of this lesson you shall be able to
- **describe the method of cost estimation**
- **explain about economy in welding.**

The following factors are to be considered for cost estimation.

Material cost: Material cost involves the cost of all basic materials such as steel sheets, plates, rolled sections, forgings, angle irons, forgings, casting etc. as may be used.

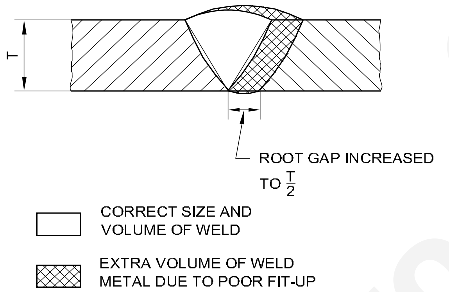
Fabrication cost: Fabrication cost involves cost of (1) preparation (2) welding and (3) finishing.

Preparation cost: Preparation cost involves cost of material handling, cutting, machining or shearing plates or sections, preparing the edges for welding, forming, fitting up, positioning, labour for these operations etc.

Welders should ensure that the plates and sections are prepared for welding, either by machining or by flame cutting in accordance with the recommendations of the design office.

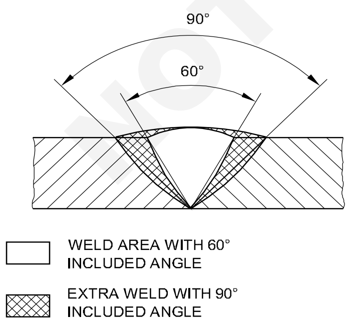
The effects of inaccurate edge preparation and poor fit up resulting in extra welding and the consequent additional welding costs are illustrated in Figs 1 and 2.

Fig 1



EFFECTS OF POOR FIT-UP IN A BUTT WELD: EXTRA WELDING AND HIGHER COST

Fig 2



BUTT WELD MADE WITH BEVELLED EDGE: 60° INCLUDED ANGLE (CORRECT) AND 90° INCLUDED ANGLE (INCORRECT)

Welding cost: The welding cost involves the cost of electrodes, power consumed, welding labour etc.

In determining the direct welding cost, the following factors are taken into consideration.

- Cost of electrodes - this being dependent on the type and size of electrode and edge preparation employed.
- Power consumed.

$$\text{Power cost} = \frac{V \times A}{1000} \times \frac{T}{60} \times \frac{1}{E} \times \text{rate per unit}$$

where V = Voltage, A = Current in amperes

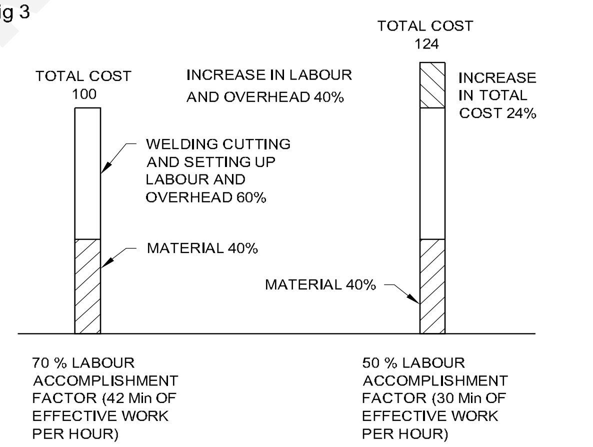
T = Welding time in minutes

E = Efficiency of the machine.

E is assumed to be 0.6 in the case of a welding transformer and 0.25 in the case of a welding generator.

- Speed of welding
- Welding labour cost (Fig 3)
- Position of welding

Fig 3

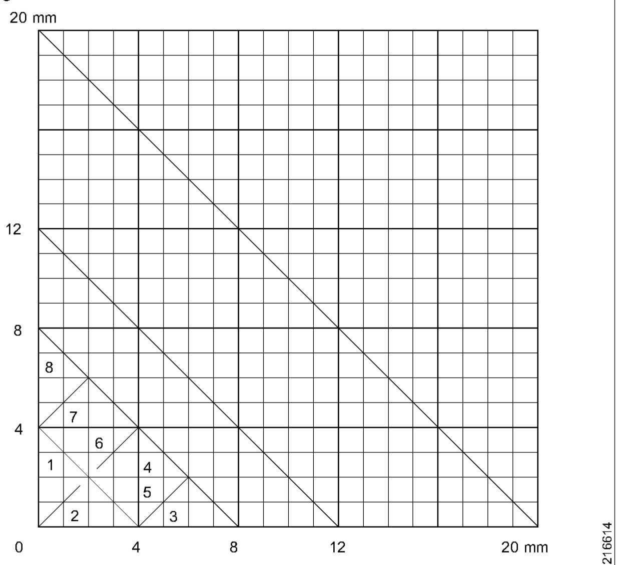


Finishing cost: Finishing cost involves cost of all post welding work, such as machining, grinding, sand-blasting, pickling, heat treatment, painting etc. and the labour involved in carrying out these operations.

Overhead cost: Overhead costs involve all other costs, such as office and supervisory expenses, lighting, depreciation on capital, etc. which are not to be directly charged to a job. There exists an elaborate and accurate system of computation and allocation of overhead expenses to the various stages of manufacturing process.

Economics of welding: Over-welding, that is excessive build up in the case of butt weld and fillet welds larger than those specified, should always be avoided. (See size comparison in Fig 4)

Fig 4



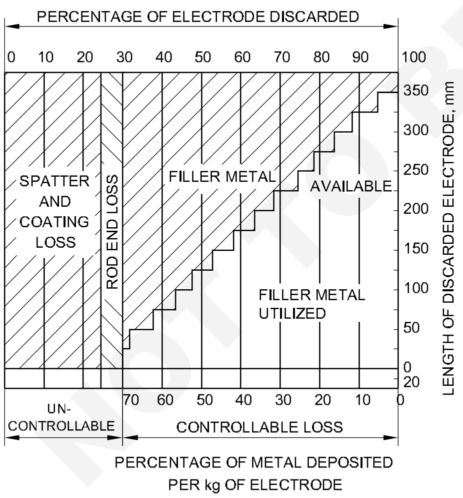
COMPARATIVE SIZE OF 90° FILLETS

Ensure that the largest size of electrode compatible with the plate thickness is used. Use of smaller electrode will increase labour hours and excessive distortion.

Use proper welding current. Excessive current will lead to excessive spatter loss and unsatisfactory weld.

Avoid excessive stub end loss; ensure that most of the usable portion of the electrode is used. The stub end should never be more than 50mm. (Fig 5)

Fig 5

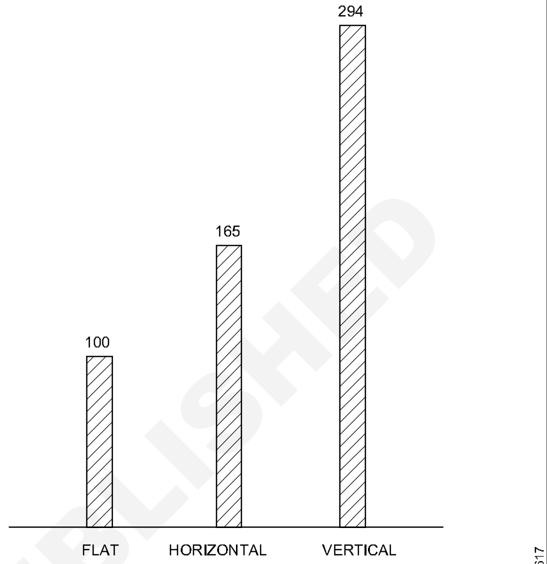


AMOUNT OF FILLER METAL UTILIZED FOR DIFFERENT DISCARDED LENGTHS OF ELECTRODES

The most convenient position of welding is in the down hand (flat) position. Whenever possible welding should be carried out in the flat position. A graphic form of the relative cost and speed of welding is shown in Fig 6 & 7.

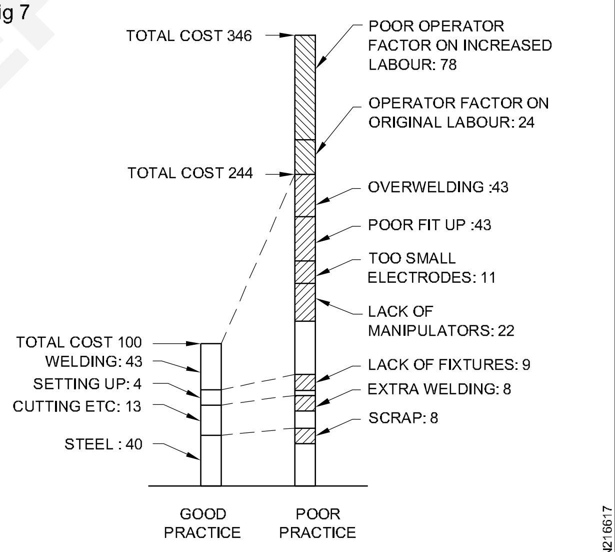
Observance of these few simple rules by the welders will go a long way in achieving a cost-effective operation. Good practice and poor practice are illustrated in Fig 7.

Fig 6



RELATIVE COSTS AND SPEEDS FOR MAKING 10mm FILLET WELDS IN DIFFERENT POSITION

Fig 7



CUMULATIVE EFFECT OF POOR PRACTICES ON COST

Safety precaution in Gas Metal Arc Welding and Gas Tungsten Arc Welding

Objective: At the end of this lesson you shall be able to
- **explain safety precaution to be followed in GMAW & GTAW process.**

Safety in GMA welding/CO_2 welding: The general safety precautions for arc welding (SMAW) are also applicable to GMAW.

During MIG welding Ultra Violet Light production is at the higher end of the scale and suitable eye protection must be used.

Adequate eye protection should always be worn. If welding for long periods, flash goggles with A#12 lens shade should be worn under the arc helmet. A#11 lens is recommended for nonferrous GMAW and A#12 for ferrous GMAW.

All welding should be done in booths or in areas protected by curtains. This is done to protect others in the weld area from arc flashes.

Welding in any form produces heat which can cause burns and the possibility of fire.

Suitable clothing must be worn. This is done to protect all parts of the body from radiation or hot metal burns. Leather clothing offers the best protection from burns.

The MIG welding of galvanised metal is extremely dangerous to the operator because of zinc poisoning unless suitable protection is used.

Ventilation should be provided. This ventilation and/or filtering equipment is necessary to keep the atmosphere around the welder clean.

Carbon monoxide is generated when doing GMAW and using CO_2 as a shielding gas. It is suggested that all welding be done in well ventilated areas.

Ozone is also produced when doing GMAW and ozone is a highly toxic gas.

Protect arc cables from damage. Do not touch uninsulated electrode holders with bare skin or wet gloves. Welding in wet or damp areas is not recommended.

Shielding gas cylinders must be handled with caution.

Safety in GTAW: GTAW/TIG welding is a skill which may be performed safely with a minimum of risk if the welder used good common sense and safety rules.

Check your equipment regularly and be sure that your environment is safe.

- never install fuses higher than specified
- always ground/earth the welding machine properly
- install electrical components as per the codes given by the electricity boards
- ensure electrical connections are tight
- never open a welding machine when it is operating
- lock primary voltage switches, open and remove fuses when working on electrical components inside the machine
- keep the welding power supply dry
- keep the power cable, ground cable and torch dry
- do not weld in damp area. If you must, wear rubber boots and gloves
- make sure the ground clamp is securely attached to the power supply and the work piece
- High frequency components in some GTAW machines produce a spark for starting the initial arc or maintenance of the arc during the alternating current welding.
- Use storage vessels for inert gases approved by the department of transportation.
- Ensure the welding area is well ventilated with good air circulation.

Welding environment safety rules for GMAW & GTAW

- keep the welding area clean
- keep combustibles out of the weld area
- maintain good ventilation in the weld area
- repair or replace damaged power cables
- make sure the part to be welded is securely grounded/earthed
- welding helmets should have no light leaks. Should not have scratches or cracks
- use the proper colored lens with correct shade number in the helmet
- wear safety glasses when grinding
- do not see the arc with bare eyes
- use safety screens or shields to protect your area
- wear proper clothing. Your entire body should be covered to protect you from arc radiation
- when welding on cadmium coated steels, copper or beryllium copper use special ventilation to remove fumes from the weld area.

Introduction to GMAW equipment and accessories

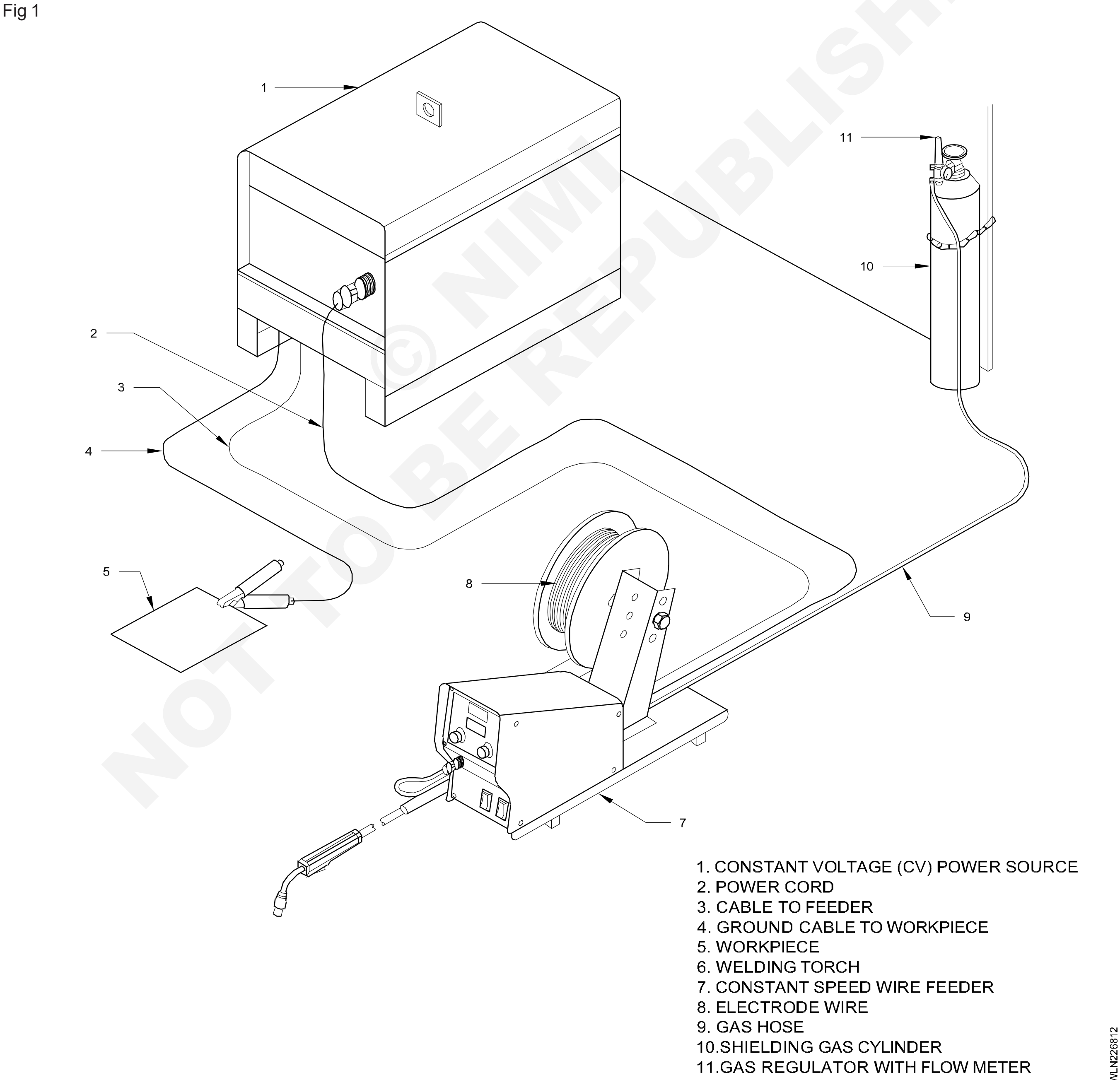
Objectives: At the end of this lesson you shall be able to
- **state the power sources of GMAW**
- **identify the GMAW equipment and accessories.**

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 continuously through the torch.

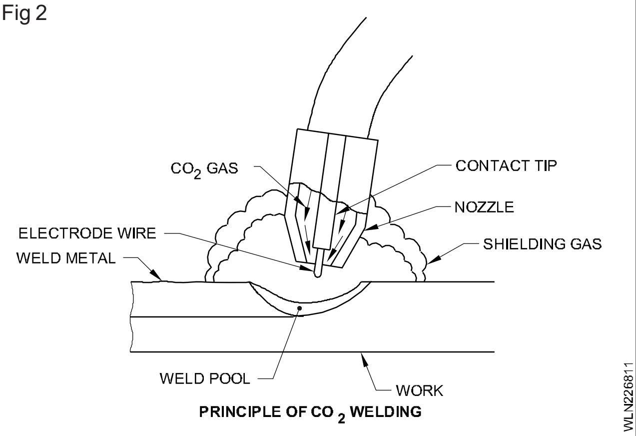
Accessories of GMAW (Fig 1)

Fig 1



Principle of GMA welding (Fig 2): 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/non inert gas passing through the welding torch/gun.

Fig 2



PRINCIPLE OF CO_2 WELDING

Accessories of GMAW

1 Power source (Fig 3)

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.

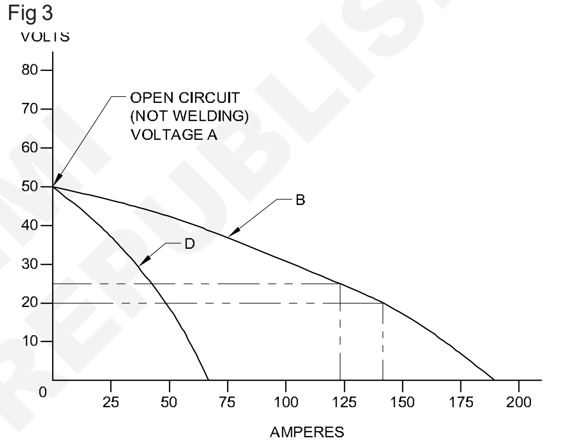
This means that the lead that is connected to the positive side of the welder, will carry 70% of the total energy (heat) output.

This type of power source is used in SMAW & GTAW process.

Characteristics curve for GMAW: The open circuit voltage curve for a setting of 50 volts on the machine is shown as curve B in the Fig 2. 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.

This is called flat characteristic power source. Also called constant Voltage(CV)power source.

Fig 3

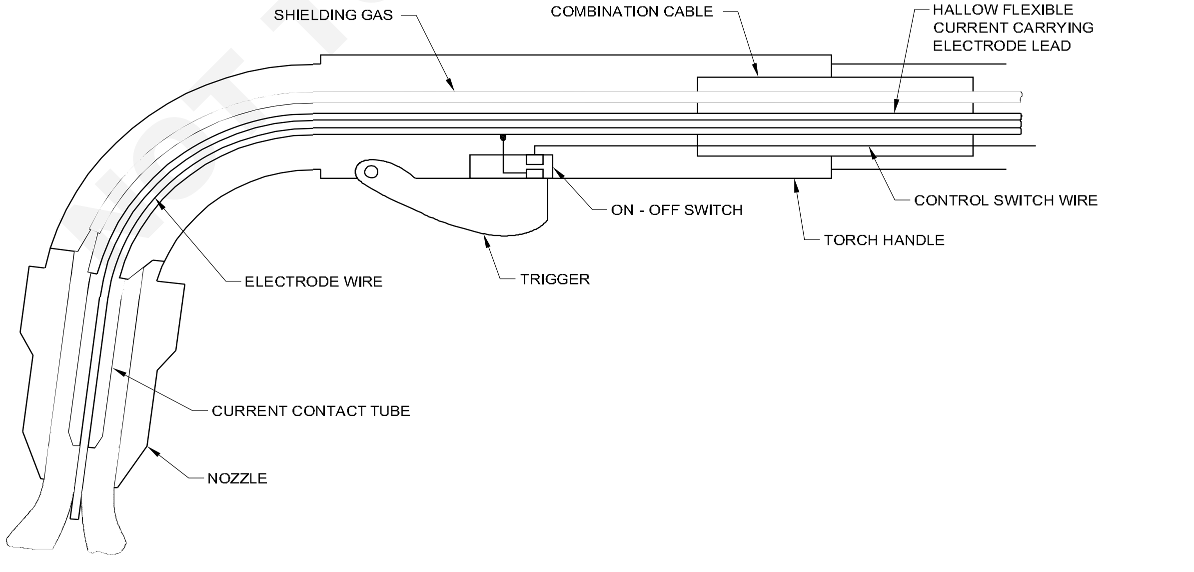


CONSTANT VOLTAGE TYPE

This type of power source is used in **GMAW & SAW** process.

2 MIG/MAG torches (Fig 4)

Fig 4



A SCHEMATIC CROSS SECTION OF AN AIR COOLED GAS METAL ARC WELDING TORCH

The MIG Torch is connected to the wire feeder, and its job is to deliver the wire electrode, shielding gas and the electrical welding current to the welding area. There are a lot of different shapes and styles of MIG Torch out in the marketplace but they all have things in common.

Liner: The liner parts of torch liner have a life span that is approximately one to four rolls of MIG wire depending on the quality of the liner and wire.

There are also different materials for different types of wire electrode, eg **steel or stainless liners for solid wires and Teflon liner for aluminium.**

Gas diffusers The gas diffuser's job is to make sure that the shielding gas is delivered to the shielding nozzle correctly. It is designed to make the gas come out as straight as possible and equally supplied around inside the gas shield nozzle. Diffusers can be made of different materials, eg copper, brass or fibre. Some diffusers will also be the tip holder.

Contact tip holder This is the item which holds the welding tip in place.

Contact tips The Contact tip/tube is the key to good welding.

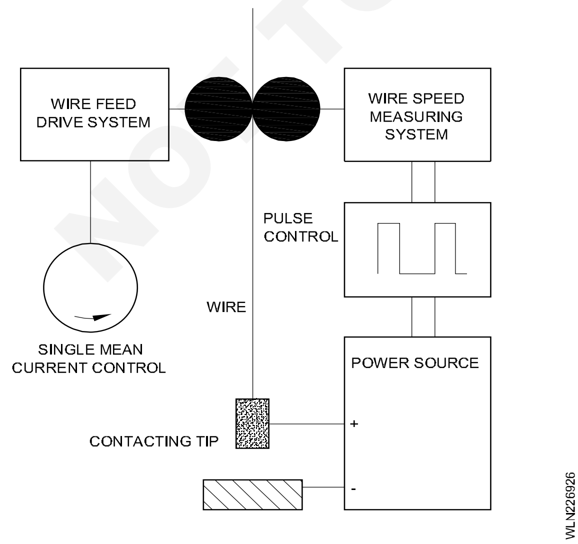
Most contact tips are made of copper alloy, the better the alloy the better the tip will pass current to the wire electrode and the less wear the MIG tip will have.

Nozzle: Guns are available with a straight or curved nozzle. The curved nozzle provides easy access to intricate joints and difficult-to-weld.

Synergic Control: The complexity of setting welding parameters in conventional DC and pulsed GMAW promoted the development of equipment with 'Single-knob' controls known as Synergic Control. These systems relied on selection of combinations of present welding (e.g. Wire feed speed/mean current and voltage) by means of a single control.

It is possible to store both the predetermined parameters and the control equations in the equipment and automatically adjust the output in response to a single input signal. This system is known as Synergic Control. (Fig. 5)

Fig 5



3 **Wire feeder:** 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.

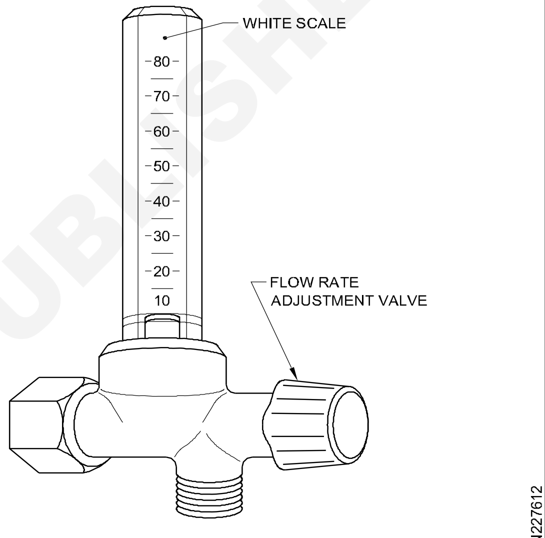
ii Provides the path for welding current to be passed from the welding power source through the interconnecting lead to the feeder and then to the welding torch.

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.

4 **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.

5 **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. 6.

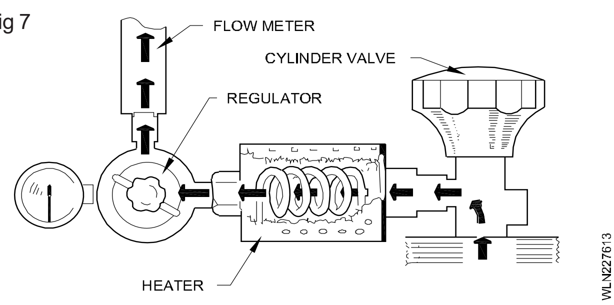
Fig 6



FLOW METER

6 **Gas Preheater for CO_2 welding (Fig 7):** Carbon dioxide 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 7



Various other names of the process (MIG MAG/Co_2)

Objective: At the end of this lesson you shall be able to
- **state the other names of GMAW.**

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.

Advantages of GMAW welding over SMAW limitation and applications

Objectives: At the end of this lesson you shall be able to
- **state the advantages and disadvantages of GMAW welding over shielded metal arc welding process**
- **state the applications of GMAW 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.

Process variables of GMAW

Objective: At the end of this lesson you shall be able to
- **explain the GMAW parameters.**

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.

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.

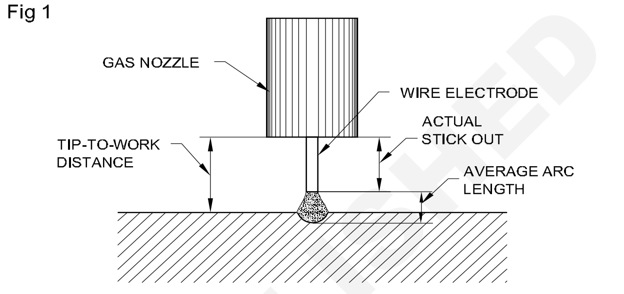
Arc travel speed: The linear rate at which the arc moves along the joint, termed arc travel speed, affects the weld bead size and penetration.

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)

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.

Fig 1



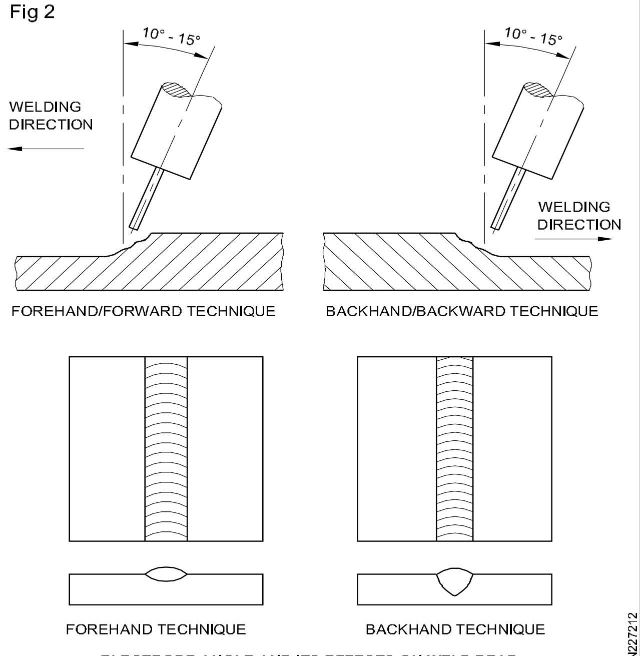
CORRECT WIRE STICK OUT IS IMPORTANT TO ACHIEVE SOUND WELDS

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°. (Fig 2)

Fig 2



ELECTRODE ANGLE AND ITS EFFECTS ON WELD BEAD

Wire feed system - Types - care and maintenance

Objective: At the end of this lesson you shall be able to
- **identify the different types of drive rollers.**

Wire feeder

Wire feeder is the part of the MIG/MAG welding set up (Fig 1).

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 Flux cored 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.

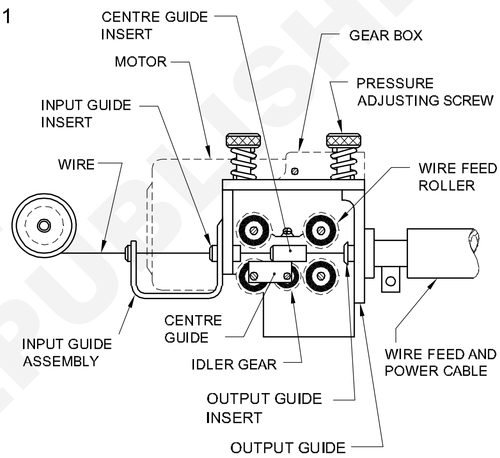
iii all guides must be as close as possible to the drive roller to prevent the possibility of the wire bunching up.

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.

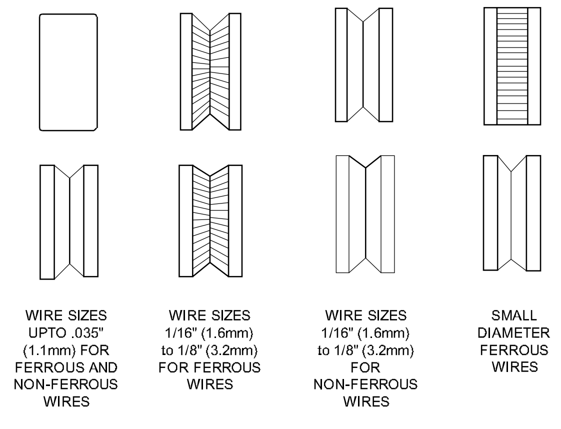
Fig 1



A SIMPLIFIED WIRE FEED MECHANISM FOR GMAW

WLN227411

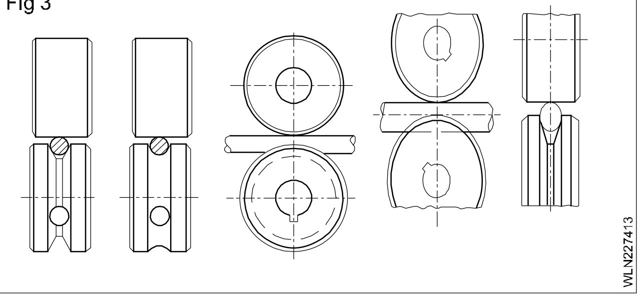
Fig 2



WL210313

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.

Fig 3



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 **Burn back -** Burn back 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 burn back the wire electrode will melt back onto the contact tip, possibly damaging it. If there is not enough burn back set, the wire electrode will not melt away from the weld pool 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.

GMAW wire feeder care and maintenance

Wire feed mechanism maintenance that prevents bird nesting drive rolls cleaning.

Welding wires used for GMAW, standard diameter and codification as per AWS

Objectives: At the end of this lesson you shall be able to
- **state the chemical composition of different electrode wires.**
- **explain the welding wires used in GMAW**
- **state the specification of 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.

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						

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

Wire electrodes selection

The selection of the wire electrode to be used in the MIG/MAG process is a decision that will depend on

1 the process being used (eg, solid wire or flux core wire)

2 the composition of the metal being welded

3 welding indoors or outdoors

4 joint design

5 cost

6 mechanical properties of the weld material and those that are a match for the base material.

Name of shielding gases used in GMAW and its application

Objectives: At the end of this lesson you shall be able to
- **name the shielding gases used in GMAW**
- **describe the application and advantages of shielding gases**
- **GMAW process.**

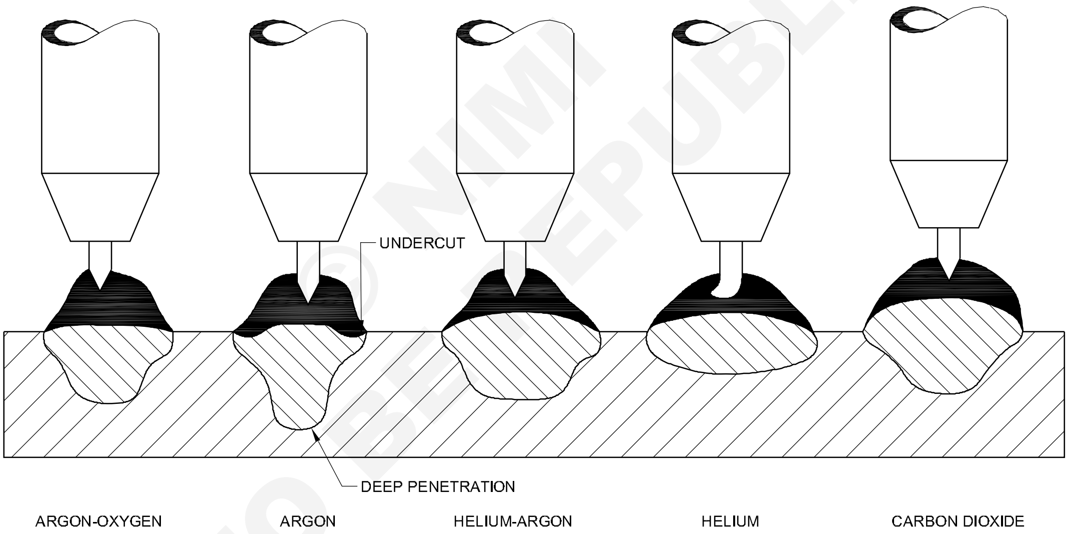
There are three types of shielding gases used for GMAW. They are inert gases, reactive gases and gas mixtures.

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 chosen 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).

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

Carbon dioxide: Carbon dioxide (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 carbon dioxide: 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 oxidase 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

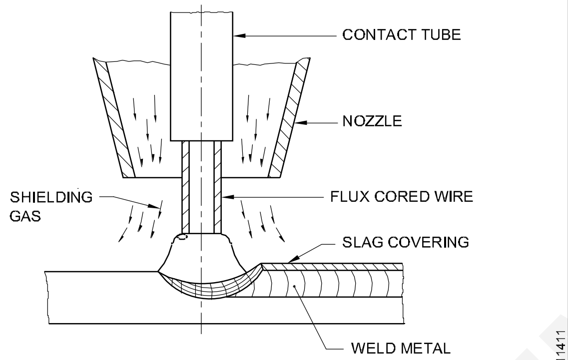
Metal	Shielding gas	Advantages
Aluminium	Argon 75% Helium 25% argon	0.1 in.(2.5mm) thick; best metal transfer and arc stability; least spatter 1-3 in.(25-76mm) thick; higher heat input than argon
Copper, nickel and alloys	Argon	Provide good wetting; good control of weld pool for thickness up to 1/8 in.(3.2mm)
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 Argon 2% oxygen	Good arc stability; produces a more fluid and controllable weld pool, good coalescence and bead contour, minimizes under cutting on heavier stainless steels 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 CO_2	Less than 1/8 in.(3.2mm) thick; high welding speeds without melt through; minimum distortion and spatter; good penetration 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

Flux cored arc welding (FCAW) - description, advantage, welding wires, coding as per AWS

Objectives: At the end of this lesson you shall be able to
- **explain the flux cored arc welding**
- **explain the type of metal transfer in flux cord Arc welding**

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.

Fig 1



FLUX CORED ARC WELDING

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.

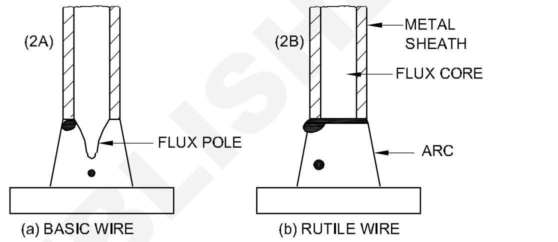
However, the self shielded type FCAW is mainly used for carbon steel welding and the quality of weld produced by this type is generally inferior to that of welds made with gas shielded type.

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

Advantages and disadvantages of flux cored arc welding (FCAW)

It has different ways of supplying shielding gas.

It may be applied to all welding position.

Shielding gas is not needed for some its wires are suitable in windy conditions.

It has high deposition rate.

Chances of porosity are very low.

Less cleaning of base metal.

Suitable for outdoor welding or shop welding.

Relatively easy to learn compared to other welding processes.

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 deoxygenates 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.

FCAW coding

AWS D1.1/D1.1M-Structural welding code, steel

AWS D1.3/D1.3M-Structural welding code, sheet steel

FCAW coding as per AWS

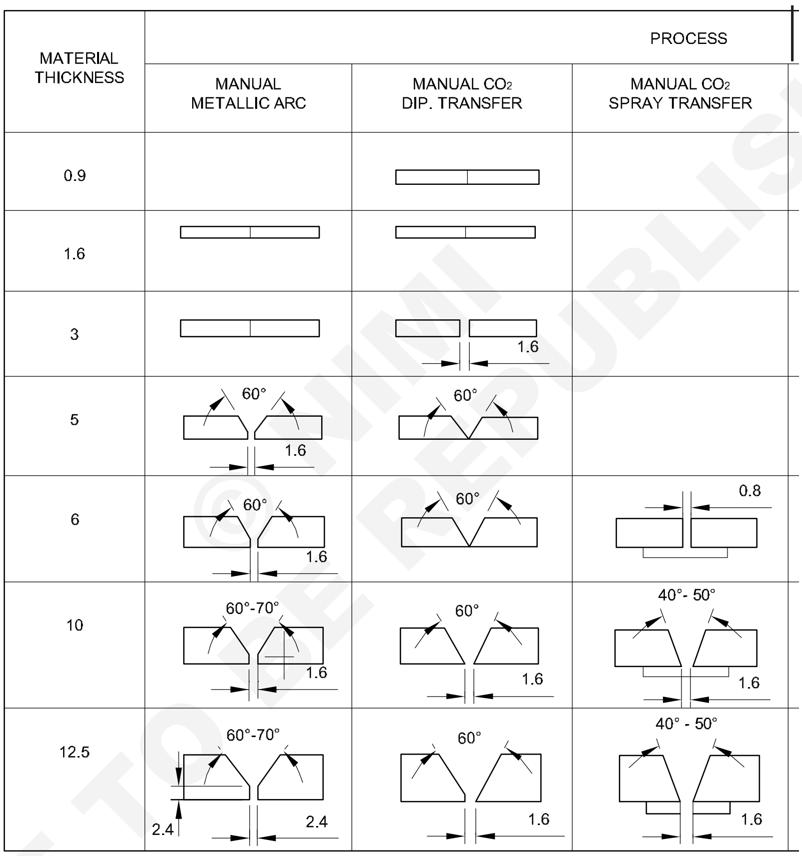
Number	Standard title
AWS B1.10	Guide for the nondestructive examination of welds
AWS B2.1	Specification for welding procedure and performance qualification
AWS D1.1	Structural welding (steel)
AWS D1.2	Structural welding (aluminium)

Edge preparation of various thickness of metals (GMAW)

Objectives: At the end of this lesson you shall be able to
- **state the edge preparation of GMAW**
- **describe the various types of welding process for required preparation.**

Base metal preparation: For GMAW/CO_2 welding the edges and the plate surfaces for welding of ferrous and non-ferrous metals are cleaned similar to Shielded Metal Arc Welding process. The groove angle for single V butt joint in case of CO_2 welding is 40^0 to 45^0 only when compared to 60^0 used for shielded metal arc welding (Fig 1). The edge preparation required for the various types of welding process.

Fig 1

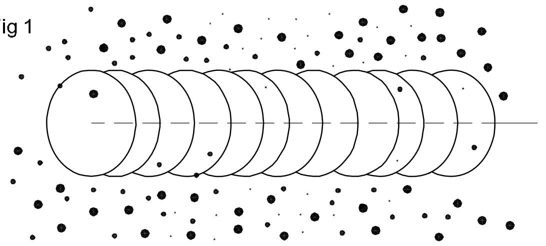


GMAW defects, causes and remedies

Objective: At the end of this lesson you shall be able to
- **explain the weld defect, causes and remedies.**

Excessive spatter

Fig 1

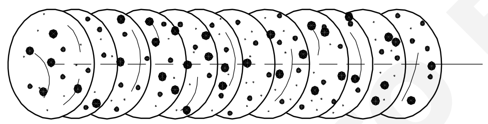


Excessive Spatter : scattering of molten metal particles that cool to solid form near weld bead.

Possible causes	Corrective actions
Wire feed speed too high.	Select lower wire feed speed.
Voltage too high.	Select lower voltage range.
Electrode extension (stick out) too long.	Use shorter electrode extension (stick out).
Workpiece dirty.	Remove all grease, oil, moisture, rust, paint, undercoating, and dirt from work surface before welding.
Insufficient shielding gas at welding arc.	Increase flow of shielding gas at regulator/flowmeter and/or prevent drafts near welding arc.
Dirty welding wire.	Use clean, dry welding wire.
	Eliminate pickup of oil or lubricant on welding wire from feeder or liner.

Porosity

Fig 2

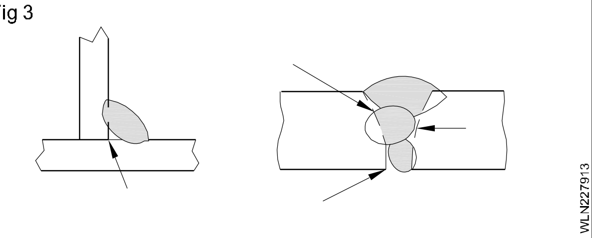


Porosity — small cavities or holes resulting from gas pockets in weld metal.

Possible causes	Corrective actions
Inadequate shielding gas coverage.	Check for proper gas flow rate.
	Remove spatter from gun nozzle.
	Check gas hoses for leaks.
	Eliminate drafts near welding arc.
	Hold gun near bead at end of weld until molten metal solidifies.
Wrong gas.	Use welding grade shielding gas; change to different gas.
Dirty welding wire.	Use clean, dry welding wire.
	Eliminate pick up of oil or lubricant on welding wire from feeder or liner.
Workpiece dirty.	Remove all grease, oil, moisture, rust, paint, coatings, and dirt from work surface before welding.
	Use a more highly deoxidizing welding wire.
Welding wire extends too far out of nozzle.	Be sure welding wire extends not more than (13 mm) beyond nozzle.

Incomplete fusion

Fig 3

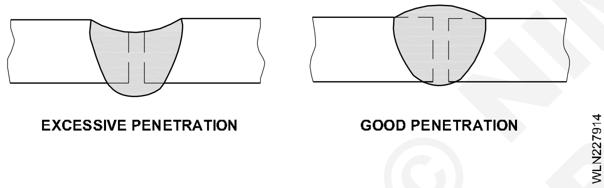


Incomplete Fusion — failure of weld metal to fuse completely with base metal or a preceeding weld bead.

Possible causes	Corrective actions
Workpiece dirty.	Remove all grease, oil, moisture, rust, paint, coatings, and dirt from work surface before welding.
Insufficient heat input.	Select higher voltage range and/or adjust wire feed speed.
Improper welding technique.	Place stringer bead in proper location(s) at joint during welding.
	Adjust work angle or widen groove to access bottom during welding.
	Momentarily hold arc on groove side walls when using weaving technique.
	Keep arc on leading edge of weld puddle.
	Use correct gun angle of 0 to 15 degrees.

Excessive penetration

Fig 4

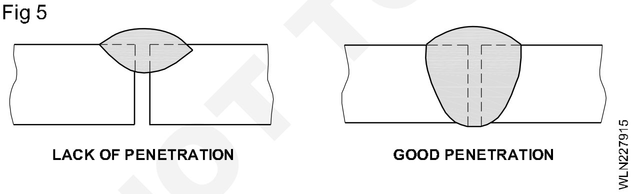


Excessive Penetration — weld metal melting through base metal and hanging underneath weld.

Possible causes	Corrective actions
Excessive heat input.	Select lower voltage range and reduce wire feed speed.
	Increase travel speed.

Lack of penetration

Fig 5



Lack of Penetration — shallow fusion between weld metal and base metal.

Possible causes	Corrective actions
Improper joint preparation.	Material too thick. Joint preparation and design must provide access to bottom of groove while maintaining proper welding wire extension and arc characteristics.
Improper weld technique.	Maintain normal gun angle of 0 to 15 degrees to achieve maximum penetration.
	Keep arc on leading edge of weld puddle.
	Be sure welding wire extends not more than (13 mm) beyond nozzle.
Insufficient heat input.	Select higher wire feed speed and/or select higher voltage range.
	Reduce travel speed.

Burn through

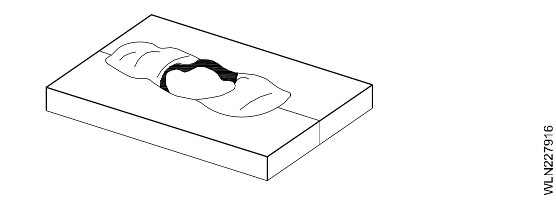


Fig 6

Burn-Through — weld metal melting completely through base metal resulting in holes where no metal remains.

Possible causes	Corrective actions
Excessive heat input.	Select lower voltage range and reduce wire feed speed. Increase and/or maintain steady travel speed.

Waviness of bead

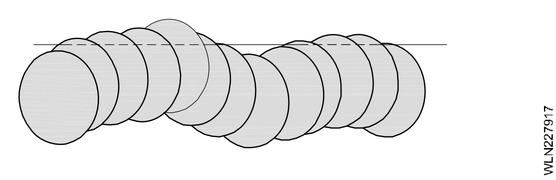


Fig 7

Waviness of Bead — weld metal that is not parallel and does not cover joint formed by base metal.

Possible causes	Corrective actions
Unsteady hand.	Support hand on solid surface or use two hands.

Distortion

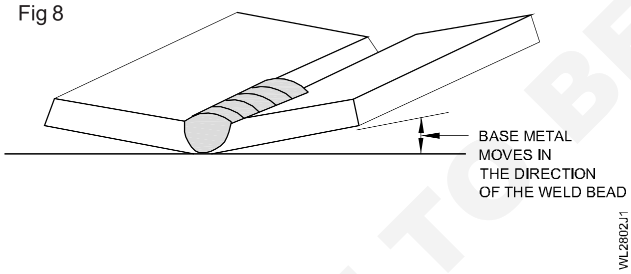


Fig 8

Distortion — contraction of weld metal during welding that forces base metal to move.

Possible causes	Corrective actions
Excessive heat input.	Use restraint (clamp) to hold base metal in position. Make tack welds along joint before starting welding operation. Select lower voltage range and/or reduce wire feed speed. Increase travel speed. Weld in small segments and allow cooling between welds.

Heat input and techniques of controlling heat input during welding

Objectives: At the end of this lesson you shall be able to
- **describe the heat input and controlling techniques**
- **state the heat affected zone.**

Weldments, preheating, heat affected zone, interpass temperature.

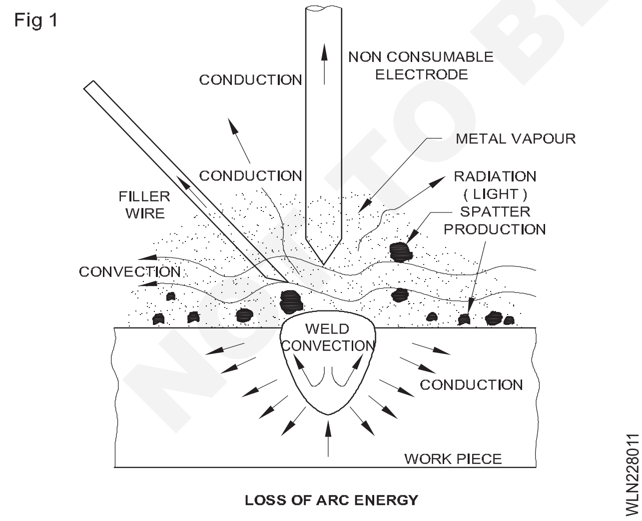
Introduction: During welding, the parent metal is heated to melting point and after that it is allowed to cool rapidly. The adjacent portion to the welded zone is also heated by to a lower temperature. This causes certain phase transformations and on rapid cooling, due to heat transfer through the colder portion of parent metal and atmosphere, the materials hardness and hence mechanical properties are also affected.

The width of parent metal that is affected due to the above cycle is called 'Heat Affected Zone'. It is quite clear that the hardness depends on rate of cooling. Higher the cooling higher will be the hardness. In order to control the cooling rate pre-heating and interpass temperature controls are adopted.

In order to relieve the welding induced stresses and to achieve better metallurgical structure to meet service conditions, post - weld heat treatment is followed.

Heat input: The energy supplied by the welding arc in a fusion welding process is called arc energy and is calculated from current voltage and welding speed. However all the arc energy is not utilized for welding; some of it is invariably lost. (Fig 1)

Fig 1



LOSS OF ARC ENERGY

The extent of energy loss varies with the welding process, welding parameters, type of material, preheat temperature etc. To account for the energy loss and estimate the actual energy given to the workpiece, a term known as heat input is employed.

The heat input of a single pass weld is calculated by multiplying the efficiency of the welding process and arc energy. Therefore heat input at best can serve as a rough guide to the amount of heat supplied to the workpiece.

Temperature changes in welding: Heat moves from one area to another whenever there is a difference in temperature. Just as water flows downhill, so that flows down the temperature hill, warning cold objects at the expense of warmer ones.

When the source is moved away, the heat in the weld is conducted outward into the plate. The temperature of the weld has fallen, while the plate temperature near the weld is rising.

The weld has cooled still further and the plate temperature is still rising. The metal reaches a maximum temperature less than the melting point of the weld metal, and cooling sets in.

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,

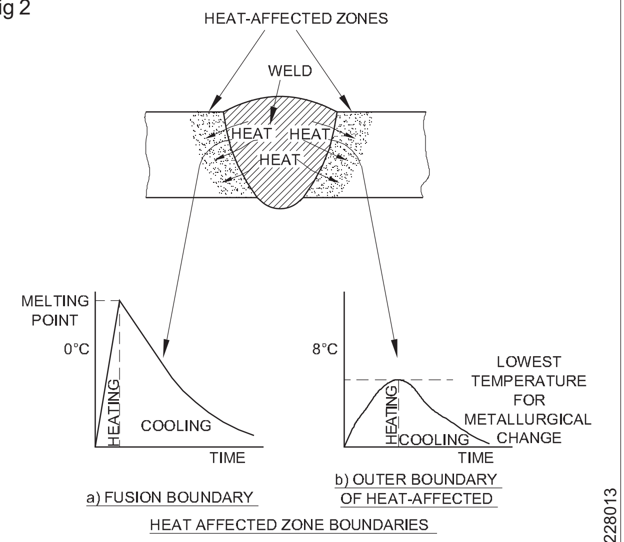
4 Heat affected zone which has not melted but is exposed to thermal cycles with temperature less than the solids temperature.

Each zone because of its characteristic micro structural features has different properties.

Heat affected zone 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. (Fig 2)

Fig 2



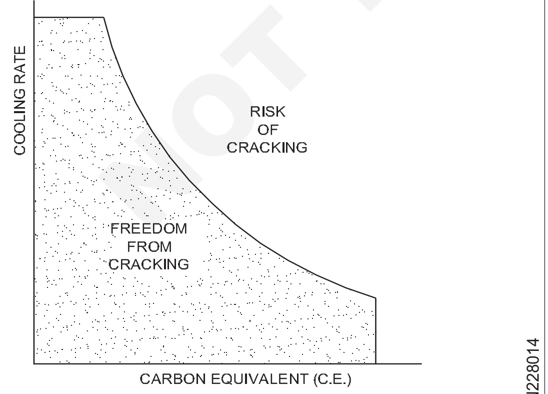
HEAT AFFECTED ZONE BOUNDARIES

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 marten site, cracks will usually develop the phenomenon called under bead 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 3. 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.

Fig 3



INTERACTION OF COOLING RATE AND CARBON EQUIVALENT

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 under bead cracking can easily 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.

Heat distribution and effects of faster cooling

Objective: At the end of this lesson you shall be able to
- **explain the necessity of heat distribution in welding.**

Heat input is increased with increasing wire feeding speed but increasing welding speed decreases the welding heat input. When heat input increases, the cooling rate decreases for weld metal and increases the volume fraction of tempered martan site and coarsening of the microstructure of weld zone.

The outcome of microstructural examination and mechanical tests should that fast cooling, immediately after submerged welding can reduce the width of heat affected and coarse grained zones, as well as improving the low temperature impact toughness.

Heat input is increased with increasing wire feeding speed but increasing welding speed decreases the welding heat input. When heat input increases, the cooling rates decreses for weld metal and increases the volume of fraction of tempered, marking and coarsening of the microstructure of weld zone.

Preheating and post heating treatment

Objective: At the end of this lesson you shall be able to
- **explain the purpose of preheat and post heating.**

Different methods of pre heating treatment

Direct preheating, Indirect preheating, Local preheating

Preheating and its purpose: Preheating means heating a joint to be welded before or during welding to a certain temperature as shown in tables 1 and 2.

Table 1

Preheating of various metals

Metal	Temperature °C
Nickel alloys (wrought)	Warm it below 16°
Nickel alloys (cast)	90° - 200°
Copper and copper alloys	200° maximum
Silicon bronze	90°
Brass low zinc	200° - 260°
Brass high zinc	260° - 370°
Phosphor bronze	150° - 200°

The preheating reduces the rate of cooling after welding. This is necessary to prevent the weld metal from cracking in restrained/rigid joints. Also some of the non-ferrous metals like copper, brass, aluminium, etc. expand more due to heating and ferrous metals like cast iron, medium and high carbon steels require preheating as they are too brittle. These materials are necessarily to be preheated to avoid cracking or distortion. In some cases, it is also necessary to preheat during welding between each layer of deposition.

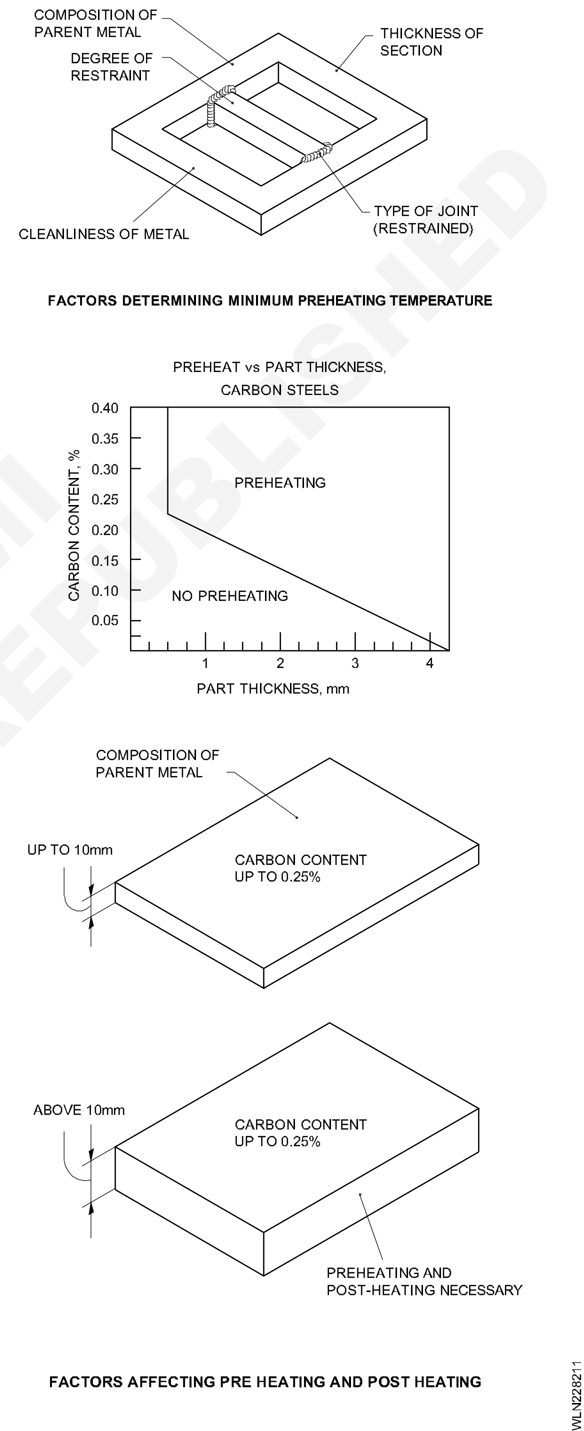
The minimum preheating temperature for satisfactory welds of different grades of steel, cast iron, non-ferrous metals will depend upon the: (Fig 1)

- type of metal
- composition and properties of the parent metal
- thickness of the plate
- type of joint
- degree of restraint of the joint
- rate of heat input.

> **Do not allow the temperature to drop below the minimum preheating temperature between each weld run.**

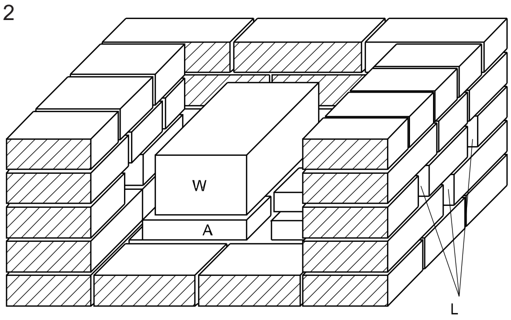
The preheating temperature can be checked by temperature indicating crayons.

Fig 1



If the job and area to be preheated are large, then it is done in a preheating furnace (Fig 2).

Fig 2



A - SUPPORTING BRICKS, W - WELDED JOB, L - AIR VENTS

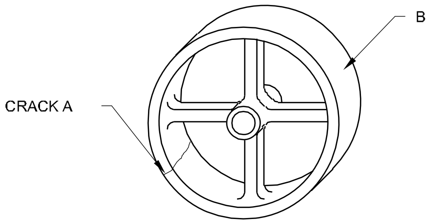
TEMPORARY BRICK FURNACE FOR REPAIR WORK

WLN228213

If it is small localised preheating is applied to the joint area only. This is called local preheating. (Fig 3)

Fig 3

IF THE FRACTURE IN THE WHEEL AT "A" IS TO BE REPAIRED, THE PREHEATING FLAMES SHOULD BE APPLIED AT "B" TO AVOID CRACKING.



TECHNIQUE OF LOCAL PREHEATING

WLN228214

Post heating: Post heating means that the part is heated immediately after welding. The reasons for post heating are to prevent hard and brittle spots from forming in the weldment. It also relieves the residual stresses caused by the welding heat and due to welding of a rigid joint.

The important aspects to be considered while post–heating are:

– the rate of heating

– temperature to which the part is to be post-heated

– holding time in the furnace

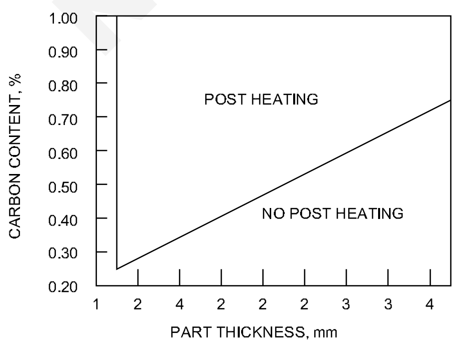
– the rate of cooling.

Post heating of carbon steels depends on the thickness of the base metal and its carbon content. (Fig 4)

Fig 4

NEED FOR POSTHEAT vs PART THICKNESS

CARBON STEELS



WLN228215

Post heating retards the rate of cooling of a welded joint.

For plain carbon steels the joint is heated from 100°C to 300° C for general post heating. This treatment will reduce the cracking tendency of carbon steel and cast iron. If they are not post heated, cracks may develop.

Also the welding heat can develop hardness and brittleness in some areas of the joint. In addition the grains of the base metal in the heat affected zone and fusion zone will grow in size which will change the property of the welded joint.

In the case of joints which are not free to expand i.e., restrained joints and in joints in which there is a stress already present before welding, the residual stresses will be more after cooling of the joint. If these residual stresses are not removed after welding, then the joint will fail or distort when they are put into use or the joint is machined or the joint is subjected to dynamic loading.

To avoid the above problems a welded job is usually either normalised or annealed or stress-relieved.

Pre-heat treatment and post weld heat treatment

Heat treatments: Heat treatments are used to obtain certain desired properties. Essentially, heat-treating metals consists of heating and cooling it after it has reached the solid state. There are a number of different methods of heat treatment for various steels in today's industry.

Normalising: Normalising is very similar to annealing except that the steel is held above the critical temperature very briefly and the cooling takes place in air at normal temperature. Normalising will result in refining the grain structure of a metal. It is sometimes used after quenching.

Annealing: Annealing involves heating of metal to a temperature above the critical point and allowing it to cool slowly. The purpose of annealing may be to accomplish one or more of the following.

– To soften the metal, e.g. to improve machinability.

– To relieve internal residual stresses.

– To refine the grains.

– To improve ductility.

– Homogenizing to reduce.

Hardening: Hardening increases the strength of the pieces after they are fabricated. It is accomplished by heating the steel to a temperature above the critical point, and then cooling it rapidly in oil, water or lime. Only medium, high and very high carbon steels can be hardened by this method. The temperature at which the steel must be heated varies with the steel used.

Case hardening: It is the process of hardening the outer surface of steel. It is done by inducing additional carbon into the case of the steel. This is done in a number of different ways all of which require heating to a high temperature and rapid cooling.

Some of the methods employed are:

- to pack the steel part in a sealed metal box which contains some carbonizing material
- to immerse the steel part in a molten cyanide salt bath
- to dip the heated steel part in a container having powdered cyanide
- to heat the steel part and pass carbonizing gas over it
- to employ manual or machine-controlled oxy-acetylene flame process.

Tempering: Tempering (grain refining) is used to relieve some of the brittleness which occurs after a piece of steel has been fully hardened, and to make the steel tough.

It is accomplished by reheating the hardened metal to a specified temperature, depending upon the hardness to be removed, and then quenching.

Quenching: Quenching is the rapid cooling of a metal usually done by immersing it in oil or water. This will cause certain changes in the structure of the metal. For example, carbon steel that is quenched will form a marten site structure.

Stress relieving: Stress relieving is a means of removing the internal stresses which develop during the welding operation.

This process consists of heating the structure to a temperature below the critical range (approximately 590°C) and allowing it to cool slowly. Another method of relieving stresses is peening (hammering). However, peening must be undertaken with considerable care because there is always the danger of weakening the physical strength of the metal.

Stress relieving should be done only if there is a possibility that the structure will crack upon cooling and no other means can be used to eliminate the expansion and contraction forces.

Importance of preheating and post heating

When welding some base materials and for some service conditions, preheating and/or post weld het treatment may be a requirement. These types of thermal treatments are generally required in order to ensure suitable weld integrity and will typically prevent or remove undesirable characteristics in the competed weld.

Preheating

Preheat, as define within the AWS standard welding terms and definition, is the heat applied to the base metal or substrate to attain and maintain preheat temperature.

Preheating may be performed by the use of burners, oxy-gas flames, electric blankets, induction heating, or by heating in a furnace.

The purpose of preheat:

1 Reduce the risk of hydrogen cracking

2 Reduce the hardness of the weld heat affected zone

3 Reduce shrinkage stresses during cooling and improve the distribution of residual stresses.

If preheat is locally applied it must extend to at least 75mm from the weld location and be preferably measured on the opposite face to the one being welded.

Industries that commonly require the benefits of preheat treatment in both shop and field applications are oil and gas, power plants, structural fabrication, transmission pipelines and ship building among others.

Post heat

A low temperature heat treatment carried out immediately on completion of welding by increasing the preheat by some 100°C and maintaining this temperature for 3 or 4 hours. This assists the diffusion of any hydrogen in the weld or heat affected zones out of the joint and reduces the risk of hydrogen induced cold cracking. It is used only on ferritic steels, where hydrogen cold cracking is a major concern i.e. very crack sensitive steels, very thick joints etc.

1 to achieve dimensional stability in order to maintain tolerances during machining operations or during shake-down in service

2 to produce specific metallurgical structures in order to achieve the required mechanical properties

3 to reduce the risk of in-service problems such as stress corrosion or brittle fracture by reducing the residual stress in the welded component

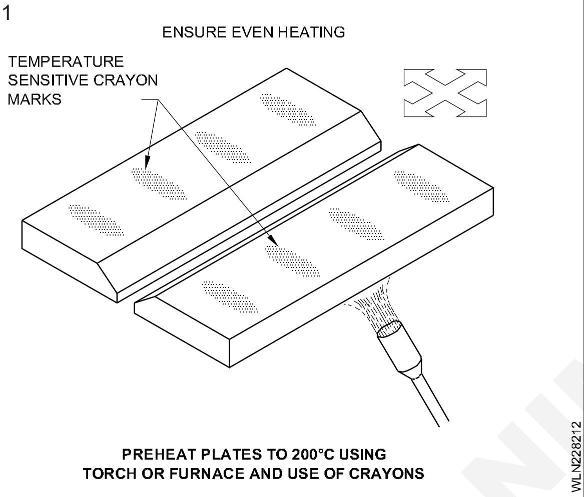
Use of temperature indicating crayons

Objective: At the end of this lesson you shall be able to
- **explain the use of temperature indicating crayons.**

Use of temperature indicating crayons

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 1

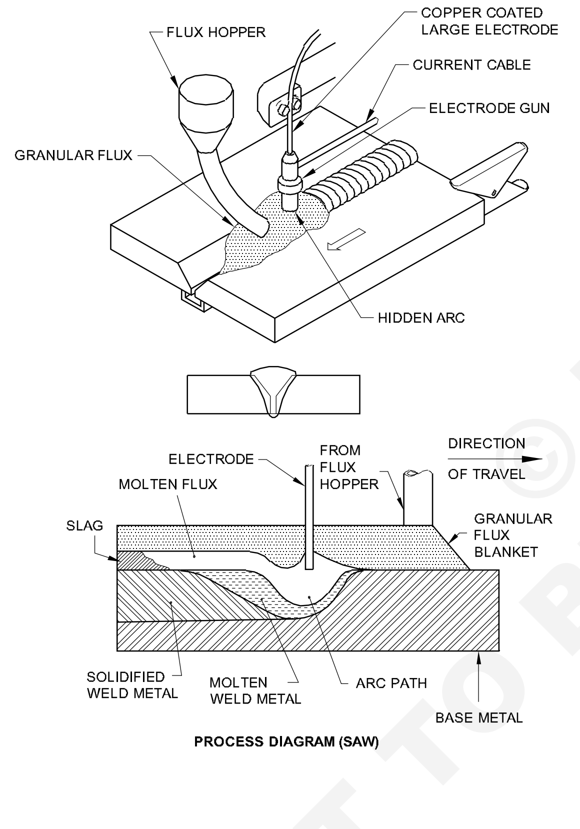


Submerged arc welding process principles equipment advantage and limitations

Objectives: At the end of this lesson you shall be able to
- **explain the principles and applications of submerged arc welding**
- **describe the welding procedure of the SAW processes**
- **state the advantages and limitations of submerged arc welding.**

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



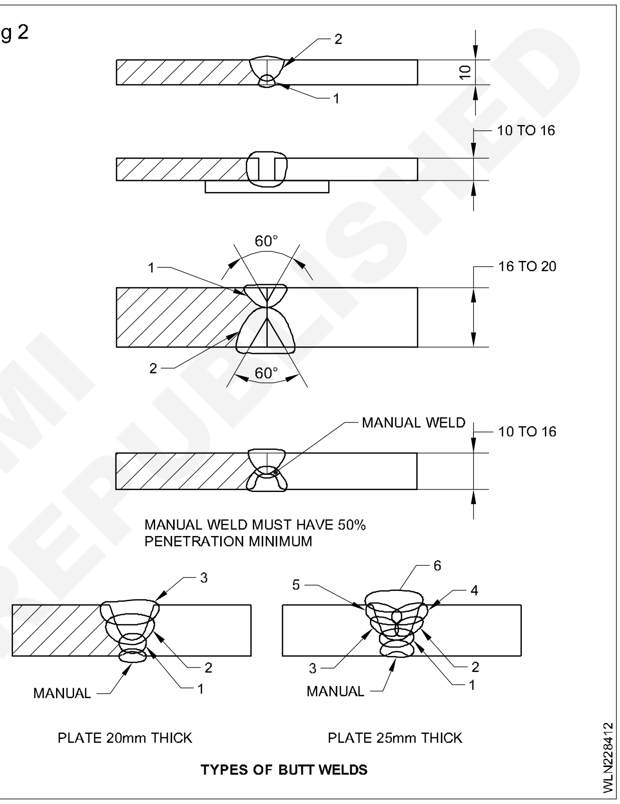
Metals which can be welded by SAW: In submerged arc welding, low and medium carbon steels, low alloy steels, high strength steels, quenched and tempered steel and stainless steel can be welded.

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

Edge preparation in SAW process: The edge preparation for Butt welds are as shown in Fig.2.

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 beveled by 45^0 and the joint is welded without a root gap.

Types of submerged arc welding process

There are two types of SAW.

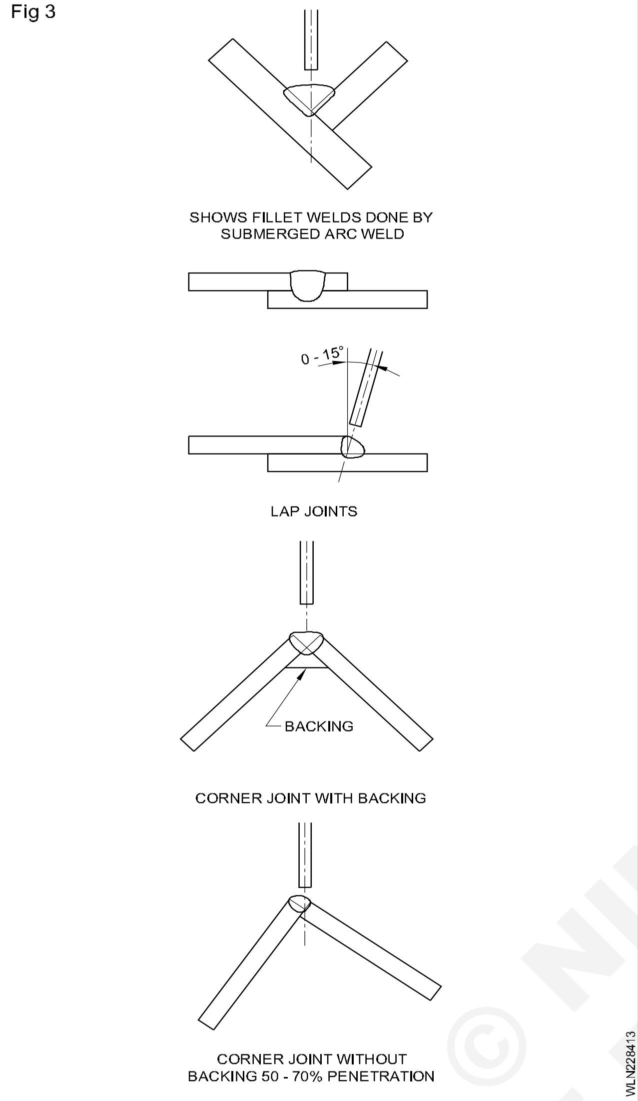
– Automatic

– Semi-automatic

Automatic SAW: In this type the arc voltage, arc length, speed of travel and electrode feed are automatically controlled.

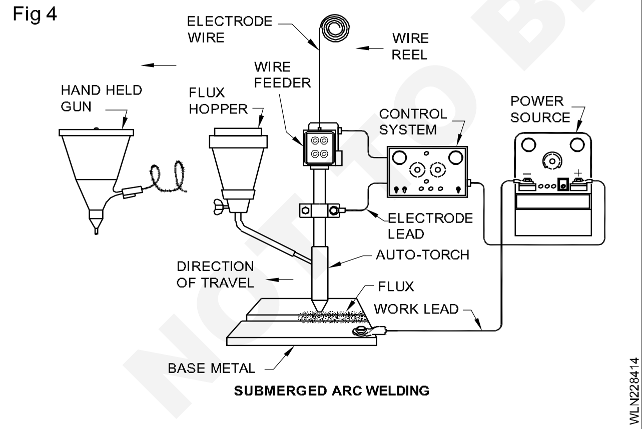
Semi-automatic SAW: The arc length, flux feeding and electrode feed are automatic but the speed of travel is controlled by the operator.

Fig 3



Parts of a SAW machine and their functions (Fig 4)

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.

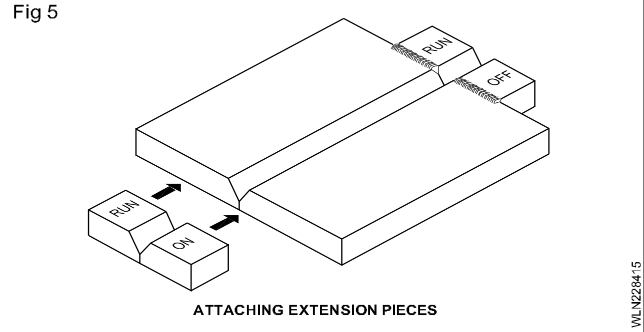
Adjust the voltage, the current and the welding speed as indicated in Table 1 and 2.

Start welding by striking an arc beneath the flux on the work.

The entire welding zone is buried under a blanket of flux and longitudinally 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)

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

Limitations: The submerged arc welding process is limited to flat position and horizontal fillet position.

Thermit welding process, types, principles, equipments thermit mixture types & application

Objectives: At the end of this lesson you shall be able to
- **state the principle of thermite welding process**
- **describe the parts of thermite welding equipment**
- **explain the sequence of operation thermite welding**
- **state the application of thermite welding.**

Thermit welding: Thermite is a trade name for a mixture of finely divided metal oxide (usually iron oxide) and a metal reducing agent. (almost always aluminum). The thermit mixture may consist of about five parts of aluminium and eight parts of iron oxide, and the weight of thermit used will depend on the size of the parts of to be welded. The ignition powder usually consists of powdered magnesium or a mixture of Aluminum and Barium Peroxide.

Principle of thermit welding; The heat necessary for joining in the thermit welding process is obtained from a chemical reaction that takes place between a metal oxide (Iron oxide) and a metal reducing agent. (Aluminum) When ignited by using a burning magnesium ribbon in one spot of thermit mixture. The reaction spreads throughout the mixture. The tremendous heat released approximately 2760°C (5000°F) causes the iron to change to a liquid state within 25 to 30 seconds. As the aluminium in the mixture combines with the oxygen from the iron oxide, it forms Alumina oxide, which serves as slag and float to the top. Thermit reaction is an exothermic process. There are two types of Thermit Welding:

1 Plastic or Pressure Thermit Welding
2 Fusion of Non-pressure Thermit Welding

Equipments, materials and supplies

The thermit welding processs requires an adequate supply of

1 Thermit mixture
2 Thermit Ignition powder and a
3 Device (Flint Gun, Hot Iron Rod etc…)

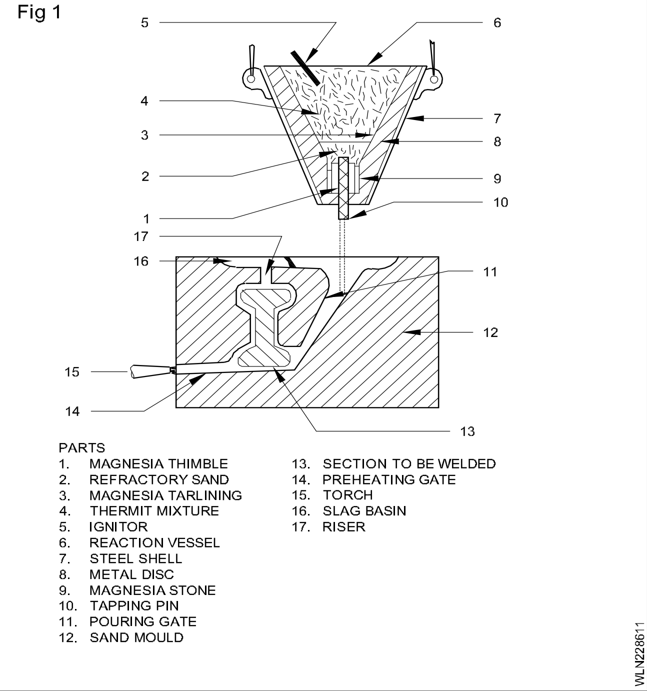
Thermit mixture

The most commonly used types of thermit for welding the various ferrous metals are:

1 Plain Thermit
2 MS Thermit or Forging Thermit
3 Cast Iron Thermit
4 Steel Mill Wabblers
5 Rail welding Thermit
6 Thermit for welding electric connections

Thermit welding procedure: The ends are to be welded are thoroughly cleaned of scale and rust. After cleaning, the parts to be welded are to be lined up with a gap of 1.5 to 6mm depending upon the size of parts. The next stage is making wax pattern of the weld. A refractory sand mould is rammed up around the wax joint and necessary gates and risers provided. Ramming should be light between the moulding sand and the wax. When ramming is completed, the pattern may be drawn and loose sand may be wiped out. Then, the heat is given to the wax pattern through the heating gate to melt and burn out wax. The heating is continued until the ends to be welded are at a red heat. This prevents the thermite steel being chilled, as it would be if it came into contact with cold metal. The preheating gate is now sealed off with sand. Now, charge the thermite in the crucible. The approximate weight of thermit is 12 to 14 kgs against one kg. of wax. The outside shell of crucible is made by steel and is lined with manganese tar lining. The thimble is inserted in the stone which provides a channel through which the molten metal is poured for each reaction a new thimble is used. The thimble is plugged by suspending the tapping pin and placing a metal disc above pin. The metal disc is lined with refractory sand. At the top of the thermite, low ignition temperature thermite is placed in the crucible. When ignited in one spot of thermite mixture, the reaction spreads throughout the mixture. The intense heat of thermite melts the preheated ends of the parts to be welded and the fusion welding takes place. Then the mould is allowed to cool overnight. The gates and risers with a cutting torch and finish the weld. (Fig 1)

Fig 1



Application: Thermit welding is mainly used in rail welding, concrete reinforcement rod welding, building up of steel mill wobbler ends and for electrical connections.

Use of backing strips and backing bars

Objectives: At the end of this lesson you shall be able to
- **understand the principle of backing strips and backing bars.**
- **state the use of backing strips and bars**

Definition

While welding the product supported and control the distortion of the concened jobs/product. To minimise the distortion and contraction we can use backing strips and backing bars.

The following sketches are to be used.

Fig 1

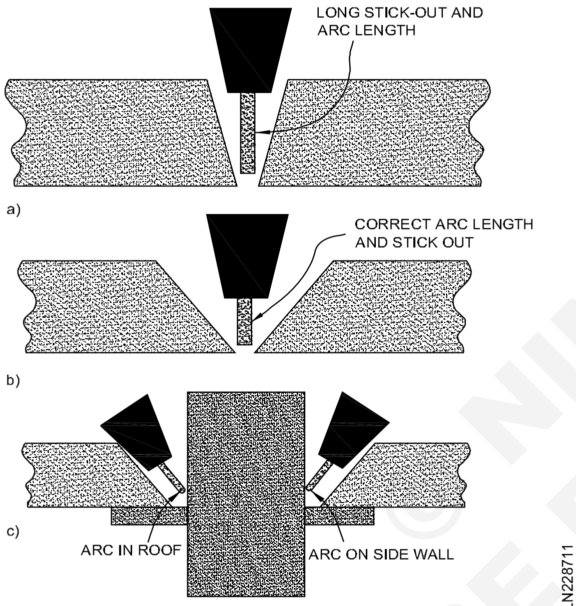
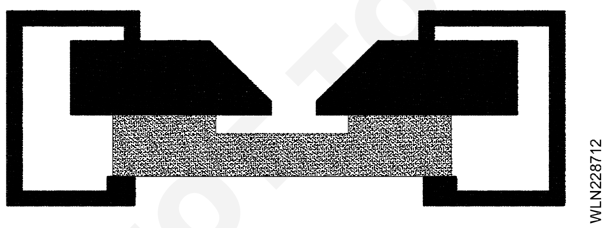


Fig 2



The temperature and fast cooling is applied on fully heat treated samples.

The microstructure results due to cooling at the maximum holding temperature as well as independent of the applied pressure value.

The effect of heat treatment and cooling rate on the properties of fast cooling from the upper limit and preside destruction do not change significantly throughout the sample sarees.

In the experiments the effect of fast and slow cooling the bathing prior to heating these was a heat distribution of intervals.

Fig 3

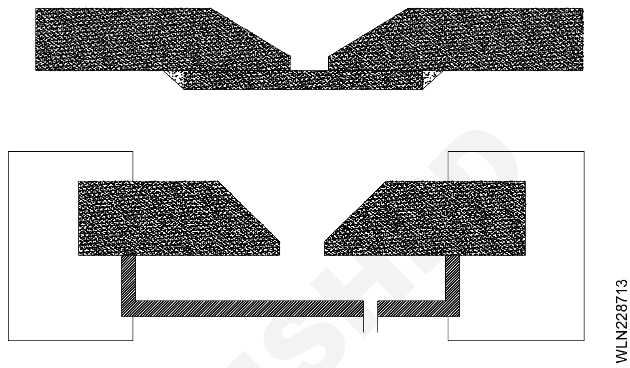
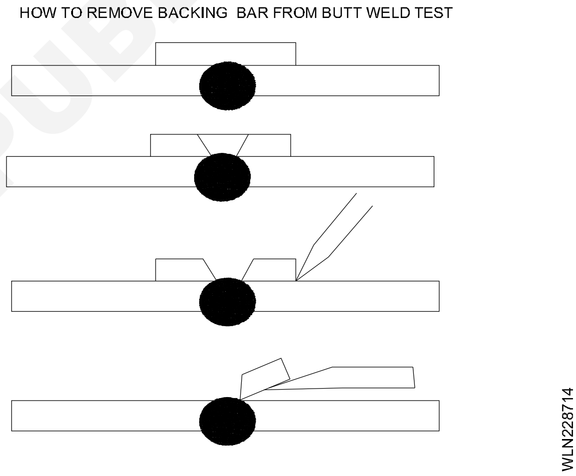


Fig 4



Use of backing strips and bars

A piece of metal, asbestos, or other nonflammable material placed behind a joint to facilitate welding. Also known as backing.

Non-Fusible Backing Copper backing is a frequently used non-fusible backing in the welding of steel. It is used when the base metal does not have sufficient mass to provide adequate weld metal support, or when complete weld penetration must be obtained in one pass.

A material or device placed against the back side of the joint adjacent to the joint root, or at both sides of a joint in electro slag and electro gas welding, to support and shield molten weld metal.

Why are backing tape used on some joints? Increase penetration and prevent burn through.

Fig 5

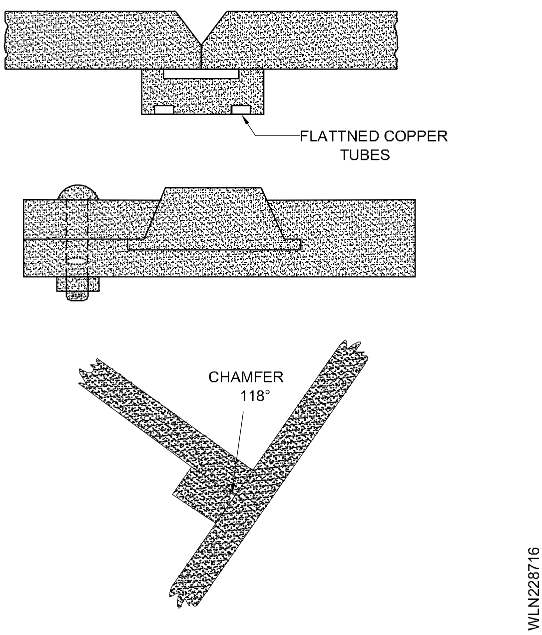


Fig 6

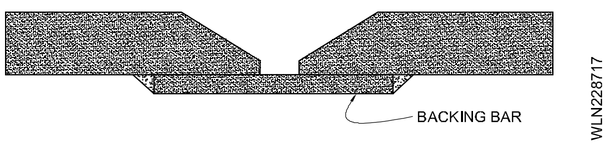
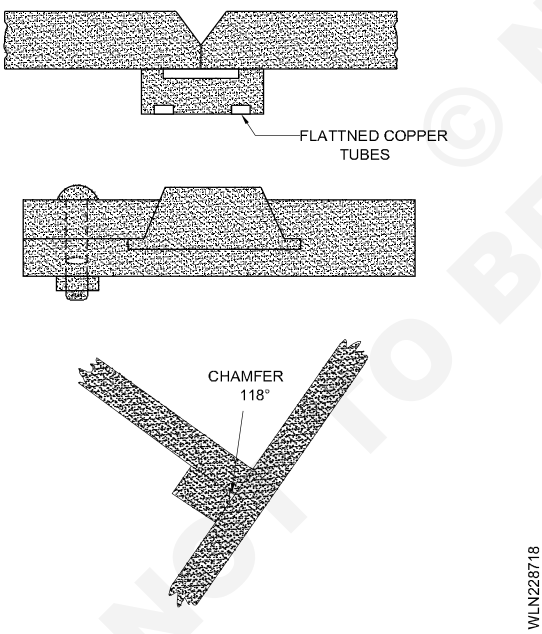
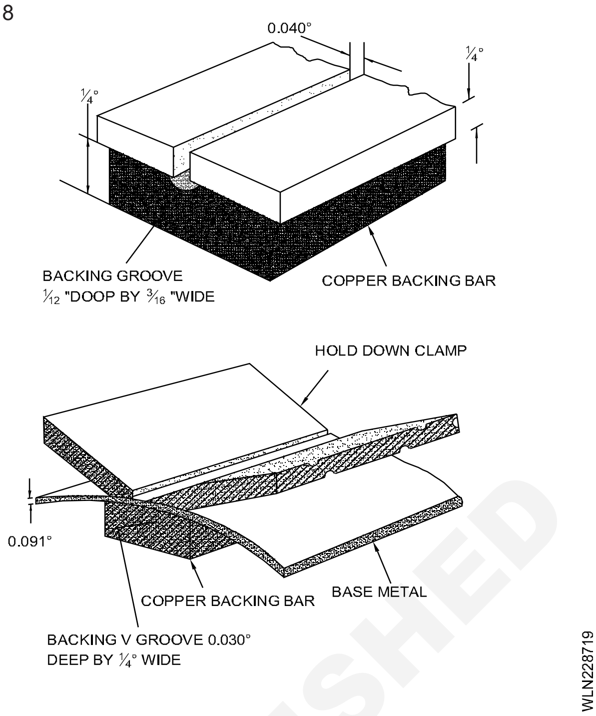


Fig 7



The use of ceramic backing strips enables welding to be carried out from a single side, with full penetration and reduces (and often removes) the need to grind out and re-weld a root from the reverse side. The strips are available in a range of configurations for differing applications and resulting weld bead shapes.

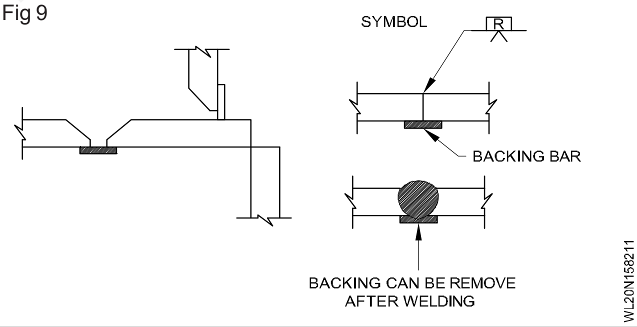
Fig 8



The purpose of the backing bar or strip is to support the root pass where conditions make the control of the bead difficult. Conventionally, a backing bar is temporary and can be lifted away as soon as the weld had been completed, and a backing strip is a permanent part of then joint.

A backing (strip) is a piece of metal that is placed on the backside of a weld joint to prevent the molten metal from dripping through the open root (burn through). It helps to ensure that 100% of the base metal's thickness is fused by the weld (full penetration).

Fig 9



GTAW process brief description - difference between AC/DC welding - equipment polarities and application

Objectives: At the end of this lesson you shall be able to
- **state the principle of GTAW process**
- **explain the difference between AC/DC welding equipment & polarities**
- **state the advantages and disadvantages of GTAW**
- **state the application of GTAW process.**

Various other name of the process (Tig)

History of Gas Tungsten Arc Welding (GTAW)

GTAW welding was, like GMAW developed during 1940 at the start of the Second World War.

GMAW's development came about to help in the welding of difficult types of material, eg aluminium and magnesium. The use of GMAW today has spread to a variety of metals like stainless mild and high tensile steels.

GTAW is most commonly called TIG (Tungsten Inert Gas welding).

The development of TIG welding has added a lot in the ability to make products, that before the 1940's were only thought of.

Like other forms of welding, TIG power sources have, over the years, gone from basic transformer types to the highly electronic power source of the world today.

Overview

TIG welding is a welding process that uses a power source, a shielding gas and a TIG torches. The power is fed out of the power source, down the TIG torches and is delivered to a tungsten electrode which is fitted into the torches. An electric arc is then created between the tungsten electrode and the workpiece. The tungsten and the welding zone is protected from the surrounding air by a gas shield (inert gas). The electric arc can produce temperatures of up to 3000^0Fand this heat can be very focused local heat.

The weld pool can be used to join the base metal with or without filler material.

The TIG process has the advantages of -

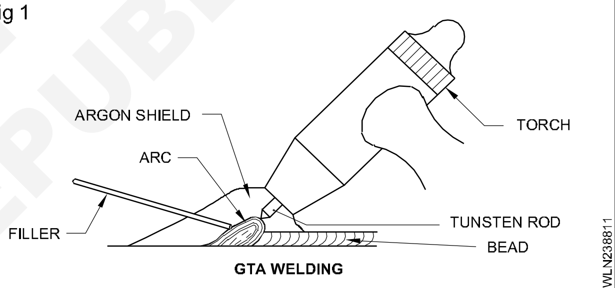
1 Narrow concentrated arc
2 Able to weld ferrous and non-ferrous metals
3 Does not use flux or leave a slag
4 Uses a shielding gas to protect the weld pool and tungsten
5 A TIG weld should no spatter
6 TIG produces no fumes but can produce ozone

The TIG process is a highly controllable process that leaves a clean weld which usually needs little or no finishing. TIG welding can be used for both manual and automatic operations.

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 non consumable 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 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.

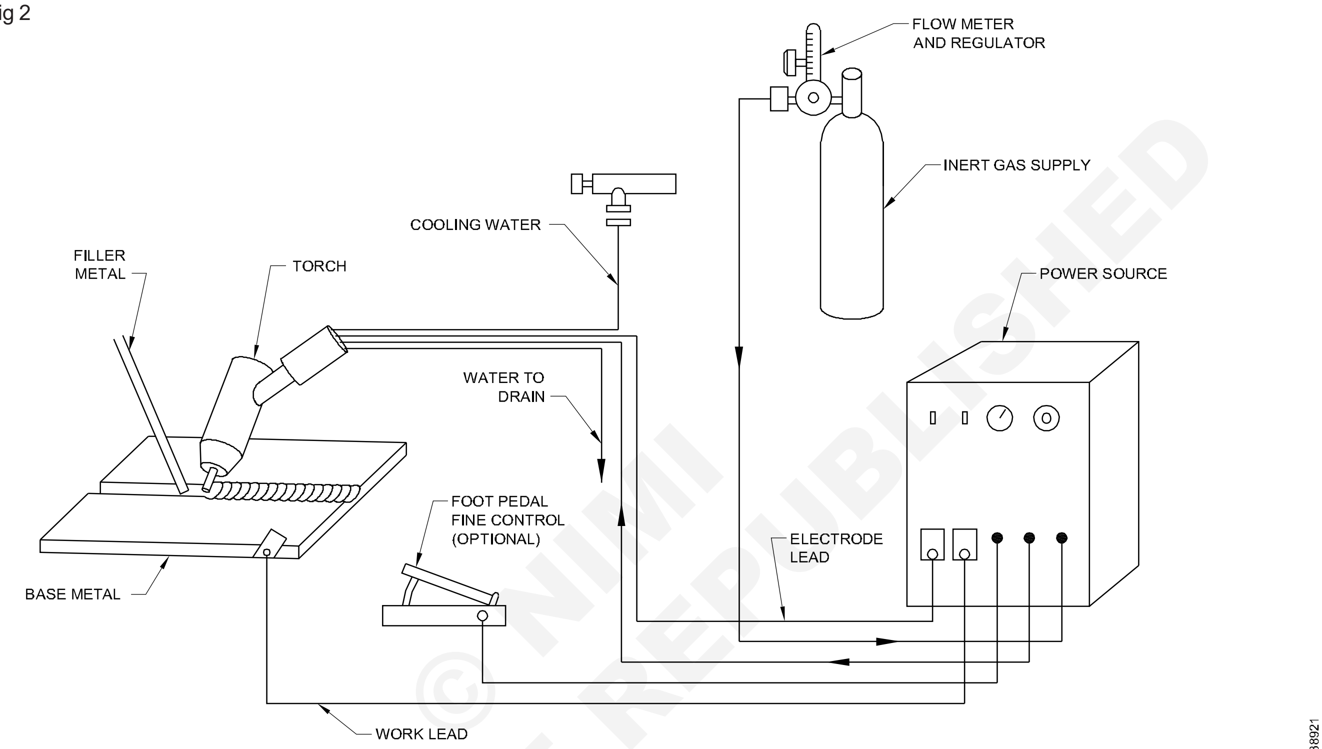
Parameter	DC Arc Welding	AC Arc Welding
Power Consumption	The power consumption by the DC arc welding is high.	Power consumed by the AC arc welding is lower than that of DC arc welding.
Efficiency	The efficiency of DC arc welding . is low	The AC arc welding is more efficient than DC arc welding.
Cost	The cost of DC arc welding is high.	The AC arc welding is less costly than DC arc welding
Arc Stability	The DC arc welding produces a stable arc.	The arc produced by the AC arc welding is unstable.
Weight	The welding set required for DC arc welding is heavy.	The welding set of AC arc welding is light weight.
Operation	The operation of DC arc welding is noisy.	The operation of AC arc welding is noiseless.
Electrode Used	In DC arc welding, all types of electrodes, i.e. bare and coated electrodes can be used because the polarity of the supply can be changed suit the electrode.	In AC arc welding, only coated electrodes can be used. It is because the current constantly reverses with every cycle.
Welding of thin sections	DC arc welding is preferred for welding of thin sections.	AC arc welding is generally not preferred for welding of thin sections.
Polarity	In case of DC arc welding, the electrode is always negative and the job is positive.	In AC arc welding, the electrode can act as anode while job acts as cathode and vice-versa.
Machinery	The DC generator used in DC arc welding has rotating parts and hence it is more complicated.	The transformer used in AC arc welding has no moving parts and is simpler.
Capital & Maintenance Cost	The cost of DC generator is high and its maintenance cost is also high.	The cost of AC transformer is low. Also its maintenance cost is low.
Arc Blow	In DC arc welding, the problem of arc . blow is severe and cannot be controlled easily	The problem of arc blow does not arises in case of AC arc welding

GTAW process and equipment

TIG welding equipment (Fig 2)

- 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 2



A DIAGRAMMATIC DRAWING OF A COMPLETE GAS TUNGSTEN ARC WELDING

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.

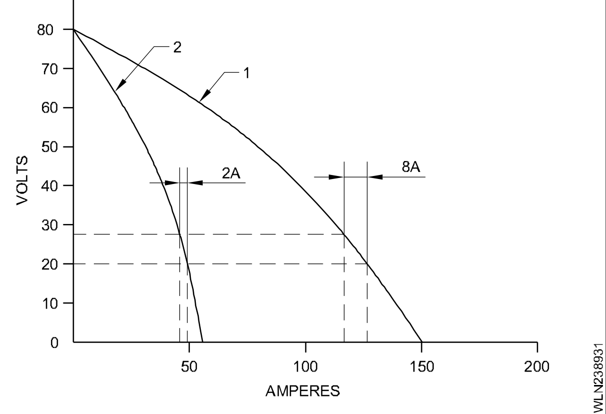
The one thing that all TIGs have in common is that they are CC (Constant Current) type power sources. This means only output adjustment will control the power source amps. The voltage will be up or down depending on the resistance of the welding arc.

Characteristics of power force :The output slope or volt ampere 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 3).

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 3

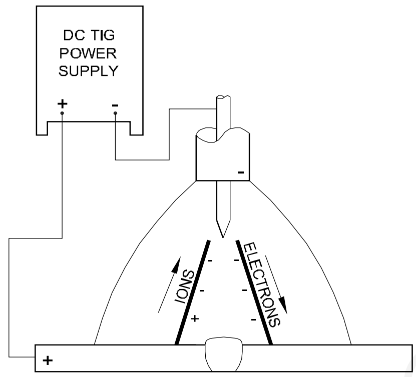


Types of welding current used for GTAW

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 stabilization. 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 4): (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.

Fig 4

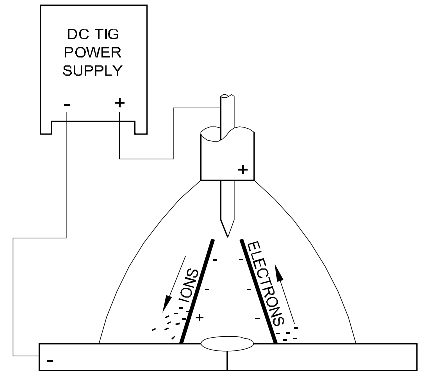


Current type	DCSP
Electrode Polarity	Electrode Negative
Oxide Cleaning Action	No
Heat Balance in the Arc	70% at work end 30% at electrode end
Penetration Profile	Deep, narrow
Electrode Capacity	Excellent

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

DCRP - Direct Current Reverse Polarity (Fig 5): (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 over heat and burn away. DCRP produces a shallow, wide profile and is mainly used on very light material at low amps.

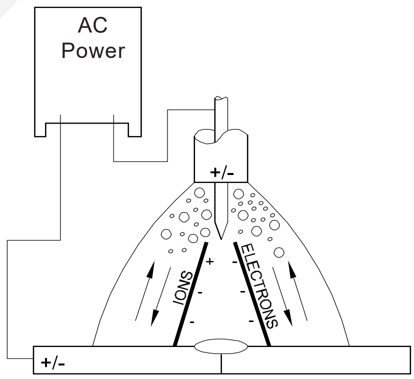
Fig 5



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

AC - Alternating Current (Fig 6) 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.

Fig 6



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.

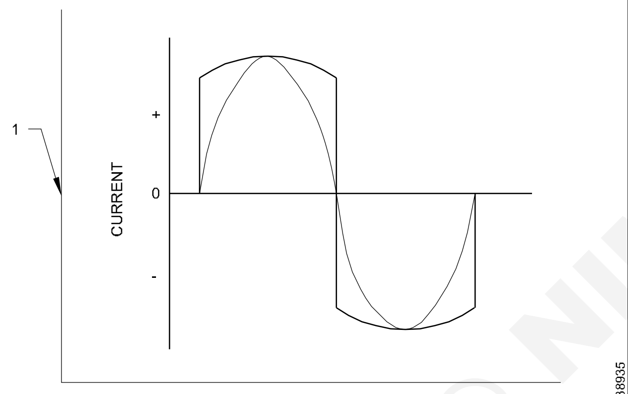
HF is also often used for starting the welding arc initially without the tungsten touching the workpiece. This helps on materials that are sensitive to impurities. HF start can also be used on DC welding current to initially start the welding current without the tungsten touching the workpiece.

AC - Alternating Current - Square Wave (Fig 7)

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.

Fig 7



1. SQUAREWAVE IMPOSED OVER SINE WAVE

Extended Balance Control (Fig 8,9 & 10)

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 8

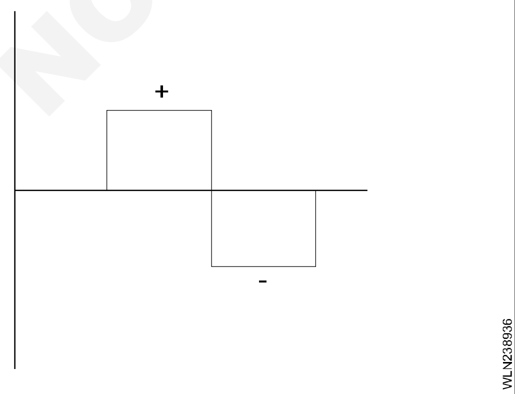


Fig 9

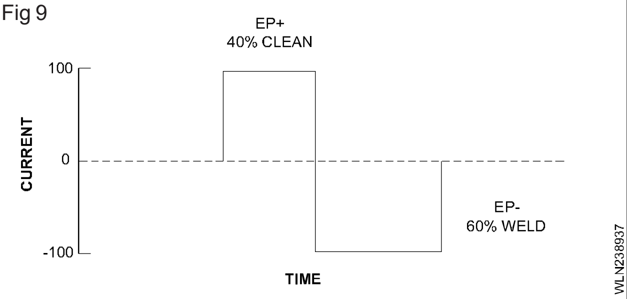
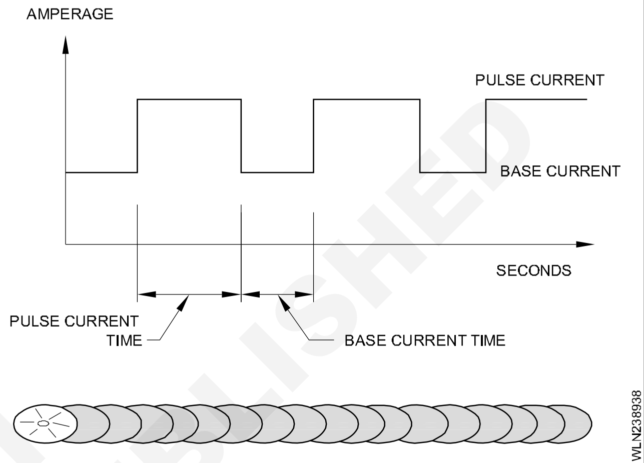


Fig 10



Pulsed TIG (Fig 11s)

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.

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.

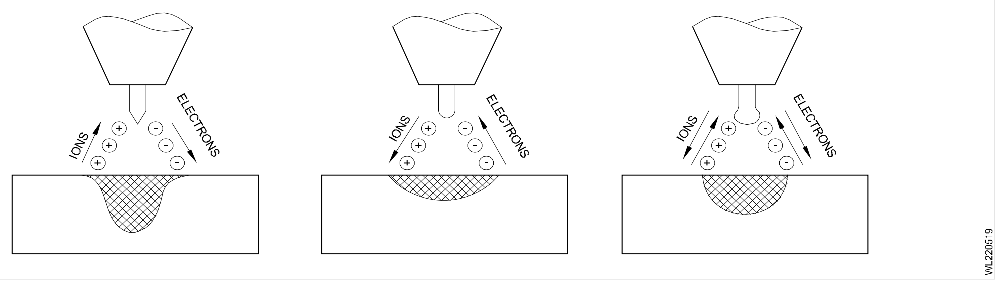
Background current - This is set lower than peak current and is the bottom current the pulse will drop to, but must be enough to keep the arc alive.

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 larger or smaller extent depending on the welding speed.

Current Type	DCEN	DCEP	AC (Balanced)
Electrode Polarity	Negative	Positive	
Electron and ion flow Penetration Characteristics	Fig 11 		
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

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 them positive and the negative semi-periods.

Application of GTAW

The TIG welding process is so good that it is wisely used in the so-called high-tech industry applications such as

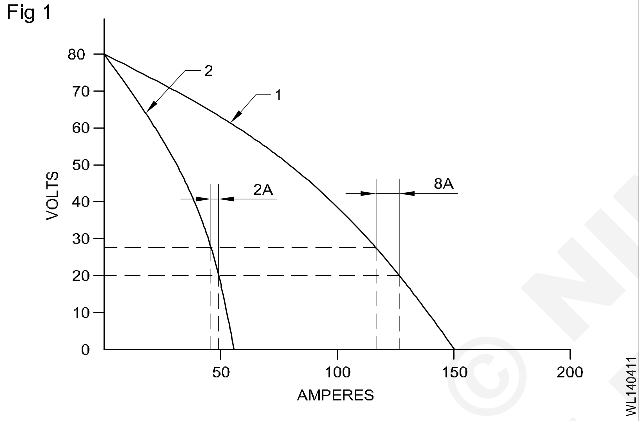
1 Nuclear industry
2 Aircraft
3 Food industry
4 Maintenance and repair work
5 Some manufacturing areas
6 The off shore industry
7 Combined heat and power plants
8 Petro chemical industry.
9 Chemical industry.

Power sources for GTAW AC/DC

Objectives: At the end of this lesson you shall be able to
- **state the different types of power sources used in GTAW**
- **state the applications of different power sources**
- **state the care and maintenance of TIG welding machine.**

Power sources for GTAW: The power source for gas tungsten arc welding (GTAW) can be an alternating current (AC) or direct current (DC) arc welding machine. These machines may be either transformers, generators, alternators or transformer rectifier type machines. Gas tungsten arc welding machines must produce or supply a constant current. In these constant current machines, the volt ampere curve is relatively sleep. Because of the shape of this curve, the machine is know as drooping voltage type machine. (Fig 1)

Fig 1



GTA welding uses a constant current type of power source which gives a more or less constant current even when there is a slight variation in the arc length. As the process is mostly used manually, the normal variations in the arc length due to the hand unsteadiness will not create a very large current variation.

Types of power sources

Motor generators/alternators: Motor generators are generally used in an area away from a stationary power source. They may be driven from an electrical motor, gasoline or diesel engine. The gasoline or diesel unit is an ideal power supply for field work as most units also provide 110 volts AC/DC power for using small power tools. There are two basic type of rotating power sources, the alternator which produces alternating current and the generator which produces direct current.

Some manufacturers produce power supplies which will produce both AC and DC from a single unit. Amperage control may be supplied in ranges, with fine adjustment control within the individual ranges. Some models allow adjustment of the open circuit voltage (OCV) to give the welder complete control of the welding amperage.

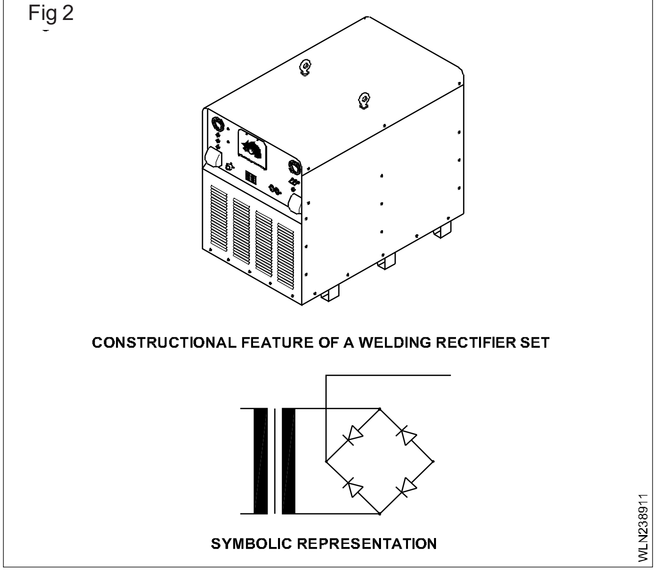
Alternating current transformers: Alternating current power sources are normally single phase transformers that use alternating current from the incoming (primary) power line. High voltage and low amperage current is then changed (transformed) into low open circuit voltage and high amperage currents for welding power.

Alternating current transformers/direct current rectifiers: The alternating current transformer / direct current rectifier type of machine, commonly called an AC/DC welding power supply, is very useful in the welding industry because of the dual current selection from a single machine. The machine produces alternating current or direct current straight or reverse polarity. A single phase transformer with a saturable reactor is used to produce alternating current.

The direct current is produced by rectifiers, which are commonly called SCRs (Silicon Controlled Rectifiers). An SCR is essentially an electrical gate which opens and closed to allow either straight or reverse polarity to pass through into the welding circuit. This type of output current cannot be used for welding as it is wavy or ripple. To reduce the ripple, inductor capacitors are placed into the circuit.

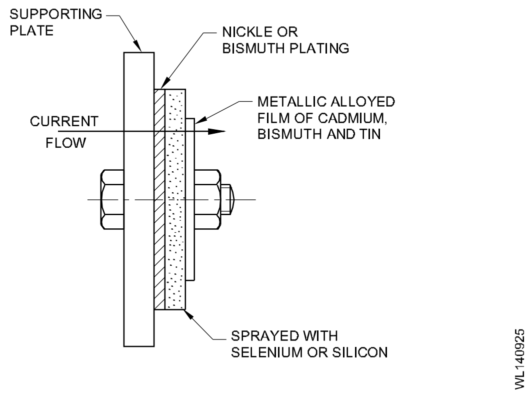
Constructional features of AC/DC welding rectifier: A welding rectifier set is used to convert AC welding supply into DC welding supply. It consists of a step down transformer and a welding current rectifier cell with a cooling fan. (Fig 2) The rectifier cell consists of a supporting plate made of steel or aluminium (Fig 3) which is plated with a thin layer of nickel or bismith, sprayed with SELENIUM or SILICON. It is finally covered with an alloyed film of CADMIUM, BISMITH and TIN.

Fig 2



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 on 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 3



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 atleast once in a month.

Keep the air ventilation system in good order.

Never run the machine without the fan.

Difference between of AC and 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 blow 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.

GTAW process and equipment

TIG welding equipment

- 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)

Tungsten electrodes - types - uses size and preparation

Objectives: At the end of this lesson you shall be able to
- **state the properties of tungsten**
- **name different types of tungsten electrodes used in TIG welding**
- **state the uses of tungsten electrodes.**

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 ThO2
- Zirconium oxide ZrO2
- Lanthanum oxide LaO2
- Cerium oxide CeO2

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

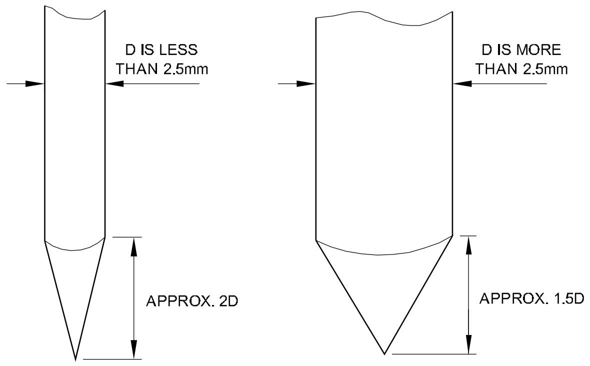
An important condition for obtaining a good result of TIG welding is that the point of the tungsten electrode must be ground correctly.

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

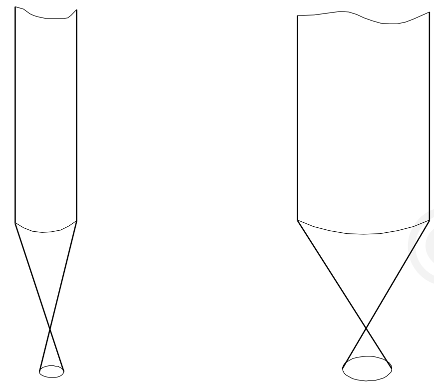


EXAMPLE OF GRINDING OF TUNGSTEN ELECTRODES FOR DC WELDING

WL220811

The pointed angle also has an influence of the penetration depth of the weld (Fig 2).

Fig 2

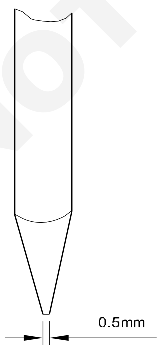


CONNECTION BETWEEN THE POINTED ANGLE AND THE WELD POOL

WL220812

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

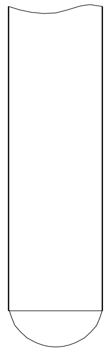


FLAT ELECTRODE POINT

WL220813

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



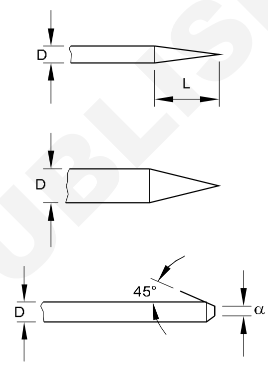
TUNGSTEN ELECTRODE FOR AC WELDING

WL220814

Grinding of the Tungsten Electrode

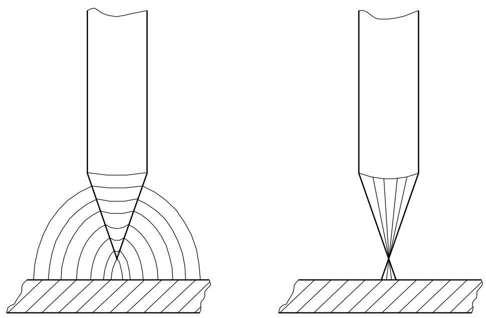
When grinding the electrode its point must point in the direction of the rotation of the grinding disc so the grinding traces will lie lengthways the electrode (Fig 5, 6, 7).

Fig 5



WL220815

Fig 6

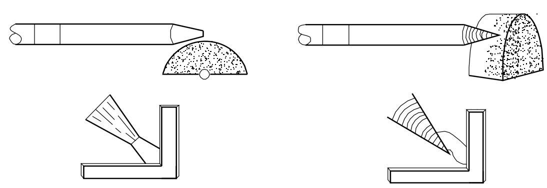


WRONG GRINDING

RIGHT GRINDING

WL220816

Fig 7



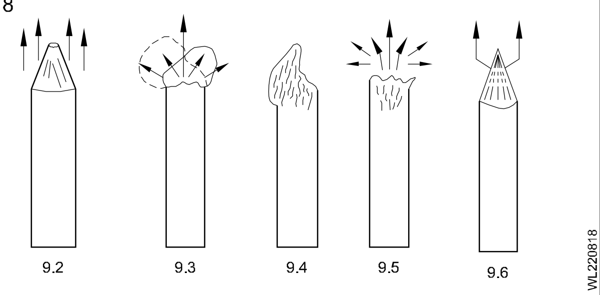
IDEAL TUNGSTEN
PREPARATION STABLE ARC

WRONG TUNGSTEN
PREPARATION WANDERING ARC

WL220817

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 radio graphics.

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 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

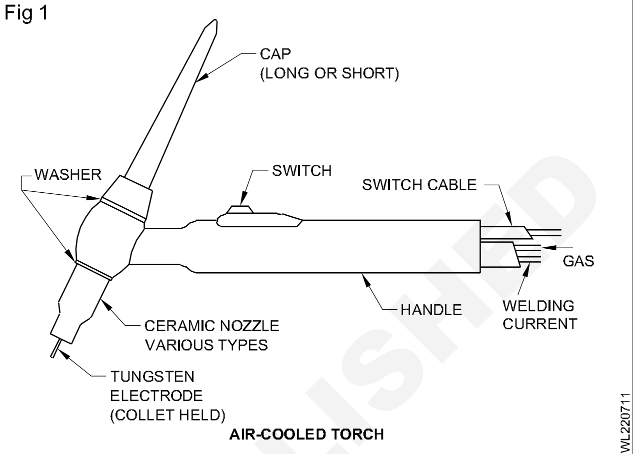
Torch: There is a variety of torches available varying from light weight air cooled to heavy duty water cooled types. Figs1 & 2. The main factors to be considered in choosing a torch are:

– Current carrying capacity for the work in hand

– Weight, balance and accessibility of the torch head to the work in hand.

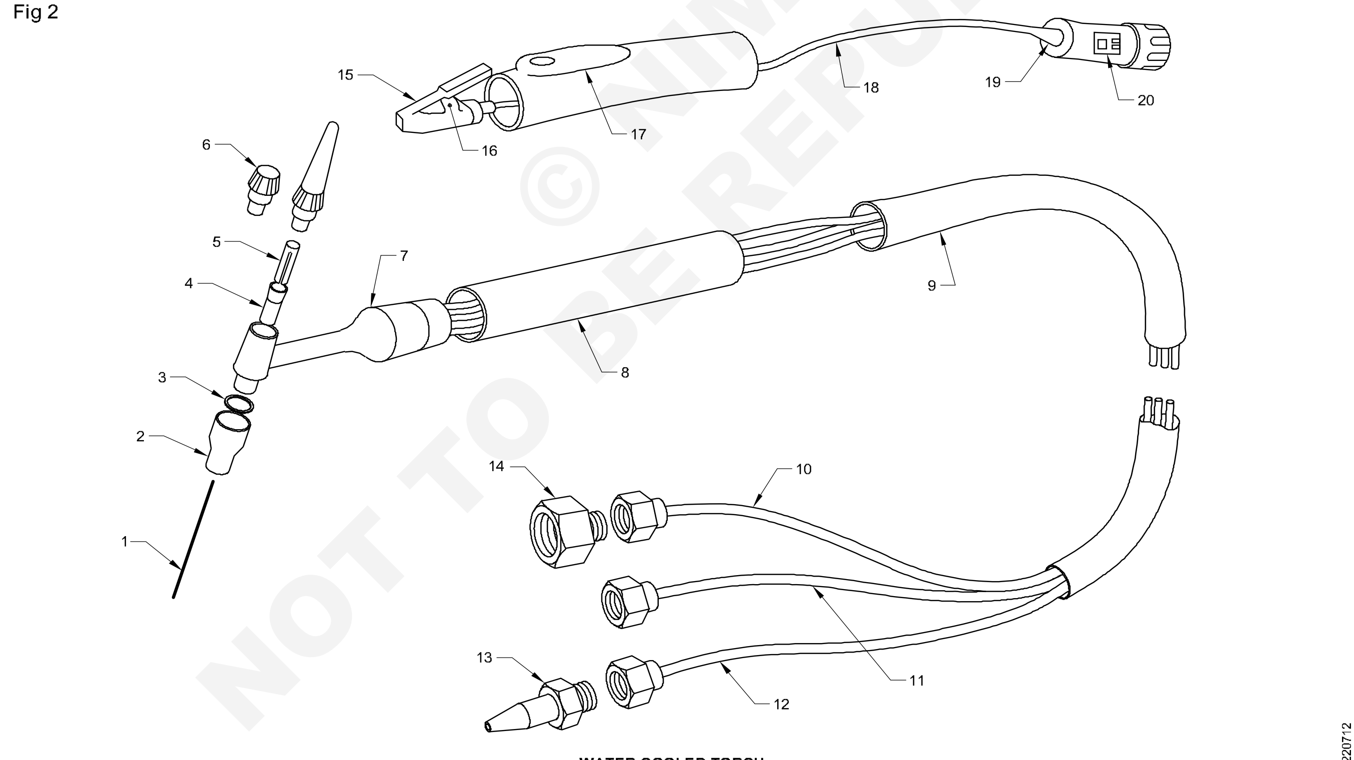
The torch body holds a top loading compression-type collet assembly which accommodates electrodes of various diameters. They are securely gripped, yet the collet is easily slackened for removal or reposition of the electrode. As the thickness of plate to be welded increases, size of torch and electrode 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

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 with 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 tungsten 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).

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.

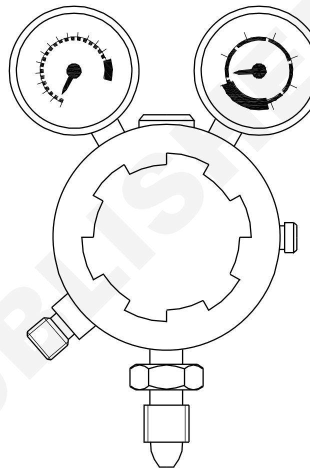
Please make sure when ordering a TIG torch to tell the supplier the amperage rating, whether water- or air-cooled, and the fitting that is to go on the end of the TIG torch lead suitable to fit the TIG power source it will be used from. This may include power cable fit up, gas fittings and control plug 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.

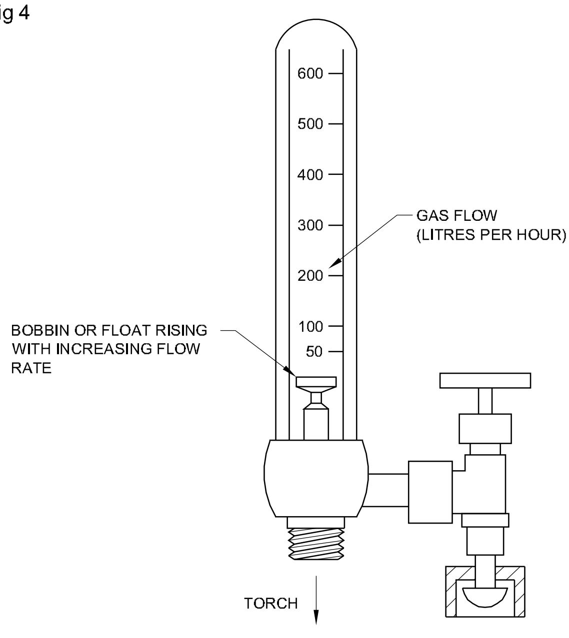
Fig 3



TWO STAGE ARGON REGULATOR

WL220713

Fig 4



ARGON FLOWMETER

WL220714

GTAW filler rods and selection criteria

Objectives: At the end of this lesson you shall be able to
- **state the GTAW filler rods**
- **describe the selection of criteria.**

In the welding process (GTAW or gas tungsten) is an arc welding process taht operates the filler rods.

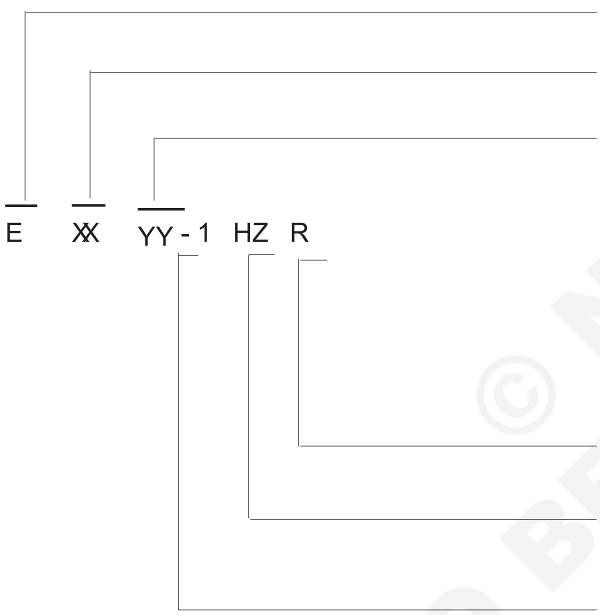
The TIG torch may be cooled by air or water and the process uses a filler metal in road form. The tungsten electrode selection and parameters for welds are guided them.

Gas tungsten arc welding also know as tungsten inert gas (TIG) welding, is an arc development within the GTAW process.

Now always the filler rods is withdraw from the weld pool each time the electrode can be changed.

Welding filler metal designators

1 Carbon steel electrodes



Mandatory classification designators

Designates an electrode

Designates minimum tensile strength, in Ks, of the as-deposited weld metal.

Designates the welding position, the type of covering and the type of welding current for which the electrodes are suitable (See table below)

Optional supplemental designators

Designates that the electrode meets the requirements of absorbed moisture.

Designates that the electrode meets the requirements of the diffusible hydrogen test - with an average value no exceeding "Z" mL of H2 per 100gms of deposited metal.

Designates that the electrode meet the requirements for improved toughness and ductility.

Optional supplemental designators

AWS Classification	Type of covering	Welding position	Type of current [b]
E6010	High cellulose, sodium	F,V,OH, H	dcep
E 6011	High cellulose, potassium	F,V,OH,H	as or dcep
E 7018	Low hydrogen, Potassium, Powder	F,V,OH,H	ac or dcep
E7024	Iron Powder, Titania	H-Fillets, F	ac, dcep or dcen

Note

a The abbreviations indicate the welding positions

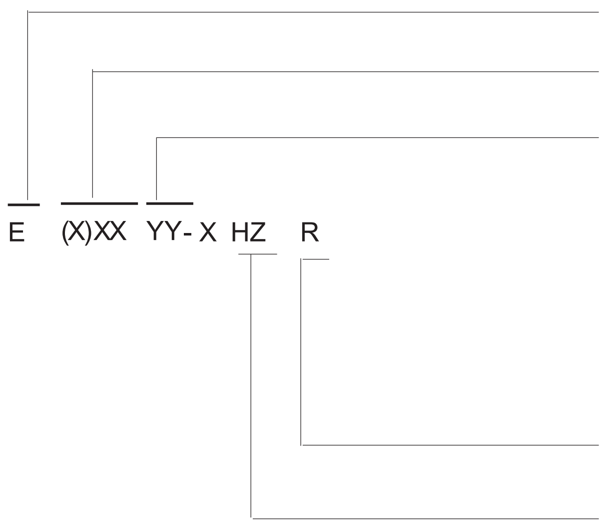
F=Flat; V=Vertical, OH=overhead, H=Horizontal, H=Fillets = Horizontal fillets.

b The term DCEP refers to direct current electrode positive (dc, straight polarity)

Also note that the above electrode classifications are the most widely used and does not include all of the available classifications. **Refer to AWS A 5.1 for complete listing.**

2 Alloy steel electrodes

Mandatory classification designators



Designates and electrode

Designates minimum tensile strength, in Ksi, of the as-deposited weld metal

Designates the welding position, the type of covering and the type of welding current for which the electrodes are suitable.

Designates the chemical composition of the undiluted weld metal produced by the electrode using SMAW process.

Optional supplemental designators

Designates that the electrode meets the requirements of absorbed moisture.

Designates that the electrode meets the requirements of the diffusible hydrogen test - with an average value not exceeding "Z" mL of H2 per 100gms of deposited metal, where "Z" is 4,8 or 16.

Refer to AWS A 5.5 for complete listing of mechanical properties, chemical composition of as deposited weld metal and testing procedures for SMAW process.

3 Stainless steel filler metal

Usability classification

Types of welding current and position of welding		
AWS classification	**Welding current**	**Welding position**
EXXX (X) - 15	dcep	All
EXXX (X) - 16	dcep or ac	All
EXXX (X) - 17	dcep or ac	All
EXXX(X) - 25	dcep	H,F
EXXX (X) - 26	dcep or ac	H,F

For more details on the usability classifications, refer to AWS A 5.4

Table 1: Carbon and low - alloy steel welding consumables for SMAW process

Types of welding current and position of welding						
Base material	**Carbon steel**	**Carbon-molybdenum steel**	**1 and 1 1/4 Cr-1/2 Mo steel**	**2 1/4 Cr-1 Mo steel**	**5 Cr-1/2 Mo Steel**	**9 Cr - 1 Mo steel**
Carbon steel	AB	AC	AD	AE	AF	AG
Carbon-Molybdenum steel		C	CD	CE	CF	CH
1 and 1 1/4 Cr-1/2 Mo steel			D	DE	DF	DH
2 1/4 Cr-1 Mo steel				E	EF	EH
5 Cr - 1/2 Mo steel					F	FH
9 Cr-1 Mo steel						H

Legend

A AWS A 5.1 classification E 70XX low hydrogen (E7018 preferred)

B AWS A 5.1 classification E 70XX low hydrogen (E7018 preferred)

C AWS A 5.5 classification E70XX - A1, low hydrogen

D AWS A 5.5 classification E70XX - B2L or E80XX-B2, low hydrogen

E AWS A 5.5 classification E80XX-B3L or E80XX-B6L, low hydrogen

F AWS A 5.5 classification E80XX-B6 or E80XX-B6L, low hydrogen

G AWS A 5.5 classification E80XX-B7 or E80XX-B7L, low hydrogen

H AWS A 5.5 classification E90XX-B8 or E80XX-B8L, low hydrogen

1 Table 1 refers to coated electrodes (SMAW process) only. For bare wire welding (SAW, GMAW, GTAW and FCAW), use equivalent electrode classifications (AWS A 5.14, A 5.17, A5.18, A 5.20, A 5.23, At 28)

2 Higher allow electrode specified in the table should normally be used to meet the required tensile and toughness after post weld heat treatment (PWHT). If no PWHT is required, the lower alloy electrode specified may be required to meet the hardness requirements.

Table 2: Austenitic, super-austenitic and duplex stainless steel alloys

Types of welding current and position of welding										
Base Material	**304L SS**	**304H SS**	**316L SS**	**317L SS**	**904L SS**	**6% Mo SS**	**7% Mo SS**	**Alloy 20Cb-3**	**2304 Duplex SS**	**2205 Duplex SS**
Carbon and low alloy steel	ABC	ABC	ABC	ABC	ABC	ABC	ABC	ABC	N	N
Type 304L stainless stell	D	DE	DF	DG	DC	C	C	DCH	NL	NL
Type 304H stainless steel		E	EF	EG	*	*	*	ECH	*	*
Type 316L stainless steel			FG	FG	FC	FC	FC	FCH	NL	NL
Type 317L stainless steel				GC	GC	GC	GC	GC	L	L
Type 904L stainless steel					C	C	C	C	L	L
Type 6% Mo stainless steel						CJK	CJK	*	*	*
Eg: 254 SMO, AL 6XN							CJK	*	*	*
Type Alloy 20Cb-3								H	*	*
Type 2304 Duplex SS									LM	LM
Type 2205 Duplex SS										LM

Legend

A-AWS A 5.4 classification E309L-XX

B-AWS A 5.11 classification ENiCrFe-2 or -3 (-2 is alloy 718 and -3 is inconel 182)

C-AWS A 5.11 classification ENiCrMo-3 (Inconel 625)

D-AWS A 5.4 classification E308L-XX

E-AWS A 5.4 classification E308H-XX

F-AWS A 5.4 classification E316L-XX

G-AWS A 5.4 Classification E317L-XX

H-AWS 5.4 classification E320LR-XX

J-AWS A5.11 classification ENiCrMo-4 (Hastelloy C-276)

K-AWS A 5.11 classification ENiCrMo-11 (Hastelloy G-30)

L-AWS A 5.4 classification E2209-XX

M-AWS A 5.4 classification E2553-XX

N-AWS A 5.4 classification E309MoL-XX

Table 2 refers to coated electrodes only. For wire welding (GMAW & GTAW) use equivalent electrode classification (AWS A5.14)

There are many proprietary alloys available in the market and material combinations you might encounter. Consult the manufacturer or the DFD for proper filler metal selection.

Edge preparations fit up, different thickness of metals

Objective: At the end of this lesson you shall be able to
- **explain the edge preparation fit up of GTAW**

Edge preparation (GTAW): For a Tee fillet, lap fillet and corner fillet joints a square edge preparation for thickness upto 3.15mm is used.

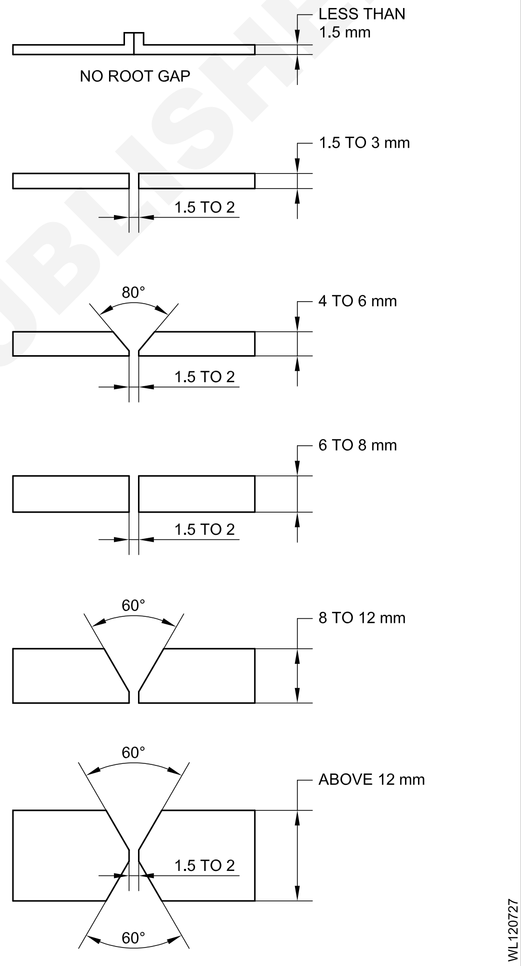
For butt joints, the edges are prepared as given below.

Plate edge preparation

Fig 1 shows the plate edge preparation depending on the thickness of the material to be welded.

Metal thickness	Diameter of filler	Edge preparation
Upto 1.6mm	None to 1.6mm	
1.6mm to 2.5mm	1.6mm to 2.5mm	
2.5mm to 4.0mm	2.5mm to 3.15mm	
4.0mm to 6.0mm	3.15mm	
6.0mm to 15mm	3.15mm	
15mm and over	5.0mm	

Fig 1



Argon/helium gas properties and uses

Objectives: At the end of this lesson you shall be able to
- **state the properties of argon and helium gas**
- **explain the uses of argon/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.

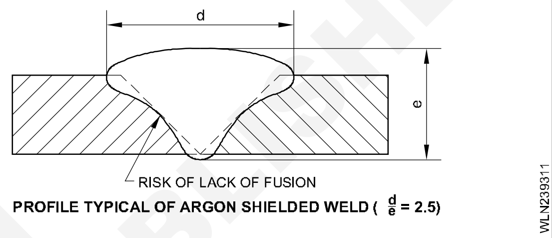
Quality : Argon gas of welding quality should be used.

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)

Fig 1



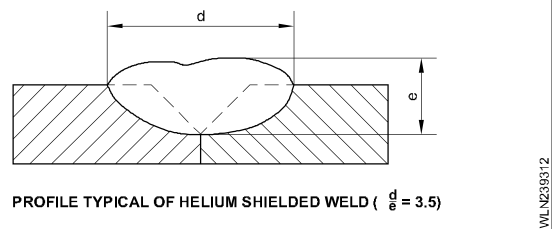
PROFILE TYPICAL OF ARGON SHIELDED WELD ($\frac{d}{e} = 2.5$)

Helium: Helium is used mainly in TIG welding and is normally used with direct current whatever the metal being welded (light alloys, copper, etc.)

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

Fig 2

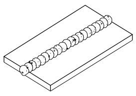
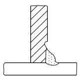
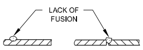
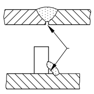
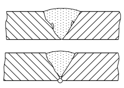
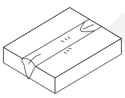


PROFILE TYPICAL OF HELIUM SHIELDED WELD ($\frac{d}{e} = 3.5$)

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 (eg.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  SLAG INCLUSION IN BUTT WELD	Usually internally and only detected by suitable testing techniques. Normally oxide or tungsten inclusions.	Oxide inclusions. Inadequate cleaning of parent material before welding. Contamination on surface 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. Exclude 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.

Friction welding process equipment and application

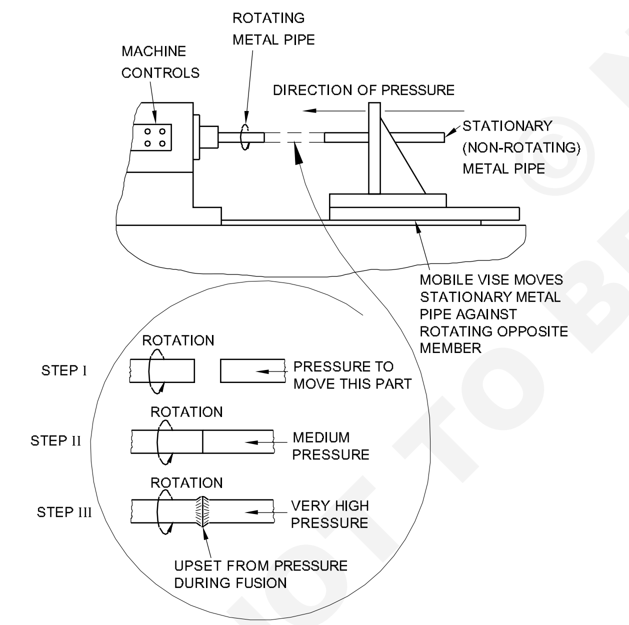
Objectives: At the end of this lesson you shall be able to
- **state the principle of friction welding**
- **explain the method of welding**
- **state the application of friction welding**
- **state the advantages & limitations of friction welding**

Friction welding

Principle: Friction welding uses friction to create heat to fuse two pieces of metals together. This process is used mainly in butt welding of large sections round rods, very heavy tubes and pipes.

Method of welding: No external heat is supplied. One of the pieces is made to rotate. The ends of the parts to be joined are then brought together under a light pressure. The resulting friction between the stationary and rotating parts develops the heat required to form the weld. As the metal surfaces reach the plastic stage, they are forced together under a much higher pressure. The process produces a clean metal-to-metal welding surface. (Fig 1)

Fig 1



SCHEMATIC OF FRICTION WELDING

A 1/2” diameter low carbon steel rod with welding temperature of 1650ºF can be joined with a contact pressure in the range of 5000 to 10000 pounds/inch while rotating at approximately 3000 rounds per minute for about 5 second. Medium and high alloy steels require heating pressure (Contact Pressure) ranging from 10000 to 30000 pounds/inch and forging pressure between 15000 to 60000 pounds/inch.

Applications

Metals that can be welded by the friction welding process include Carbon Steel, Steel Alloys. Stainless Steel, Copper, Aluminium and Titanium.

Limitations

– The machine is costly.

– Plates/sections of less thickness/size cannot be welded.

– Welding can be done only inside a factory/shop and not at sites.

– Soft metals and metals with low compressive strength cannot be welded.

– Only butt joint can be done.

– There is a burr surrounding the weld area.

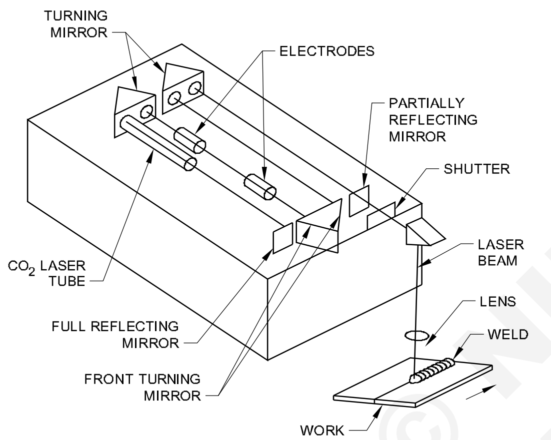
Laser beam welding (LBW)

Objectives: At the end of this lesson you shall be able to
- **explain the process of LBW**
- **describe the equipment and uses of LBW**
- **state the advantage and disadvantage of LBW.**

Laser welding (Fig 1)

LASER is the acronym for Light Amplification by Stimulated Emission of Radiation. Laser Welding is a method in which work piece is melted and joined by narrow beam of intense Monochromatic Light. (Laser Beam) When the beam strikes the job, the heat produced melts and fuses even the hardest materials.

Fig 1



A CO_2 LASER MIRRORS ARE USED TO REFLECT AND AIM THE LASER BEAM. A LENS IS USED TO FOCUS THE BEAM

WLN239421

Process

Electrical energy stored in a capacitor bank is discharged into a flash lamp. The stimulating light source usually in a linear arc discharge lamp such as Zeon, Argon, or Krypton gas flash lamp. When the flash lamp fires, and then is a powerful burst of light that pumps electrons with the light emitted (Ruby Rod) to higher than normal energy levels. The light emitted by ruby rod is in pulse and is of single wave length travelling parallel to ruby rod. The mirrors are provided to reflect the light coming to the ends of ruby rod. So that light may pass back through the ruby rod increasing the energy level of electrons further to emit Laser Beam.

It goes through a focusing device where it is pin pointed on the work piece. Fusion takes place and the weld is accomplished. There are three basic types of Lasers.

a The solid laser

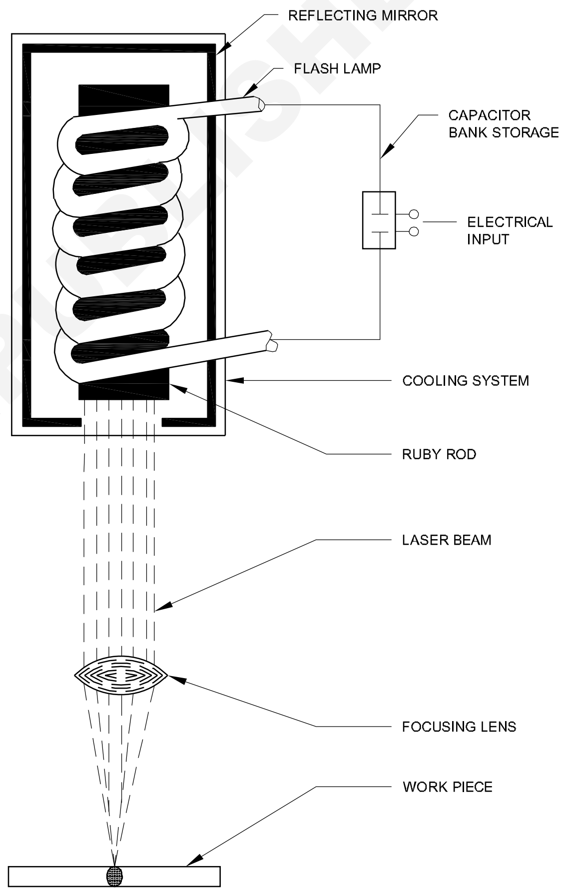
b The gas laser and,

c The semi-conductor.

The type of Laser depends upon the lasing source. The Solid Laser some type of crystal such as the Ruby or the Sapphire used for its lasing ability.

The gas laser consists of a gas (Carbon Di-oxide, Xenon) or a mixture of gases (90% Helium, 10% Neon) contained in a glass tube with highly polished mirrors at each end. One of the most widely used Gas Laser is CO_2 Laser. The radiant energy density of the CO_2 Laser is greater than that of the sun.

Fig 2



LASER WELDING

WLN239422

Equipment and setup (Fig 2)

Fig 2 shows a line diagram of a laser beam welding equipment/setup. The light or heat energy is put into a single molecule of a substance (ruby or carbon-di-oxide) to create the beam. This single frequency energy of the single molecule substance in the form of a beam, when travelling between the rear and front mirrors, increases in intensity until it passes through the partially reflecting mirrors. The release of the laser beam is controlled by the operator/ welder.

Advantages:

- Speed and flexibility. Laser welding is a very fast technique.
- Deep, narrow welds.
- Low distortion and low heat input.
- Suitable for a range materials and thicknesses.
- Performed out of vaccum.
- Non-contact, single-sided process.
- Non-continuous welding.
- Versatility.

Applications of Laser Beam Welding Process

- It is prominent in the automotive industry
- It is employed for high precision welds.
- The laser welding is also frequently used in making of jewellery.
- However, laser beam welding is used in medical industries to hold metals together on a small scale.
- The metalizing process starts with preparing the surface of the product. Then a metal wire is melted in metalizing spray equipment to become molten. After this, clean and compressed air atomizes the material, and the air then transports the atomized metal onto the product surface to form the coating.

Plasma arc welding (PAW) and cutting (PAC) process equipment & principle of operation, types of plasma arc, advantage and applications

Objectives: At the end of this lesson you shall be able to
- **state the types of plasma arc welding**
- **state the equipment of PAW & types of plasma arc**
- **explain the principle and processes of PAW**
- **explain the advantages and application of PAW**

Plasma Arc Welding is welding process in which plasma producing gas (Argon, Nitrogen, Helium, and Hydrogen) is ionized by the heat of an electric arc and passed through a small welding torch orifice. A shielding gas protects the plasma arc from atmospheric contamination in welding or cutting. A non-consumable Tungsten electrode is used in Plasma Arc Welding and additional metal is added to the weld with a filler rod.

Plasma Arc welding uses the keyhole method to obtain a full penetration and can be done manually or automatically. The works of temperature obtained in this process is about 20000ºC to 30,000ºC.

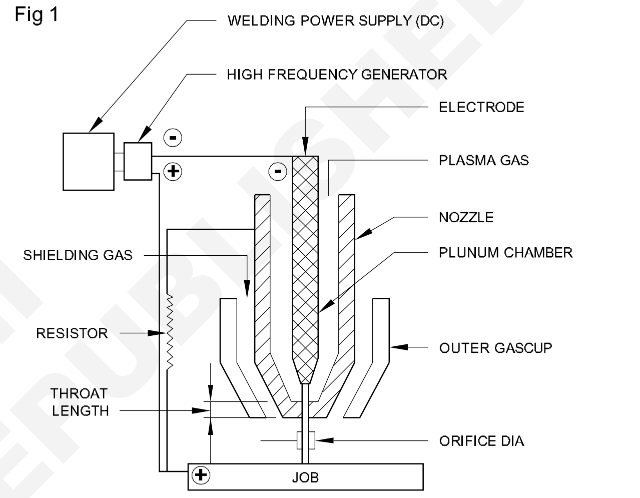
It is divided in to two basic types. They are:

1 Transferred arc

2 Non-transferred arc

Transferred arc process (Fig 1): The arc is formed between the electrode(-) and the work piece (+). In other words, arc is transferred from the electrode to the work piece. A transferred arc possesses high energy density and plasma jet velocity. For this reason it is employed to cut and melt metals. Besides carbon steels this process can cut stainless steel and nonferrous metals also where oxyacetylene torch does not succeed. Transferred arc can also be used for welding at high arc travel speeds.

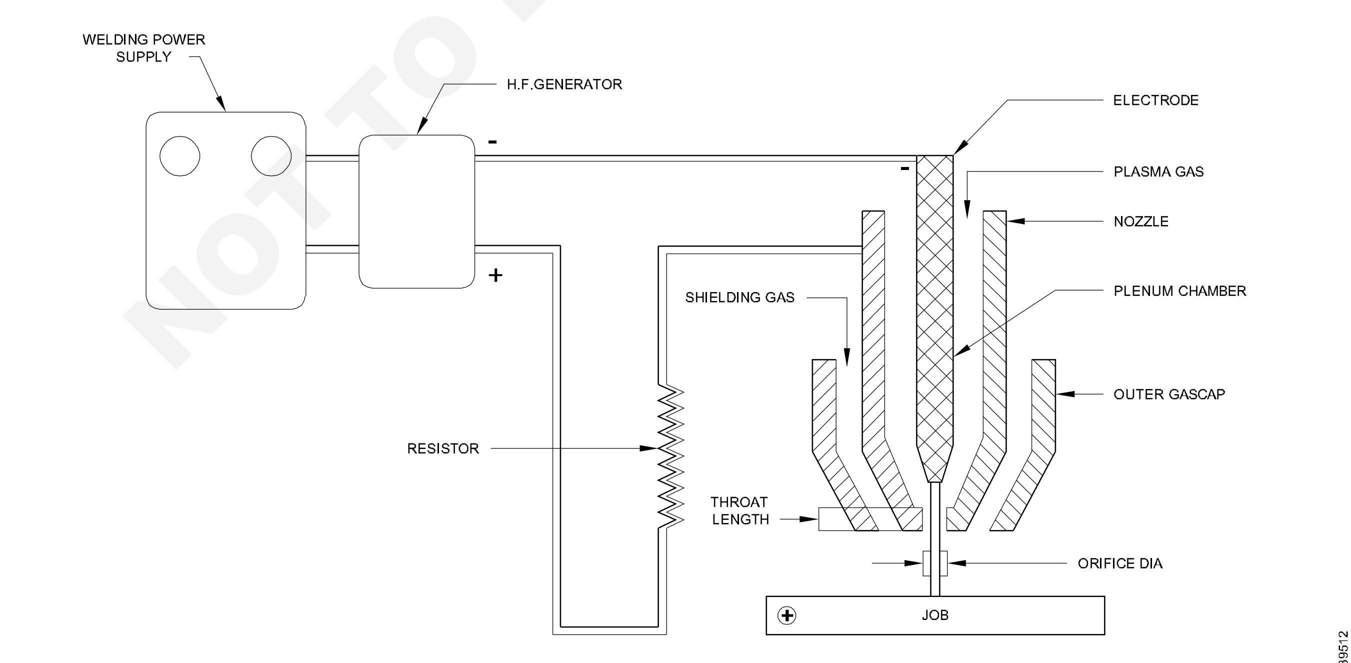
Fig 1



PLASMA ARC WELDING (TRANSFORMED ARC)

Non-transferred arc process (Fig 2)

Fig 2



PLASMA ARC WELDING (NON-TRANSFORMED ARC)

The heat of the laser beam which is of high intensity is conveniently directed towards the joint to be welded by different combination of mirrors. This is possible because the laser beam can be reflected like light rays. The laser beam produced can be either a continuous heat source or a pulsed beam. When the beam contacts the base metal to be welded through a lens the heat is instantaneously released. The amount of heat applied on the base metal can be controlled by controlling the input to the laser beam source depending on the melting of the base metal being welded.

Equipment

1 DC power source
2 Welding control console (Contain flow meter)
3 Recirculating water cooler
4 Plasma welding torch (up to 500 amps capacity)
5 Gas cylinders and a gas supply
6 Gas pressure regulator
7 Gas hoses and hose connections
8 Water cooled power cables

Applications

Laser Welding is used in the Space, Aircraft, Electronics industries for thinner section metals and dis-similar metals.

Advantages

1 Work piece does not get hot except at one point.
2 The heat affected zone is narrow.
3 No electrode / filler rod is required.
4 Sensitive materials can be welded.

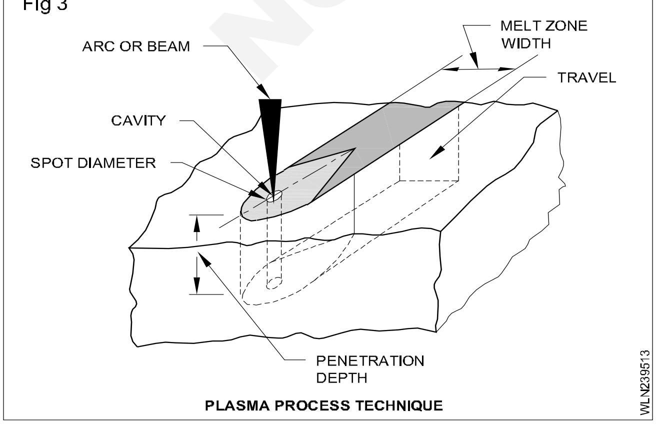
Disadvantages

1 It has high capital and operating cost.
2 It needs a skilled operator.

The arc is formed between the electrode(-) and the water cooled constricting nozzle(+). Arc plama comes out of the nozzle as a flame. The arc is independent of the work piece and the work piece does not form a part of the electrical circuit. Just as an arc flame, it can be moved from one place to another and can be better controlled. The non transferred arc plasma possesses comparatively less energy density as compared to a transferred arc plasma and it is employed for welding and in applications involving ceramics or metal plating (spraying).

Application of the plasma process

Fig 3



PLASMA PROCESS TECHNIQUE

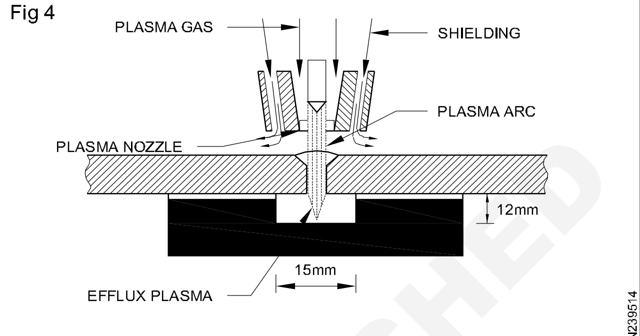
Three operating modes possible by varying current bore diameter and gas flow rate.

Limitations of plasma arc welding

1 PAW requires relatively expensive and complex equipment as compared to GTAW; proper torch maintenance is critical
2 Welding procedures tend to be more complex and less tolerant to variations in fit-up, etc.

Types of plasma arc, advantages and applications

Fig 4



KEYHOLE PLASMA WELDING

Cutting processes - plasma arc cutting

Plasma arc cutting process, was introduced in the industry in the mid 1950s. The process is used to cut all metals and non-metals. The common oxy-fuel cutting process (based on a chemical process) is suitable for cutting carbon steel and low alloy steel cutting only. Materials such as copper, aluminium and stainless steels were earlier separated by sawing, drilling or sometimes by power flame cutting. These materials are now cut using a plasma torch, at faster rates and more economically. The Plasma cutting process is basically a thermal cutting process, free of any chemical reaction, that means, without oxidation. In plasma arc cutting an extremely high temperature and high velocity constricted arc is utilized.

Principle of operation

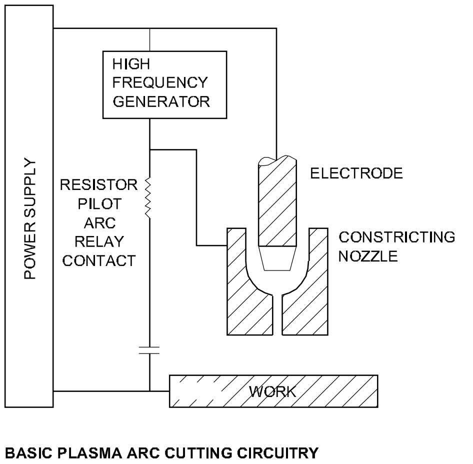
Plasma arc cutting is a process resulting from ionizing a column of gas (argon, nitrogen, helium, air, hydrogen or their mixtures) with extreme heat of an electric arc. The ionized gas along with the arc is forced through a very small nozzle orifice, resulting into a plasma stream of high velocity (speed up to 600 m/sec) and high temperature (up to 20000°K). When this high speed is reached, high temperature plasma stream and electric arc strike the workpiece, and ions in the plasma recombine into gas atoms and liberate a great amount of latent heat. This heat melts the workpiece, vaporizes part of the material and the balance is blasted away in the form of molten metal through the heat (Fig 5).

Plasma cutting system (Fig 6,7,8)

Plasma cutting requires a cutting torch, a control unit, a power supply, one or more cutting gases and a supply of clean cooling water (in case water-cooled torch is used).

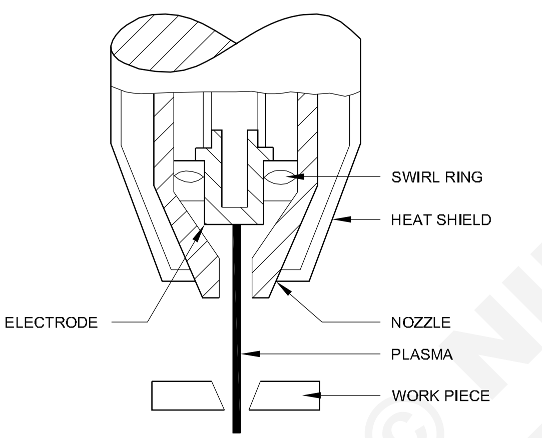
Equipment is available for both manual and mechanical cutting. A basic plasma arc cutting circuit Fig 1. It employs direct current straight polarity (DCEN). The nozzle surrounding the electrode is connected to the workpiece (positive) through a current limiting resisitor and a pilot arc relay contact.

Fig 5



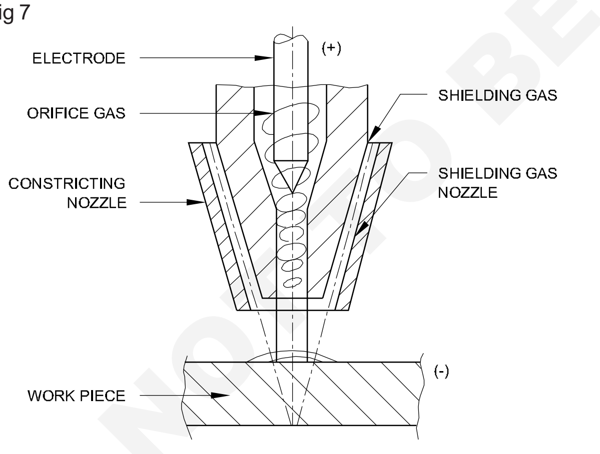
BASIC PLASMA ARC CUTTING CIRCUITRY

Fig 6



COMPONENTS OF AN AIR-PAC TORCH

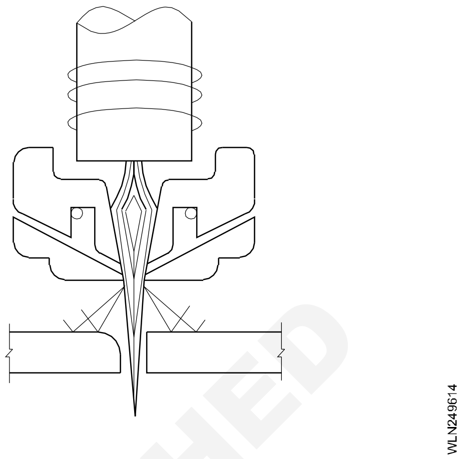
Fig 7



DUAL FLOW PLASMA ARC CUTTING

The pilot arc between the electrode and nozzle is initiated by a high frequency generator connected between the electrode and nozzle. The orifice gas ionized by the pilot arc is blown through the constricting nozzle orifice and forms a low resistance path to ignite the main transferred arc between the electrode and the workpiece when the ON/OFF switch is closed. The pilot arc relay may be opened automatically when the main arc ignites, to avoid unnecessary heating of the constricting nozzle. The constricting nozzle is of copper and normally water cooled to withstand the high plasma flame temperature (about 20000°K) and to have longer life.

Fig 8

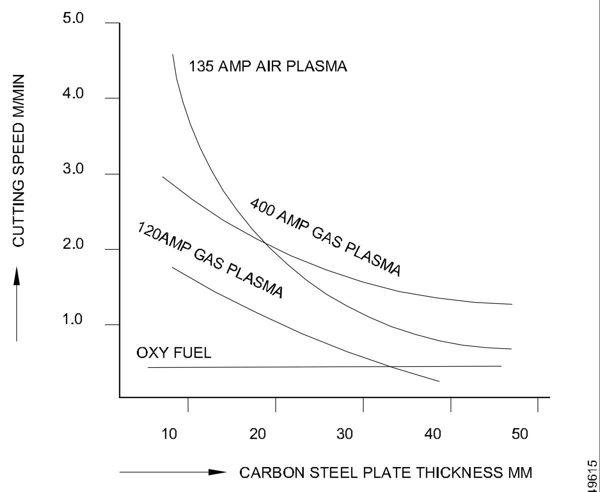


In conventional gas plasma cutting, discussed above, the cutting gas can be argon, nitrogen, (argon + hydrogen), or compressed air. For all the cutting gases other than compressed air, the non-consumable electrode material is 2% thoriated tungsten. In air plasma cutting (Fig 2) where dry, clean compressed air is used as the cutting gas, the electrode of hafnium or zirconium. In used because tungsten is rapidly eroded in air. Wet and dirty compressed air reduces the useful life of consumable parts and produces poor quality.

Several process variations are used to improve the cut quality for particular applications. Auxiliary shielding in the form of gas or water is used (Fig 3) to improve the cut quality and to improve the nozzle life. Water injection plasma cutting (Fig 4) uses a symmetrical impinging water jet near the constricting nozzle orifice to further constrict the plasma flame and to increase the nozzle life. Good quality cut with sharp and clear edges with little or no dross is possible in water injection plasma cutting.

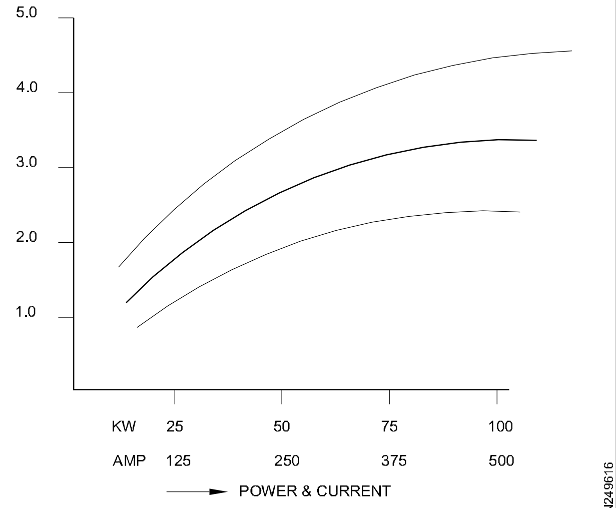
Process variables (Fig 9 & 10)

Fig 9



COMPARISON OF OXY FUEL AND PLASMA CUTTING PROCESSES

Fig 10



RELATIONSHIP BETWEEN CUTTING SPEED & POWER

Advantages of plasma cutting

i All metals and non-metals can be cut due to the high temperature and high velocity plasma flame.

ii Cuts are of very clear form with little or no dross.

iii High speed piercing is achieved.

iv Cutting of piled plates is possible, even with different materials.

v Cutting cost is quite low as compared to other processes, especially for stainless steels.

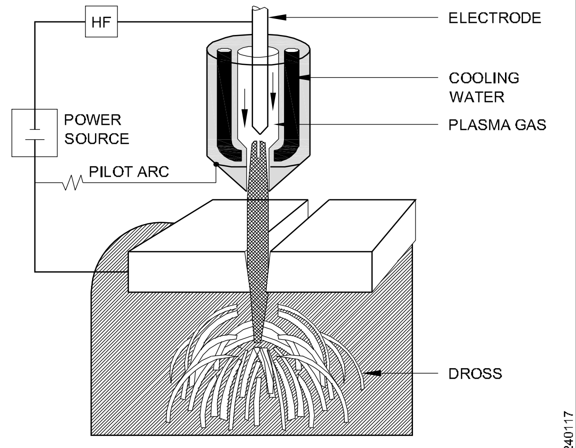
vi Cutting speed is high.

vii Cutting is possible in all positions and locations (underwater also).

Gases for plasma cutting (Fig 11)

- no need to promote oxidation & no preheat
- works by melting and blowing and/or vaporisation

Fig 11



GASES FOR PLASMA CUTTING

- “gases : air, Ar, N_2, O_2, mix of Ar + H_2, N_2 + H_2
- air plasma promotes oxidation and increased speed but special electrodes need
- shielding gas - optional
- applications : stainless steels, aluminium and thin sheet carbon steel.

Palsma cutting applications

- EGYROBO plasma cutting solution is used to cut steel or a non-ferrous material less than one inch thick. Using a robotic plasma cutting machine offers higher quality cuts at faster travel speeds. This versatile application effectively cuts very thin & thick metals consistently.
- Palsma cutting robots create great angled or curved shapes, as well as a smoother surface compared to manual application. The material of the product can be mild steel, stainless steel, carbon steel, expanded steel, aluminium, copper and brass.

Resistance welding process & types - principle power source & welding parameter

Objectives: At the end of this lesson you shall be able to
- **explain the principle and types of resistance welding process**
- **explain the main elements of a resistance welding machine**
- **state the applications and advantages of resistance welding.**

Principle of resistance welding: Resistance welding is a welding process wherein coalescence is provided by the heat obtained from the resistance offered by the work to the flow of electric current in a circuit and the joint is effected by the application of pressure.

The fundamental principle on which all resistance welding is based is as follows.

The heat is generated due to the resistance offered by the parts to the passage of heavy electric current for a fraction of a second.

Heat produced at the junction is calculated by the formula

$$H = I^2Rt$$

where H for Heat, **I** stands for the amount of current in amps.

R for resistance offered in ohms

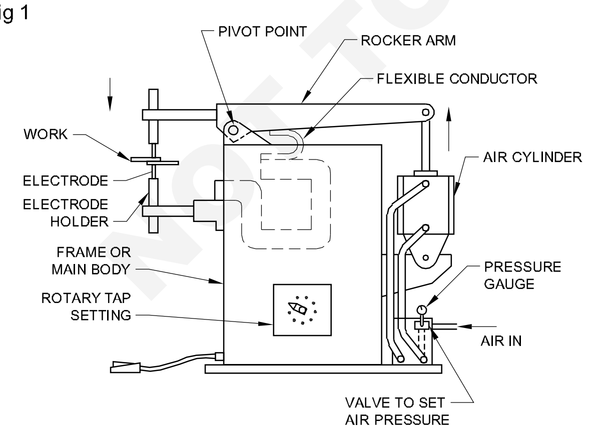
t - time taken for duration of current flow in seconds.

This heat at the junction of the two parts changes the metal to a plastic state, and when combined with the correct amount of pressure, fusion takes place.

The different types of resistance welding machines are spot welding, seam welding, projection welding, flash butt welding and upset welding machines.

A standard rocker arm type resistance welding machine. Fig 1. The main parts are:

Fig 1



ROCKER ARM TYPE RESISTANCE WELDING MACHINE

WLN249711

1 **The frame:** It is the main body of the machine which differs in size and shape for the stationary and portable types.

2 **Force mechanism:** The compressed air cylinder and the pivoted rocker arm gives the necessary high pressure to the lever to which the upper electrode holder is attached.

3 **The electric circuit:** It consists of a step down transformer which provides for the necessary current to flow at the point of weld.

4 **The electrodes:** The electrodes include the mechanism for making and holding contact at the weld area.

5 **The timing controls:** The switches which regulate the value of current, current flow time and contact period time as the timing controls.

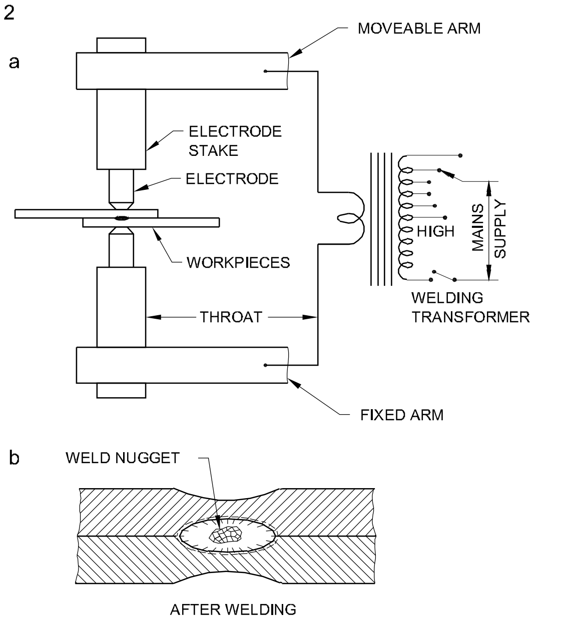
6 **Water cooling system** to circulate cooling water to the electrodes.

This is the additional part consisting of a water reservoir and flow system.

Spot welding: This type of resistance welding machine is most commonly used for resistance welding. The material to be joined is placed between two electrodes as shown in Fig 2a. Pressure is applied after a quick shot of electricity is sent from one electrode through the job to the other electrode.

Spot welding is made in three steps.

Fig 2



WLN249712

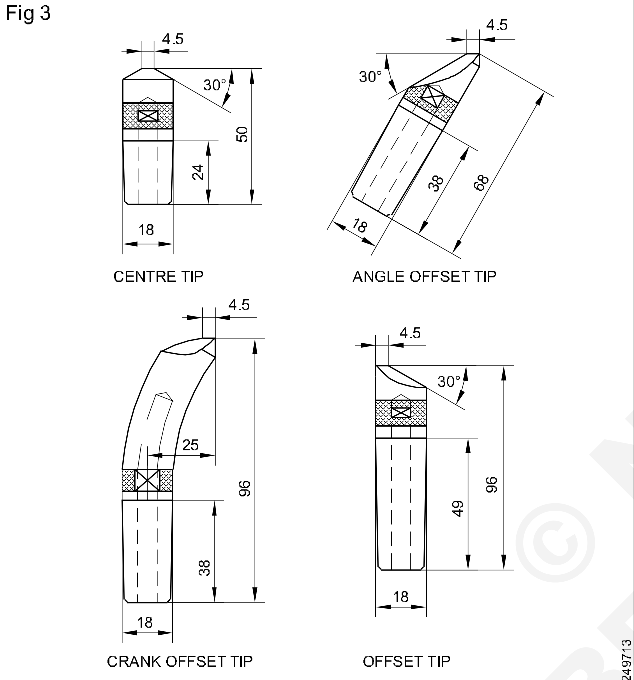
The first step is when the parts to be joined are clamped between the electrodes. In the second step, a high current is allowed to pass through the clamped members and is raised to the welding temperature. The third step sees the current being cut off and high pressure being applied to the joint and the joint completed. A nugget is formed as shown in Fig 2b.

A special copper alloy material has been developed for use as electrodes.

Cooling of the electrodes is accomplished by internally circulating water.

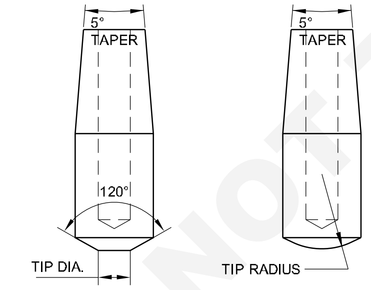
Electrodes are of many shapes and sizes, the most common being the centre tip and offset tip types. (Figs 3 and 4)

Fig 3



FOUR STANDARD TYPES OF ELECTRODES

Fig 4



THE RADIUS OF THE DOMED TIP (RIGHT) VARIES FROM 25mm FOR WELDING 26 S.W.G. MATERIAL, UPTO 150mm FOR 3 S.W.G. THE DIAMETER OF FLAT PART OF THE OTHER ELECTRODE VARIES FROM 4mm TO 12mm FOR SIMILAR MATERIAL THICKNESS.

TWO STANDARD TYPES OF CENTER TIP ELECTRODE

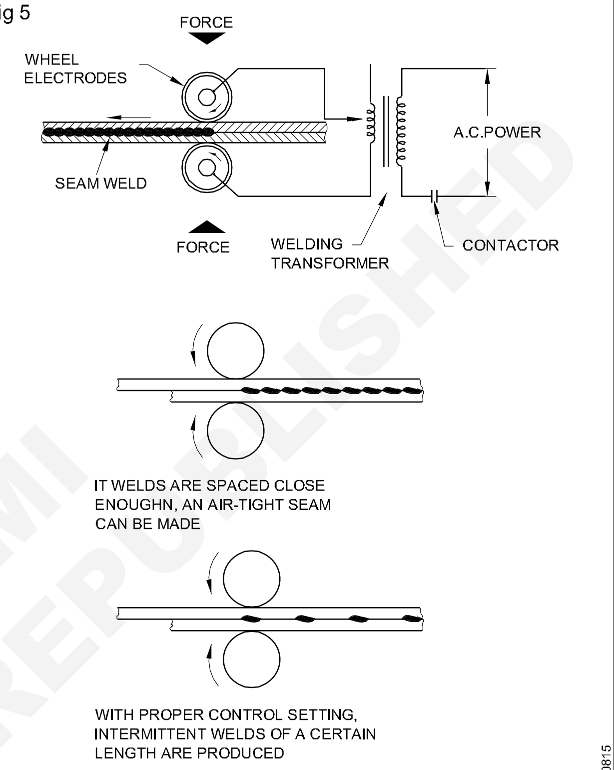
Regular spot welding leaves slight depressions on the metal. These depressions are minimized by the use of larger sized electrode tips and by inserting 1.6 mm copper sheets between the electrode and the job.

Spot welds may be made one at a time or several welds may be completed at one time.

Spot welding is utilized extensively for welding steel, and when equipped with an electronic timer, it can be used for other materials, such as aluminium, copper, stainless steel, galvanised metals etc.

Seam welding: Seam welding is like spot welding except that the spots overlap one another, making a continuous weld seam. In this process the metal pieces pass between the roller type electrodes as shown in Fig 5.

Fig 5



RESISTANCE SEAM WELDING PROCESS

As the electrodes revolve, the current is automatically turned 'on' and 'off' at intervals corresponding to the speed at which the parts are set to move. With proper control, it is possible to obtain airtight seams suitable for containers, water heaters, fuel tanks etc.

When spots are not overlapped long enough to produce a continuous weld, the process is sometimes referred to as roller spot welding.

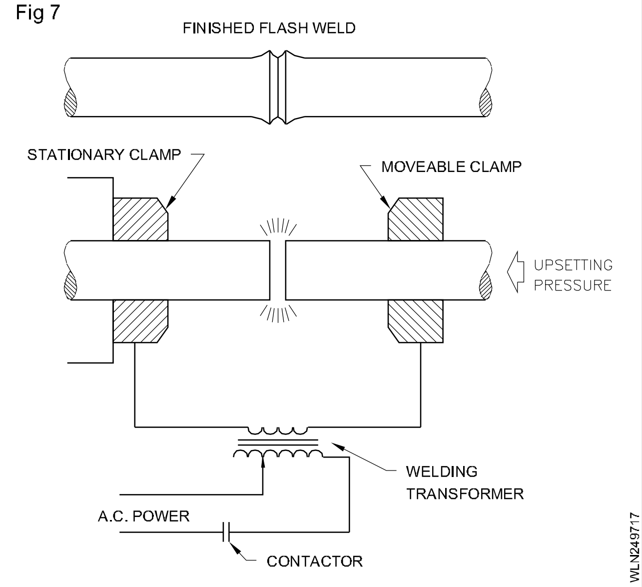
Cooling of the electrodes is accomplished either by circulating water internally or by an external spray of water over the electrode rollers.

Both lap and butt joints are welded by seam welds. In the case of butt joints, foils of filler metals are used on the joints.

Projection welding: Projection welding involves the joining of parts by a resistance welding process which closely resembles spot welding. This type of welding is widely used in attaching fasteners to structural members.

The point where welding is to be done has projections which have been formed by embossing, stamping or machining. The projections serve to concentrate the welding heat at these areas and facilitate fusion without the necessity of employing a large current. The welding process consists of placing the projections in contact with the mating part and aligning them between the electrodes (flat copper electrode) as illustrated in Fig 6.

Fig 7

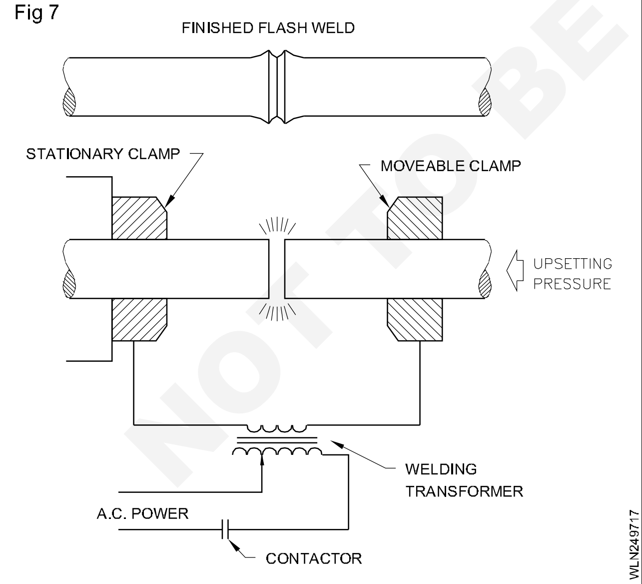


Either single or a multitude of projections can be welded simultaneously.

Not all metals can be projection-welded. Brass and copper do not lend themselves to this method because the projections usually collapse under pressure. Galvanised iron and tin plates, as well as most other thin gauge steels, can be successfully projection-welded.

Flash butt welding: In the flash butt welding process the two pieces of metals to be joined are firmly held in clamps which conduct current to the work.(Fig 7)

Fig 7



The ends of two metal pieces are moved towards and away from each other until an arc is established. The flashing action across the gap melts the metal, and as the two molten ends are forced together, fusion takes place. The current is cut off just before the heavy pressure is applied through the movable clamp.

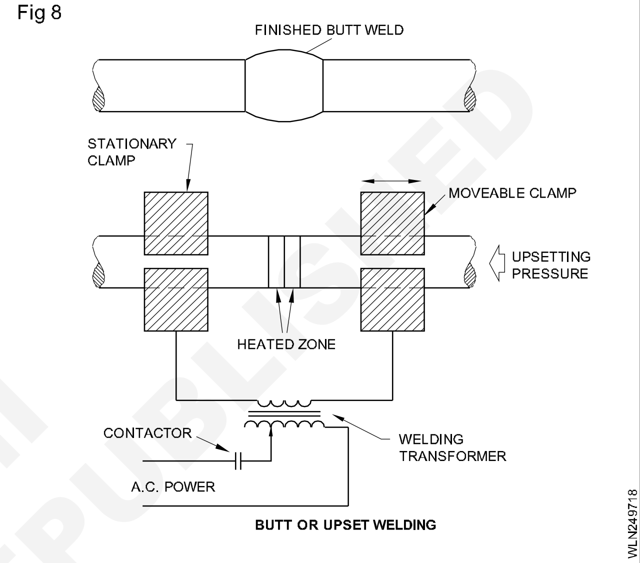
Flash butt welding is used to butt-weld plates, bars, rods, tubing and extruded sections. It is not generally recommended for welding cast iron, lead and zinc alloys.

The only problem encountered in flash butt welding is the resultant bulge at the point of the weld. It should be removed by grinding or machining if the part needs finishing.

Butt or upset welding (Slow butt weld)

In butt welding the metals to be welded are in contact under pressure. An electric current is passed through them, and the edges are softened and fused together as illustrated in Fig 8.

Fig 8



This process differs from flash butt welding in that constant pressure is applied during the heat process which eliminates flashing. The heat generated at the point of contact results from resistance. The operation and control of the butt welding process is almost identical to that of flash butt welding.

Butt or upset welding is limited to parts with a cross-section area of not more than 200-250 mm^2. Bars with cross-sectional area of 250mm^2 and above are joined by flash butt welding.

Parameters of welding

- Current
- Length of Arc
- Angle
- Manipulation

Speed

Butt or upset welding is limited to parts with a cross-section area of not more than 200-250 mm^2. Bars with cross-sectional area of 250mm^2 and above are joined by flash butt welding.

Application: Spot, seam and projection welding is widely used in the production of cars, tractors, farm machines, rail coaches etc. where thin sheets are to be joined.

Large sections like square, rectangular, cylindrical rods with regular and irregular end faces are welded without any edge preparations by flash butt or butt welding processes.

Advantages of resistance welding

- Widely used for joining sheet metals.
- Speedy process.
- No distortion.
- Less skilled operators can do the job.
- No problem of edge preparation.

Limitations

- The resistance welding machine is highly expensive
- lower tensile nod fatigue strength
- It is limited only to lab joints
- The limit of sheet metal thickness is less than 3mm.
- Less efficient for high conductive mentenil
- High electric power is required.

Metallizing, types of metallizing - principles

Objectives: At the end of this lesson you shall be able to
- **explain the purpose of metallizing in various process**
- **explain the principles and types of metallizing.**

Definition

Metallizing is a very common coating process which is used to improve the resistance of material agent/against corrosion, wear and fatigue.

Metallizing is the general name for the technique of coating metal on the surface of objects. Metallic coating may be decorative, protective or functional.

Types

Metallizing can be done by following

1 By electric arc spray process

2 By spray process

3 By thermal spray coating

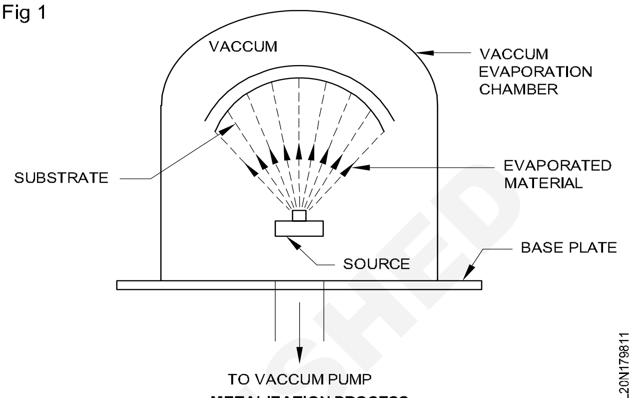
Application

1 Arc metalizing of products that will not corrective or rust proof

2 A steel structure protected by metalizing.

3 To improve the resistance of the material against the corrosion.

Fig 1



METALIZATION PROCESS

Principle

The metalizing process starts with preparing the surface of the product. Then a metal wire is melted in metalizing spray equipment to become molten. After this, clean and compressed air atomizes the material, and the air then transports the atomized metal onto the product surface to form the coating.

Manual oxy-acetylene powder coating - process principle of operation and applications

Objectives: At the end of this lesson you shall be able to
- **describe the manual powder coating process.**
- **explain the principle and applications of powder coating.**

Principles of powder coating

The powder coating process is very similar to a painting process except that the paint is a dry powder rather than a liquid.

The powder sticks to the parts due to electrostatic charging of the powder and grounding of the parts.

Any substance can be used that can tolerate of the heat of curing the powder and that can be electrically grounded to enhance charged particle attachment. The powder flows and curves during the application of heat.

Advantages of powder coating

1 Powder recovery for reuse
2 Expenditure will be less
3 Can be more durable than paints
4 Easily can do a work

Disadvantages of powder coating over paints are

1 Can have less leveling than paint
2 Curing is similar, typically more energy intensive than point drying due to higher temperature requirements.
3 Difficult to set a certain plants.

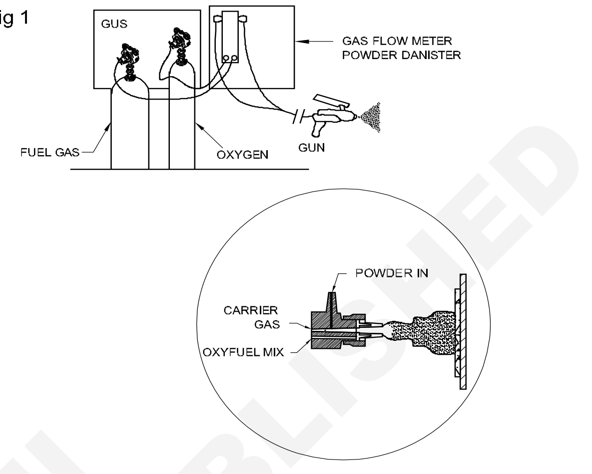
Operations

1 Cleaning
2 Rinsing
3 Phosphating
4 Drying
5 Powder coating
6 Curing

Uses of powder coating operating wings / Application

1 Railway factory
2 BEML factory
3 Dozer can be painted
4 Complicated parts are to be painted
5 Used in large scale industries
6 Maintenance of fabricated parts.

Fig 1



POWDER FLAME SPRAYING

Fig 2

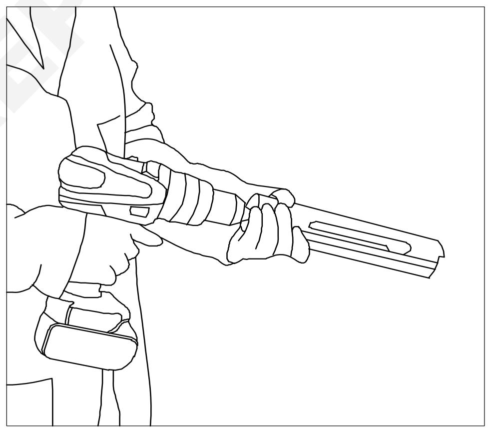
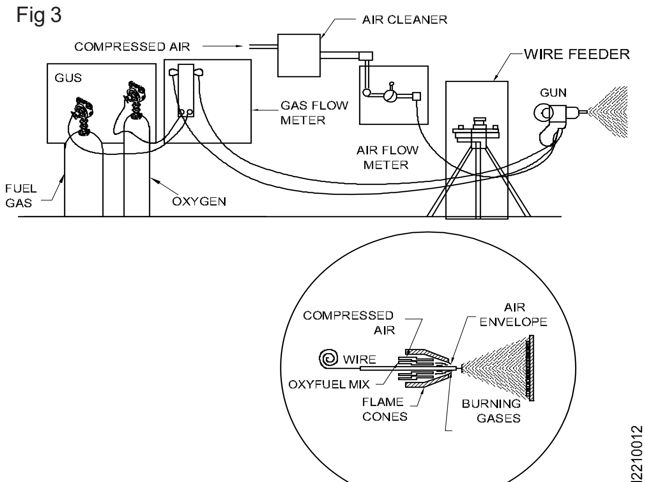


Fig 3

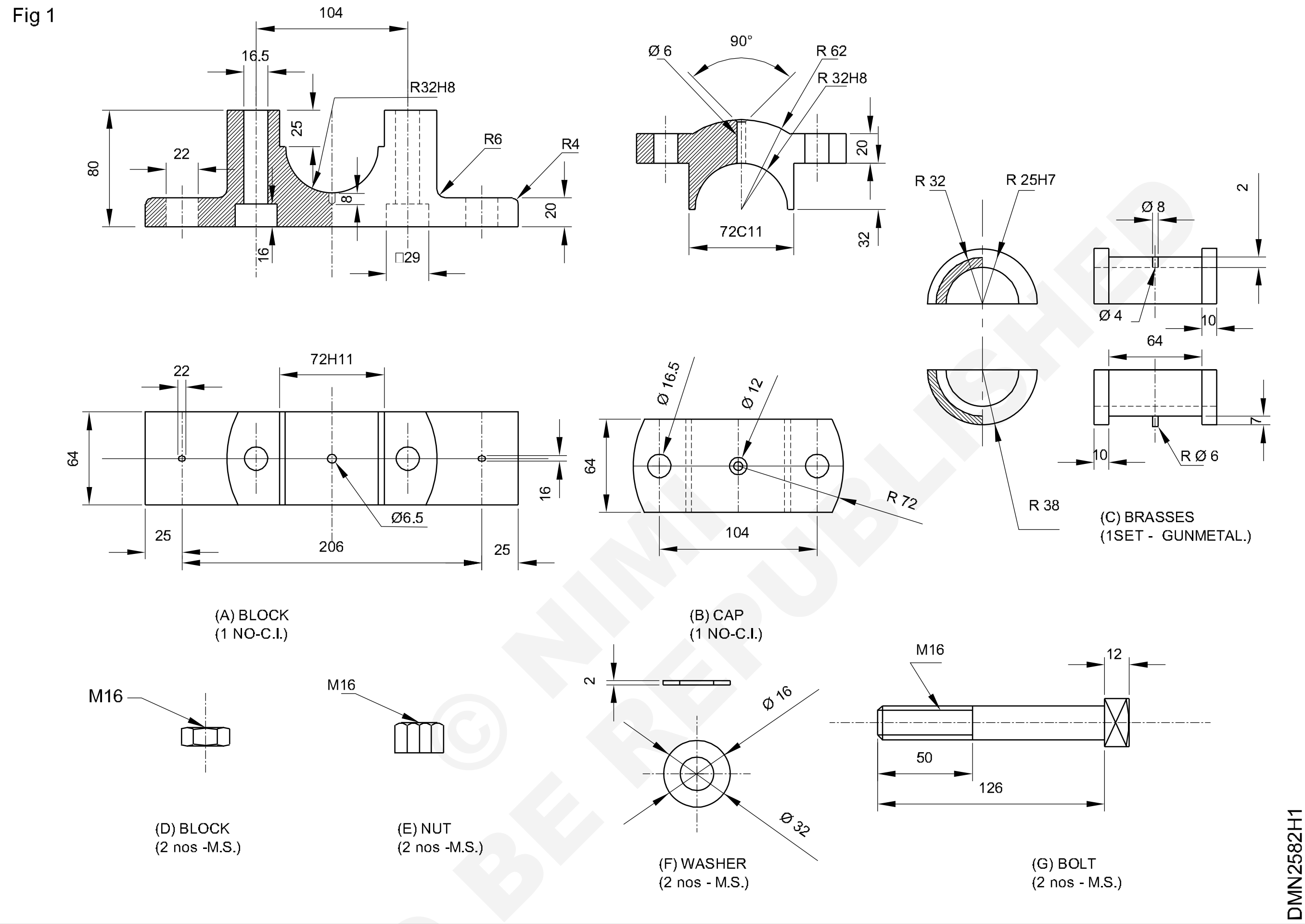


WIRE or ROD FLAME SPRAYING

Reading of assembly drawing

Objective: At the end of this lesson you shall be able to
- **identified the assembled jobs.**

Fig 1



Welding procedure specification (WPS) and procedure qualification record (PQR)

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 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 intended 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.

"F" numbers

All the electrodes and filler metals are grouped under different "F" numbers. The object of the "F" number grouping (Table 2) is to reduce the number of welding procedures and performance qualifications.

Table 2

"F" Number grouping

F1 to F6	Steel and steel alloys
F21 to F24	Aluminium and aluminium based alloys
F31 to F 37	Copper and copper based alloys
F41 to F45	Nickel and nickel based alloys
F51	Titanium and titanium alloys
F61	Zirconium and zirconium alloys
F71 to F72	Hard facing weld metal overlay.

The "F" number grouping is based essentially on their usability characteristics, with respect to coating. This fundamentally determines the ability of the welder to make a satisfactory weld with a given filler metal. For example, the low hydrogen electrodes have been grouped under "F" Number 4 and rutile steel electrode4s under "F" Number 2.

Obviously, a welder who is able to produce a sound weld with a E6013 (rutile) electrode may not be able to produce a sound weld with a low hydrogen lime powder coated electrode.

The skill required to use these electrodes is definitely not the same. "F" Number 1 is thus the easiest (iron powder) electrode used only in downhand fillet/butt and horizontal fillet positions.

'A' Numbers

A part from classifying the filler metals under "F" numbers, they are again classified under 'A' number as shown in Table 3. 'A' number classification of the filler metals is based on the weld metal chemical analysis whereas the 'F; number classification is based on the usability, or rather operation characteristics. With these definitions of 'P' numbers and 'A' numbers, we shall now see what the code says regarding welding procedures and welders qualification.

Table 3

'A' number grouping

A 1	Mild steel
A 2	Carbon - Molybdenum
A 3 to A 5	Chrome - Molybdenum
A 6	Chrome - Martensitic
A 7	Chrome - Ferritic
A 8 to A 9	Chrome - Nickel
A 10	Nickel - 4%
A 11	Manganese-Molybdenum
A12	Nickelchrome-Molybdenum

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.

6 Post - weld heat treatment

The temperature and soaking time of the post-weld heat treatment shall be shown here. Any change in this shall require a new procedure qualification.

7 **Electrical characteristics**

The type of current, (AC or DC) polarity, amps and voltage etc. have to indicated here.

8 **Gas**

The shielding gases flow rate, details of gas purging etc. will be shown here. Change in gas composition will call for re-qualification.

9 **Technique**

The details of the welding techniques string or weave bead, method of initial and interpass cleaning, back gouging, single or multiple passes, root grinding etc., shall be written here. The test welding can be done either in a plate or pipe material and in any position. The maximum thickness for which the procedure is applicable is generally twice the thickness of the test plate or pipe. The welder who welds the test joint is also qualified for that procedure but only in that position in which he welds whereas the procedure is applicable to all positions. The results of the tests shall be recorded in the PQR including welding, NDT and mechanical test results.

Welder's qualification

The purpose of the welder's qualification is to determine the ability of the welder to make sound welds.

The welder may be qualified, based on the results of the mechanical test (two face bends and two root bend tests or four side bend tests) or by radiographic examination of a minimum length of 150 mm for a plate or the entire weld for a pipe. The position of the weld joint has been classified as 1G, 2G, 3G, 4G, 5G and 6G. Table 4 shows the positions qualifying for other positions.

Table 4

Range of positions qualified

Test position	Also qualifies
1G	1G
2G	1G
3G	1G
4G	1G & 3G
5G	1G & 3G
2G & 5G	All positions
6G	All positions

For positions 1G and 2G (flat and horizontal) qualification on a plate shall also qualify the welder in pipes. For all other positions, qualification on a pipe shall qualify for plate but not vice versa.

A qualification in a plate or pipe butt joint shall also qualify the welder for fillet welding in all plate thickness and pipe diameters.

Hard facing/surfacing necessity surface preparation various hard facing alloys and advantages of hard facing

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of hard facing**
- **describe the method of preparation for hard facing**
- **describe the various hard facing alloys**
- **explain the advantages of hard facing.**

Necessity of hard facing: This operation consists of depositing a layer of harder metal on a softer base metal in order to provide a surface having special properties such as toughness, hardness and resistance to abrasion, heat and corrosion.

This is also done to build up worn out areas of a hardened component due to long and continuous use and make them as good as new with low cost and quickly.

Preparation: Clean the surface of the part to be hard faced, by grinding, machining, filing, chipping or sand blasting until it is free from dirt, scale etc.

Remove sharp corners which melt easily or get oxidized.

Hard facing alloys

Different groups of materials used for hard facing are:

– Ferrous alloy group

– Non-ferrous alloy group

– Diamond substitute group

Ferrous alloy group: This group comprises welding electrodes having an iron base alloyed with chromium, manganese, molybdenum, nickel, zirconium, boron and silicon.

Non-ferrous alloy group: This group consists of welding electrodes which are alloys of chromium, tungsten, cobalt and molybdenum and some times small quantities of iron.

Diamond substitute group: This group composed of carbides of tungsten, tantalum, titanium and boron and the borides of chromium is so called because its hard facing materials approach the hardness of a diamond.

Hard facing electrodes are designed on the basis of hardness of their weld deposits as follows.

Application: Chromium and tungsten carbide electrodes are used for severe abrasion - resistance.

High carbon type electrodes are used for moderate abrasion and impact resistance.

Stainless steel electrodes are used for severe impact and moderately severe abrasion resistance.

Hard facing with MMAW process: Clean the surface thoroughly and arrange the work in a flat position.

Preheat to about 95°-150°C.

Use only enough amperage to provide sufficient heat to maintain the arc. Avoid high current and short arc length.

This is very important to prevent dilution of the deposit with the base metal.

Use the stringer or slight weaving technique holding a medium arc.

Deposit 25 to 50 mm long beads not wider than twice the diameter of the electrode.

Allow the work to cool between each deposit of beads.

Stagger the deposits to prevent building up of high heat at only one spot.

Chip the slag between passes.

Slow cooling by covering the job with sand or ashes or slaked lime is to be done.

The number of layers will vary from job to job. But it should be noted that the first layer deposited on mild steel is diluted by the 'pick-up' from the plate. (i.e. the soft mild steel from base metal will mix with the hard deposited metal and therefore the I layer will have less hardness.

It is never advisable to make more than three layers because such a mass of metal may crack in service or during deposition.

Advantages of hard facing

Longer life of wearing parts (2 to 20 times, depending on the type of service).

Increased mechanical operating efficiency.

Reduced idle time of plant.

Use of reconditioned worn out parts instead of costly new replacement parts.

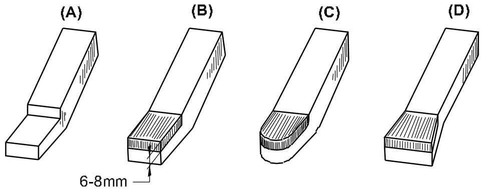
Reduced labour costs because of fewer replacements.

Greater independence during periods of replacement of parts when there is a shortage.

Applications

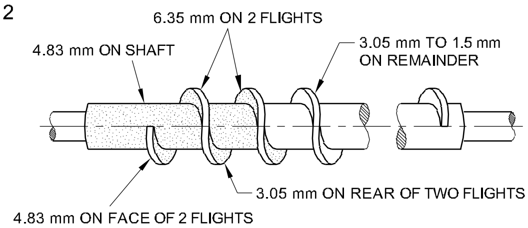
Different hard-faced products are illustrated in Figs 1 to 9.

Fig 1



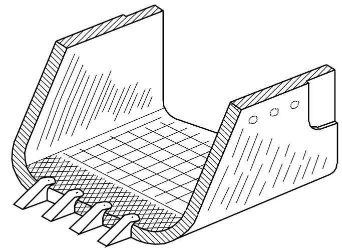
BUILDING A CUTTING TIP ON MILD STEEL SHANK
ALTERNATIVE WAYS OF FINISHING BY GRINDING

Fig 2



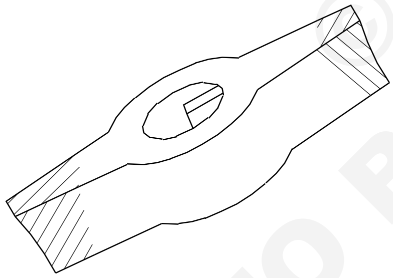
CONTROL OF HARD FACING
DEPOSIT ON A CEMENT CONVEYOR SCREW

Fig 3



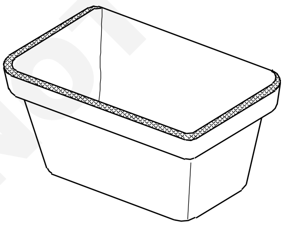
HARD FACING SHOVEL BUCKET FRONTS

Fig 4



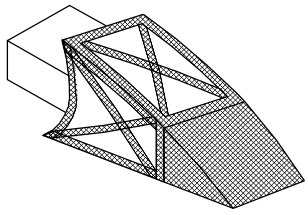
HARD FACING FEEDER BLADES

Fig 5



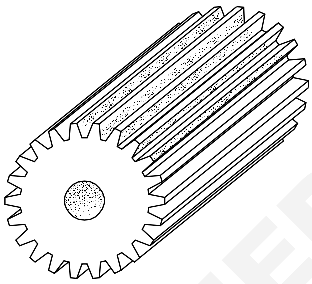
HARD FACING ELEVATOR BUCKET LIPS

Fig 6



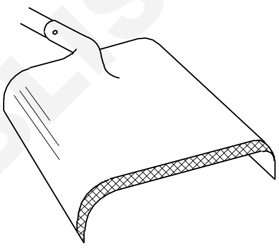
HARD FACING SHOVEL BUCKET TEETH

Fig 7



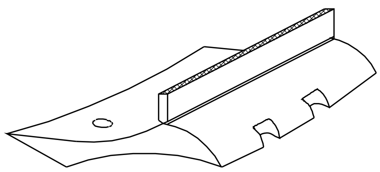
HARD FACING GEAR TEETH (PINION GEARS)

Fig 8



HARD FACING KILN SCOOP SHOVELS

Fig 9



HARD FACING TRACTOR GROUSERS

Plastic welding machine with hot air gun and plastic material

Objectives: At the end of this lesson you shall be able to
- **explain the plastic welding process**
- **explain the parts and working principle of hot air gun**
- **describe the application of hot air gun**
- **describe the welding plastic materials.**

Plastic welder processes

Plastic welding is the process of creating a molecular bond between two suitable thermoplastic, plastic welding offers superior strength and reduces cycle time.

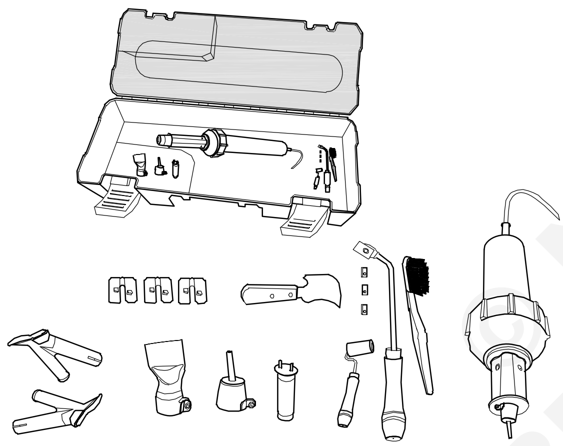
Pressing

Heating

Cooling

Plastic welding hot air gun

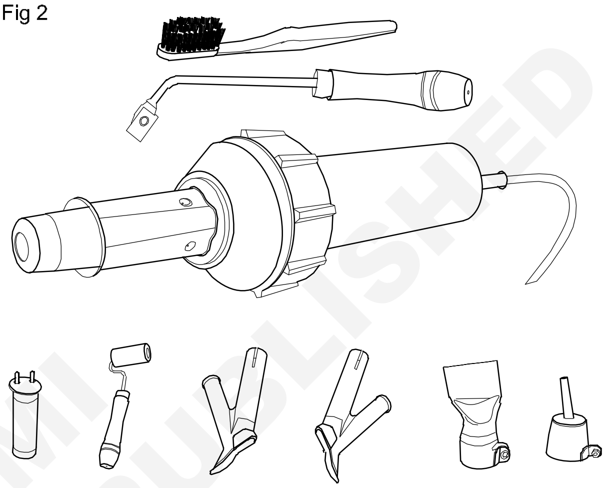
Fig 1



PLASTIC WELDING AIR GUN

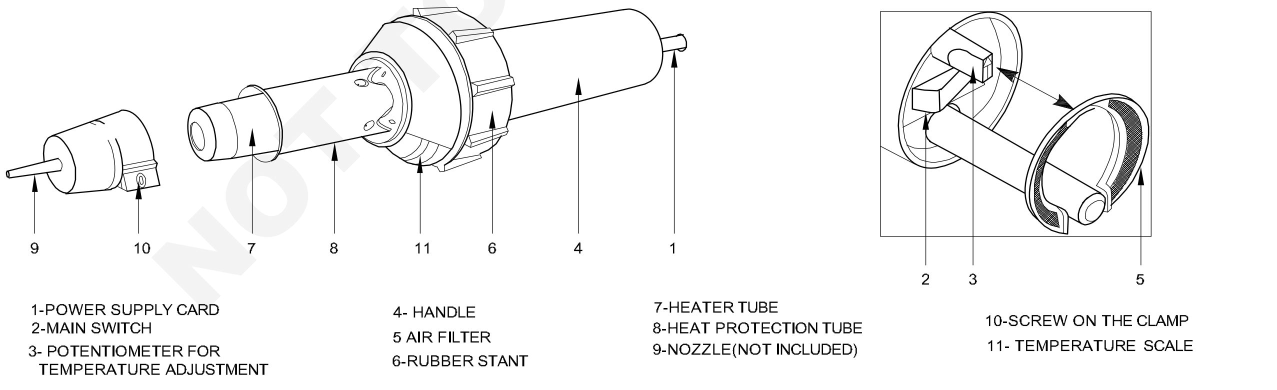
Hot air gun kit

Fig 2



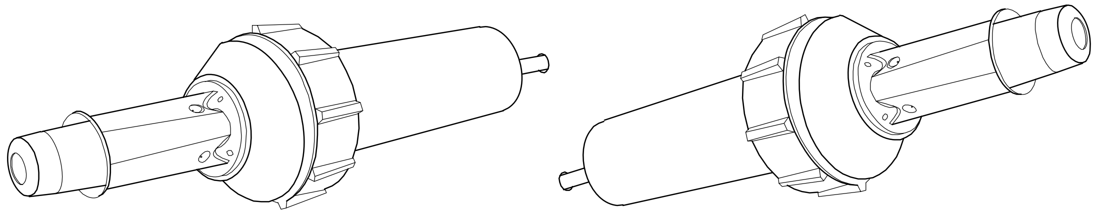
HOT AIR GUN KIT

Fig 3



1 Power supply cord
2 Main switch
3 Potentiometer for temperature adjustment
4 Handle
5 Air filter
6 Rubber stand
7 Heater tube
8 Heat protection tube
9 Nozzle (Nor included)
10 Screw on the clamp
11 Temperature scale

Fig 4



WL20N1710314

Operation

- Carry out test weld in accordance with the material
- Check the test weld
- Set welding temperature (welding parameter) as required
- Cool down the tool after use.

Application

- Welding of thermoplastic materials as well as (tubes, profiles, lining membranes, coated materials, films, foams, tiles, and sheets).
- Heating – up for forming, bending and sealing of thermoplastic semi-finished materials and plastic granules.
- Drying of water –damp surfaces
- Shrinking of heat –shrink sleeves, films, tapes, solder sleeves, pre formed and moulded parts
- Soldering of copper pipes, solder joints and metal foils
- Defrosting of frozen water pipes
- Activating /dissolving of solvent free adhesives and fusion adhesives
- Igniting of wood shavings, paper, coal or straw in furnaces

Polyethylene

Polyethylene (PE) is the most widely used thermoplastic polymer for fabricated parts and components. It is available in a variety of grades and formulations to suit different needs. In general, polyethylene offers excellent chemical; and impact resistance, electrical properties and low coefficient of friction. It is considered a dielectric material. In addition, polyethylene are lightweight, easily processed and offer near – zero moisture absorption.

Welding polypropylene

Polypropylene (PP) is one of the easiest to weld and is used for many different applications. PP has excellent chemical resistance, low specific gravity, high tensile strength and is the most dimensionally stable polyolefin. Proven applications using PP are plating equipment, tanks, ductwork, etchers, fume hoods scrubbers and orthopaedics.

Polyvinyl chloride

Polyvinyl chloride (PVC or vinyl) is an economical and versatile thermoplastic polymer widely used in the building and construction industry to produce door and window profiles, pipes (drinking and wastewater), wire and cable insulation, medical devices, etc. It is the world's third – largest thermoplastic material by volume after polyethylene and polypropylene

It is a white, brittle solid material available in powder form granules. Due to its versatile properties, such as lightweight, durable, low cost and easy process ability, PVC is now replacing traditional building materials like wood, metal, concrete, rubber, ceramics, etc. in several applications.