WELDER (PIPE)

NSQF LEVEL - 3

TRADE THEORY

SECTOR : CAPITAL GOODS & MANUFACTURING

(As per revised syllabus July 2022 - 1200hrs)

कौशलं बलम्

Directorate General of Training

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

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

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Sector : **Capital Goods & Manufacturing**

Duration : **1 Year**

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

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of Media Development Committee members of various stakeholders viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **Welder (Pipe) - Trade Theory** in **Capital Goods & Manufacturing** 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 Instructional Media Packages IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

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

Jai Hind

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New Delhi - 110 001

PREFACE

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

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

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

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

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

Chennai - 600 032 **EXECUTIVE DIRECTOR**

ACKNOWLEDGEMENT

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

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

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

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

INTRODUCTION

TRADE PRACTICAL

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

The manual is divided into Seven modules.

	Module Name
Module 1	Induction Training & Welding process
Module 2	Welding Techniques
Module 3	Weldability of Steels
Module 4	Plasma Cutting
Module 5	SMAW
Module 6	GTAW & GMAW
Module 7	Inspection & Testing

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

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

TRADE THEORY

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

The Trade theory has to be taught and learnt along with the corresponding exercise contained in the manual on trade Theory. 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

S.No	Learning Outcome	Lesson No
1	Join MS plates by SMAW in different positions following safety precautions. (NOS: CSC/N0204)	1.1.01 - 1.1.08
2	Join MS sheet by Gas welding in different positions following safety precautions. (NOS: CSC/N0204)	1.1.09 - 1.2.11
3	Perform straight, bevel & circular cutting on MS plate by Oxy-acetylene cutting process. (NOS: CSC/N0201)	1.2.12 - 1.2.34
4	Perform different types of MS pipe joints by Gas welding (OAW). (NOS: CSC/N0204)	1.3.35 - 1.3.40
5	Weld different types of MS pipe joints by SMAW. (Mapped NOS: CSC/N0204)	1.3.41 - 1.3.48
6	Perform welding of Stainless steel, Cast iron, Aluminium and Brass by OAW. (NOS: CSC/9482)	1.3.49 - 1.3.51
7	Perform Arc gauging on MS plate. (NOS: CSC/N0204)	1.3.52 - 1.3.55
8	Perform Plasma cutting. (NOS: CSC/N0207)	1.4.56 - 1.4.59
9	Carry out single V groove welds on MS plates by SMAW in 1G, 2G, 3G and 4G positions. (NOS: CSC/N0204)	1.5.60 - 1.5.73
10	Carry out single V groove welds on MS pipes by SMAW in 1G, 2G, 5G and 6G positions. (NOS: CSC/N0204)	1.5.74 - 1.6.80
11	Perform Root pass welds in Weld single Vee butt joints on schedule 40 pipes in 1G, 2G and 5G positions by GTAW. (NOS: CSC/N0212)	1.6.81 - 1.6.100
12	Perform Root pass welds in Weld single Vee butt joints on schedule 60 pipes and schedule 80 pipes in 6G positions by GTAW and intermediate and cover pass weld by SMAW. (NOS: CSC/N0212)	1.6.101 - 1.6.116
13	Perform single Vee butt joint welding on MS pipes by GMAW in 1G position. (NOS: CSC/N0209)	1.6.117 - 1.6.118
14	Carry out Dimensional inspection and testing of weldments. (NOS: CSC/N0204)	1.7.119 - 1.7.122

SYLLABUS

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 41Hrs; Professional Knowledge 08Hrs	Join MS plates by SMAW in different positions following safety precautions. (Mapped NOS: CSC/N0204)	Induction training: 1. Familiarization with the Institute. 2. Importance of trade Training. 3. Machinery used in the trade. 4. Introduction to safety equipment and their use etc. 5. Hack sawing, filing square to dimensions. 6. Marking out on MS plate and punching. 7. Setting up of Arc welding machine & accessories and striking an arc. 8. Setting of oxy-acetylene welding equipment, Lighting and setting of flame.	- General discipline in the Institute. - Elementary First Aid. - Importance of Welding in Industry. - Safety precautions in Shielded Metal Arc Welding, and Oxy-Acetylene Welding and Cutting. - Introduction and definition of welding. - Arc and Gas Welding Equipments, tools and accessories. - Various Welding Processes and its applications. - Arc and Gas Welding terms and definitions.
Professional Skill 21Hrs; Professional Knowledge 04 Hrs	Join MS sheet by Gas welding in different positions following safety precautions. (NOS: CSC/N0204)	9. Fusion run without and with filler rod on M.S. sheet 2 mm thick in flat position. 10. Edge joint on MS sheet 2 mm thick in flat position without filler rod. 11. Marking and straight line cutting of MS plate. 10 mm thick by gas.	- Different process of metal joining methods: Bolting, riveting, soldering, brazing. - Types of welding joints and its applications. Edge preparation and fit up for different thickness. - Surface Cleaning
Professional Skill 184Hrs; Professional Knowledge 36 Hrs	Perform straight, bevel & circular cutting on MS plate by Oxy-acetylene cutting process. (Mapped NOS: CSC/N0201)	12. Straight line beads on M.S. plate 10 mm thick in flat position. 13 Copper tube ½ inch swage joint by brazing with induction welding. 14. Square butt joint on M.S. sheet 2 mm thick in flat Position. 15. Fillet "T" joint on M. S. Plate 10 mm thick in flat position.	- Basic electricity applicable to arc welding and related electrical terms & definitions. - Heat and temperature and its terms related to welding - Principle of arc welding. And characteristics of arc. - Common gases used for welding & cutting, flame temperatures and uses. - Types of oxy-acetylene flames and uses. - Oxy-Acetylene Cutting Equipment principle, parameters and application.
		16. Bevelling of MS plates 10 mm thick by gas cutting. 17. Open corner joint on MS Sheet 2 mm thick in flat Position.	- Arc welding power sources: Transformer,Rectifier and Inverter type welding machines and its care & maintenance.

		18. Fillet lap joint on M.S. plate 10 mm thick in flat position. 19. Iron pipe ½ inch butt joint by induction welding 20. Fillet "T" joint on M S sheet 2 mm thick in flat position. 21. Open Corner joint on MS plate 10 mm thick in flat position.	- Advantages and disadvantages of A.C. and D.C. welding machines. - Welding positions as per EN & ASME: flat, horizontal, vertical and overhead position. - Weld slope and rotation. Welding symbols as per BIS & AWS.
		22. Fillet Lap joint on MS sheet 2 mm thick in flat position. 23. Single "V" Butt joint on M S plate 12 mm thick in flat position (1G).	- Arc length - types - effects of arc length. - Polarity: Types and applications.
		24. Square Butt joint on M.S. sheet. 2mm thick in Horizontal position. 25. Straight line beads and multi layer practice on M.S. Plate 10 mm thick in Horizontal position. 26. F "T" 10 mm thick in Horizontal position.	- Calcium carbide uses and hazards - Acetylene gas properties. - Acetylene gas Flash back arrestor.
		27. Fillet Lap joint on M.S. sheet 2 mm thick in horizontal position. 28. Fillet Lap joint on M.S. plate 10 mm thick in horizontal position.	- Oxygen gas and its properties - Charging process of oxygen and acetylene gases - Oxygen and Dissolved Acetylene gas cylinders and Color coding for different gas cylinders. - Uses of Single stage and double stage Gas regulators.
		29. Make a long elbow joint with PVC pipe by plastic welding 02.5 inch (pipe) and length 30 mm of pipe. 30. Square Butt joint on M.S. sheet. 2 mm thick in vertical position. 31. Single Vee Butt joint on M.S. plate 12 mm thick in horizontal position (2G).	- Oxy acetylene gas welding Systems (Low pressure and High pressure). Difference between gas welding blow pipe(LP & HP) and gas cutting blowpipe - Gas welding techniques. Rightward and Leftward techniques.
		32. T-joint of PVC sheet, with dimension (150*50*5mm) two pieces from plastic welding with hot air. 33. Fillet "T" joint on M.S sheet 2 mm thick in vertical position. 34. F "T" 10 mm thick in vertical position.	- Arc blow - causes and methods of controlling. - Distortion in arc & gas welding and methods employed to minimize distortion Arc Welding defects, causes and Remedies.
Professional Skill 42Hrs; Professional Knowledge 08Hrs	Perform different types of MS pipe joints by Gas welding (OAW). (NOS:CSC/N0204)	35. Structural pipe welding butt joint on MS pipe 0 50 and 3mm WT in 1G position. 36. Fillet Lap joint on M.S. Plate 10 mm in vertical position. 37. Open Corner joint on MS plate 10 mm thick in vertical position. 38. Pipe welding - Elbow joint on MS pipe 0 -50 and 3mm WT.	- Specification of pipes, various types of pipe joints, pipe welding positions, and procedure. - Difference between pipe welding and plate welding. - Pipe development for Elbow joint, "T" joint, Y joint and branch joint.

		39. Pipe welding "T" joint on MS pipe 0 50 and 3mm WT. 40. Single "V" Butt joint on M S plate 12 mm thick in vertical position (3G).	- Uses of Manifold system - Gas welding filler rods, specifications and sizes. - Gas welding fluxes - types and functions. - Gas Brazing & Soldering: principles, types fluxes & uses - Gas welding defects, causes and remedies.
Professional Skill 44 Hrs; Professional Knowledge 10 Hrs	Weld different types of MS pipe joints by SMAW. (Mapped NOS: CSC/N0204)	41. Pipe welding 45 ° angle joint on MS pipe 0 50 and 3mm WT. 42. Straight line beads on M.S.plate 10mm thick in overhead position.	- Electrode: types, functions of flux, coating factor, sizes of electrode. - Effects of moisture pick up. - Storage and baking of electrodes.
		43. Pipe Flange joint on M.S plate with MS pipe 0 50 mm X 3mm WT. 44. F "T"10 mm thick in overhead position.	- Weldability of metals, importance of pre heating, post heating and maintenance of inter pass temperature.
		45. Pipe welding butt joint on MS pipe 0 50 and 5 mm WT. in 1G position. 46. Fillet Lap joint on M.S. plate 10 mm thick in overhead position.	- Welding of low, medium and high carbon steel and alloy steels.
		47. Single "V" Butt joint on MS plate 10mm thick in over head position(4G)(06hrs.) 48. Pipe butt joint on M. S. pipe 0 50mm WT 6mm (1G Rolled).	- Stainless steel: types- weld decay and weldability.
Professional Skill 22Hrs; Professional Knowledge 04Hrs	Perform welding of Stainless steel, Cast iron, Aluminium and Brass by OAW. (NOS: CSC/9482)	49. Square Butt joint on S.S. sheet. 2 mm thick in flat position. 50. Square Butt joint on S.S. Sheet 2 mm thick in flat position. 51. Square Butt joint on Brass sheet 2 mm thick in flat position.	- Brass - types - properties and welding methods. - Copper - types - properties and welding methods. - Introduction to induction welding, its parameter and check.
Professional Skill 42 Hrs; Professional Knowledge 08Hrs	Perform Arc gauging on MS plate. (NOS: CSC/ N0204)	52. Square Butt & Lap joint on M.S. sheet 2mm thick by brazing. 53. Single "V" butt joint C.I. plate 6mm thick in flat position. 54. Arc gouging on MS plate 10mm thick.	- Aluminium, properties and weldability, Welding methods - Arc cutting & gouging,
		55. Square Butt joint on Aluminium sheet. 3 mm thick in flat position."B" butt joint) 6mm thick plate.	- Cast iron and its properties types. - Welding methods of cast iron.
Professional Skill 24Hrs; Professional Knowledge 04 Hrs	Perform Plasma cutting. (Mapped NOS: CSC/ N0207)	56. Familiarization with the machinery used in the trade. 57. Cutting practice on M.S. plates using gas cutting methods. 58. Cutting practice of M.S. plates using plasma cutting methods.	- Outline of the subjects to be covered - Importance of pressure vessels and pipe welding - Gas cutting & plasma cutting

		59. Gouging practice.	- Safety in welding
Professional Skill 123Hrs; Professional Knowledge 24Hrs	Carry out single V groove welds on MS plates by SMAW in 1G, 2G, 3G and 4G positions. (Mapped NOS: CSC/ N0204)	60. Edge preparation for plate groove welding. 61. Fit up of joints by tack welding using simple fixtures. 62. Pipe and plate flange joint welding. 63. T and Y and pipe joint welding. 64. Groove welding on plate in 1G & 2Gpositions. 65. Inspection and clearance using LPI testing during Root pass and cover pass.	- Principles of Shielded Metal Arc Welding (SMAW). - Types of power source. - Polarity type and arc length. - Welding positions and importance. - Edge preparation and tack welding procedure. - Welding fixtures and clamps.
		66. Groove welding on plate in 3G position. 67. Inspection and clearance using LPI testing during Root pass and cover pass.	- Electrodes - types - description - Functions of flux and characteristic of flux.
		68. Groove welding on plate in 3G position. 69. Inspection and clearance using LPI testing during Root pass and cover pass.	- Selection of electrodes (Rutile / Cellulosic / Low hydrogen etc.) & coating factors. - Electrode storage and backing temperature.
		70. Groove welding on plate in 4G position. 71. Inspection and clearance using LPI testing during Root pass and cover pass.	- Types of metals and their characteristics.
		72. Groove welding on plate in 4G position. 73. Inspection and clearance using LPI testing during Root pass and cover pass.	- Introduction to pipe welding. - Types of pipes and pipe schedule. - Preparation work before welding.
Professional Skill 45Hrs; Professional Knowledge 08Hrs	Carry out single V groove welds on MS pipes by SMAW in 1G, 2G, 5G and 6G positions. (Mapped NOS: CSC/ N0204)	74. Preparation of pipe joint for pipe welding (schedule 40). 75. Prepare the edges, clean the joint surfaces, Fit up the pipes and tack weld the pipes. 76. Fit up inspection.	- Basic pipe welding procedure uphill welding, downhill welding and horizontal welding.
		77. Welding of pipes (schedule 40) in 1G position. (08hrs.) 78. Inspection and clearance using LPI testing during Root pass and cover pass. (05hrs.) 79. Welding of pipes (schedule 40) in 2G position. (07hrs.) 80. Inspection and clearance using LPI testing during Root pass and cover pass. (05hrs.)	- Pipe welding position 1G, 2G, 5G & 6G - Selection of electrode (SMAW) for root pass and cover pass welding. - Procedure for welding heavy wall pipes in 5G position welding. (07 hrs.)

Professional Skill 123Hrs; Professional Knowledge 24Hrs	Perform Root pass welds in Weld single Vee butt joints on schedule 40 pipes in 1G, 2G and 5G positions by GTAW. (Mapped NOS: CSC/N0212)	81. Root welding of pipes (schedule 40) in 5G position. 82. Intermediate and cover pass welding in 5G position. 83. Inspection and clearance using LPI testing.	- Procedure for welding heavy wall pipes in 6G position welding
		84. Root welding of pipes (schedule 40) in 5G position 85. Intermediate and cover pass welding in 5G position. 86. Inspection and clearance using LPI testing.	- Welding symbols Procedure for welding of thin wall pipes in downhill position. - Procedure forwelding pipes in 2G position.
		87. Beading practice by TIG on MS sheets. 88. Square butt joint on M.S. sheet in flat position. 89. Square butt joint on M.S. sheet in flat position. 90. Inspection and clearance using LPI testing.	- Welding procedure for complicated pipe joint, T- joints with intersection. - Top, Bottom and Side - Y joint etc.
		91. Square butt joint on M.S. sheet in 2G position. 92. Inspection and clearance using LPI testing. 93. Square butt joint on M.S. sheet in 3G position. 94. Inspection and clearance using LPI testing.	- Introduction to GTAW welding - Advantages, Equipment - Electrode.
		95. Square butt joint on M.S. sheet in 4G position. 96. Inspection and clearance using LPI testing.	- Shielding Gas and Advantage of root pass welding by GTAW.
		97. Root pass welding of pipes(schedule 40) 1G positions by TIG. 98. Inspection and clearance using LPI testing. 99. Root pass welding of pipes (schedule 40) 2G positions by TIG. 100. Inspection and clearance using LPI testing.	- Importance of preheating, post heating and post weld heat treatment - Welding metallurgy - weld stress - Distortion and control. - Correction of distorted section.
Professional Skill 85Hrs; Professional Knowledge 16Hrs	Perform Root pass welds in Weld single Vee butt joints on schedule 60 pipes and schedule 80 pipes in 6G positions by GTAW and intermediate and cover pass weld by SMAW. (Mapped NOS: CSC/ 0212)	101. Root pass welding of pipes (schedule 60) 5G positions by TIG. 102. Inspection and clearance using LPI testing. 103. Root pass welding of pipes (schedule 60) 6G positions by TIG. 104. Inspection and clearance using LPI testing.	- Introduction to GMAW & Flux cored arc welding - Equipment, accessories, Advantages and Limitations.

		105.Pipe welding dia 50mm in 2G position by GTAW.	
		106.Root pass welding of pipes (schedule 60) 6G positions by TIG. 107.Inspection and clearance using LPI testing. 108.Cover pass Intermediate pass by SMAW. 109.Inspection and clearance using LPI testing.	- Power source - Wire feeder - Electrode wires - shielding gases - Types of metal transfer and welding parameters
		110.Root pass welding of pipes (schedule 80) 6G positions by SMAW (by pipe welding electrode) 111. Inspection and clearance using LPI testing. 112.Cover pass and Intermediate passes bySMAW. (by low hydrogen electrode) 113.Inspection and clearance using LP testing.	- Types of welding defects, cause and remedy. - Non-destructive testing methods. - Introduction to plastic welding (PP,PE& PVC), its parameter & Check
		114.Square butt joint on M.S. sheet in flat position by GMAW. 115.Single V joint on M.S. plate in flat position by GMAW. 116.Inspection and clearance using LP testing.	- Requirement for qualification in different codes. - Qualification procedure under various codes. - Different tests and inspection involved in qualification.
Professional Skill 22 Hrs; Professional Knowledge 04 Hrs	Perform single Vee butt joint welding on MS pipes by GMAW in 1G position. (Mapped NOS: CSC/N0209)	117.Pipe (schedule 40) welding by GMAW in 1G position by GMAW. 118.Pipe (schedule 60) welding by GMAW in 1G position by GMAW.	- Inspection and testing of weldments. - Visual inspection kits and Gauges.
Professional Skill 22 Hrs; Professional Knowledge 04 Hrs	Carry out Dimensional inspection and testing of weldments. (Mapped NOS: CSC/N0204)	119.Dimensional inspection of weldments. 120.Visual inspection of weldments. 121.Non-destructive testing of weldments 122.Bend Testing of specimen according to codes and standards.	- Pressure welding codes and standards (IBR, ASME etc.) - Writing procedure for WPS and PQR

General Discipline in the Institute

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

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

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

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

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

Do not be late to the theory and practical classes.

Do not unnecessarily interfere in other's activities.

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

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

Be interested in all the training activities.

Do not make noise or be playful while undergoing training.

Keep the institute premises neat and avoid polluting the environment.

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

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

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

Prepare well before writing a test/examination.

Avoid any malpractice during the test/examination.

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

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

Elementary First Aid

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

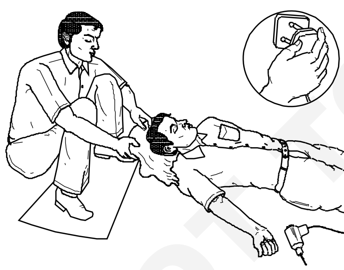
Electrical shock and breathing problems: The severity of an electric shock will depend on the level of the current which passes through the body and the length of time of contact, Do not delay to disconnect the contact.

If the person is still in contact with the electric supply break the contact either by switching off the power by removing the plug or wrenching the cable free. If not, stand on some insulating material such as dry wood, rubber or plastic, or using whatever is at hand to insulate yourself and break the contact by pushing or pulling the person free. (Fig1 & 2)

Fig 1

WP20N110211

Fig 2



WP20N110212

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

WP20N110213

Keep a constant check on the breathing and pulse rate.

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

Send for help.

Fig 4

WP20N110214

Do not give an unconscious person anything by mouth.

Do not leave an unconscious person unattended.

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

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

Other factors that contribute to the severity of shocks are:

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

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

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

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

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

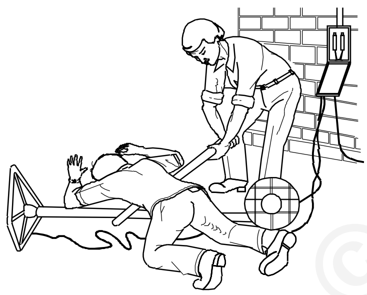
Treatment for electric shock:

Prompt treatment is essential

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

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

Fig 5



WP20N110215

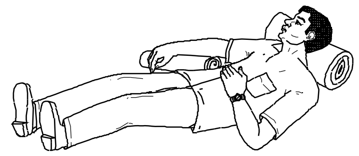
Avoid direct contact with the victim. Wrap your hands in dry material if rubber gloves are not available

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.

Fig 6

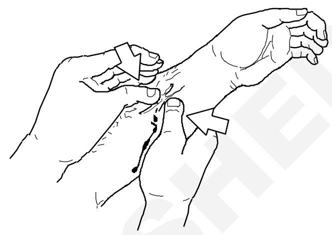


WP20N110216

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)
- Apply pressure on the wound.

Fig 7



WP20N110217

- Call for assistance.

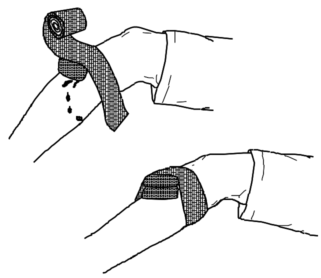
To control severe bleeding: Squeeze together the sides of the wound. Apply pressure as long as it is necessary to stop the bleeding. When the bleeding has stopped, put a dressing over the wound, and cover it with a pad of soft material. (Fig 7)

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)

Follow the right methods of artificial respiration.

Fig 8



WP20N110218

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

Importance of Welding in Industry

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

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

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

So all industries are using welding for the 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.

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

Safety in Shielded Metal Arc Welding and Oxy Acetylene Welding and Cutting

Objectives : At the end of this lesson you shall be able to
- **identify the safety apparels and accessories used in arc welding**
- **select the safety apparels and accessories to protect from burns and injuries**
- **learn how to protect yourself and others from the effect of harmful arc rays and toxic fumes**
- **select the shielding glass for eye and face protection.**

Non-fusion welding

This is a method of welding in which similar or dissimilar metals are joined together without melting the edges of the base metal by using a low melting point filler rod but without the application of pressure.

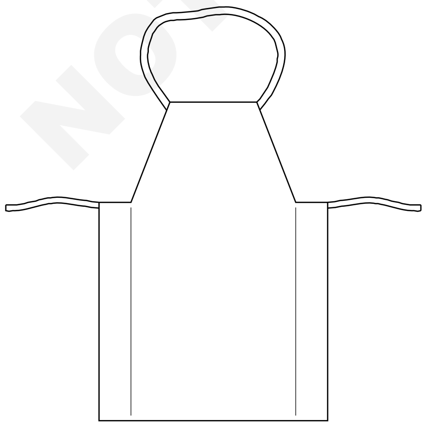
Example: Soldering, Brazing and Bronze welding.

During arc welding the welder is exposed to hazards such injury due to harmful rays (Ultra violet and infra red rays) of the arc, burns due to excessive heat from the arc and contact with hot jobs, electric shock. Toxic fumes, flying hot spatters and slag particles and objects falling on the feet.

The following safety apparels and accessories are used to protect the welder and other persons working near the welding area from the above mentioned hazards.

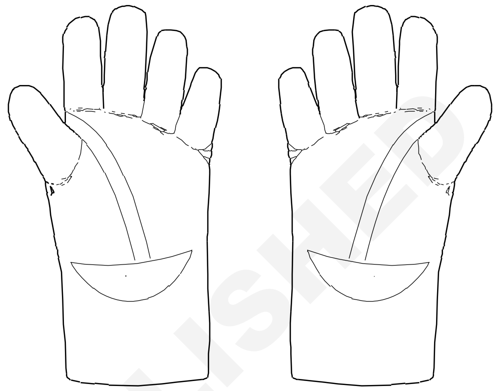
1 Safety apparels
   a Leather apron
   b Leather gloves
   c Leather cape with sleeves
   d Industrial safety shoes
2 a Hand screen
   b Adjustable helmet
   c Portable fire proof canvas screens
3 Chipping/grinding goggles
4 Respirator and exhaust ducting

Fig 1



APRON

Fig 2



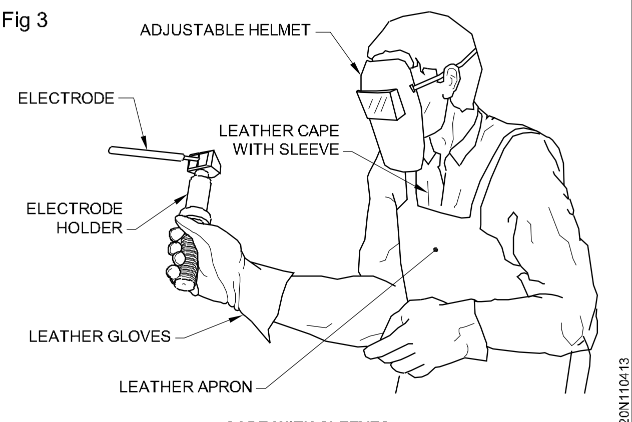
GLOVES

The leather apron, gloves, cape with sleeves and leg guard Fig 3,4,5 and 6 are used to protect the body, hands, arms, neck and chest of the welder from the heat radiation and hot spatters, from the arc and also from the hot slag particles flying from the weld joint during chipping off the solidified slag.

All the above safety apparels should not be loose while wearing them and suitable size has to be selected by the welder.

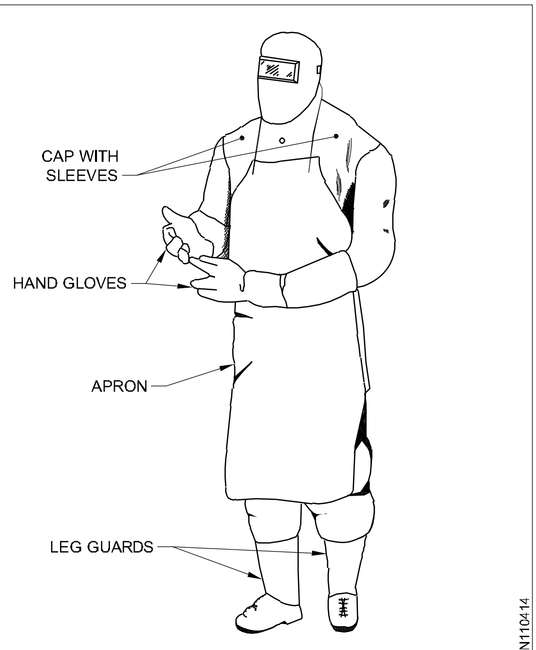
The industrial safety boot (Fig 5) is used to avoid slipping injury to the toes and ankle to the foot. It also protects the welder from the electric shock as the sole of the shoe is specially made of shock resistant material.

Fig 3



CAPE WITH SLEEVES

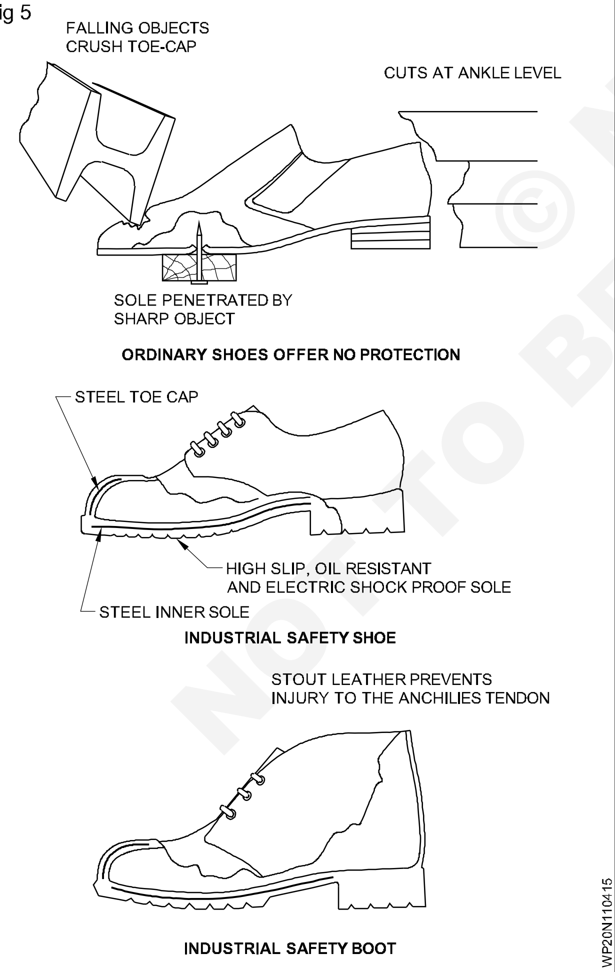
Fig 4



LEG GUARDS

Welding hand screens and helmet: These are used to protect the eyes and face of a welder from arc radiation and sparks during arc welding.

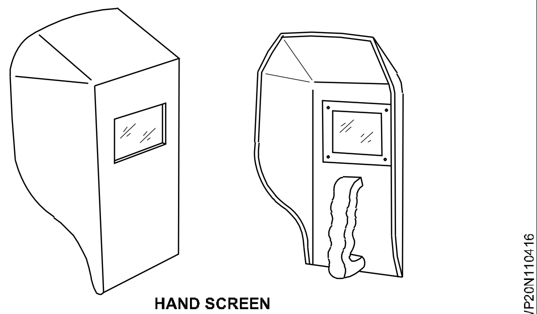
Fig 5



INDUSTRIAL SAFETY BOOT

A hand screen is designed to hold in hand. (Fig 6)

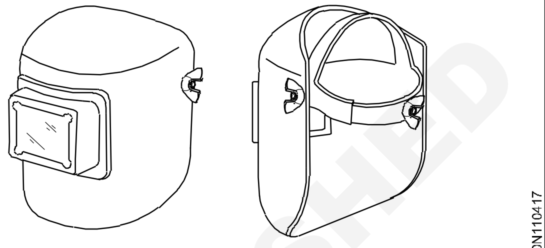
Fig 6



HAND SCREEN

A helmet screen is designed to wear on the head. (Fig 7)

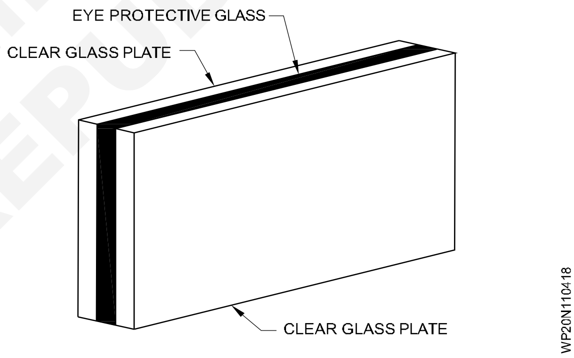
Fig 7



WELDING HELMET

Clear glasses are fitted on each side of the coloured glass to protect it from weld spatters. (Fig 8)

Fig 8



The helmet screen provides better protection and allows the welder to use his both hands freely.

Coloured (filter) glasses are made in various shades depending on the welding current ranges. (Table1)

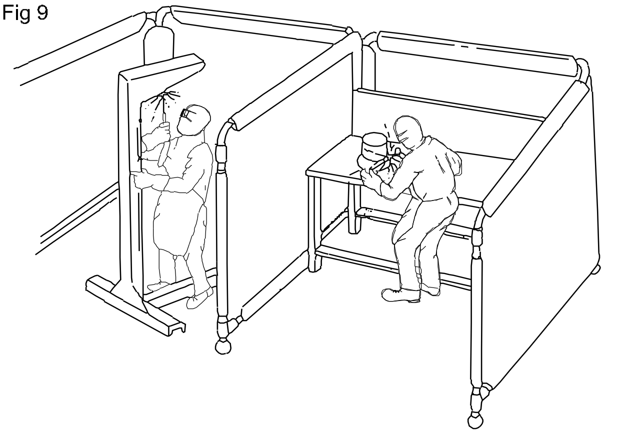
Table 1

Recommendations of filter glasses for manual metal arc welding

Shade No. of coloured glass	Range of welding current in amperes
8-9	Up to 100
10-11	100 to 300
12-14	Above 300

Portable fire proof canvas screens Fig. 9 are used to protect the persons who work near the welding area from arc flashes.

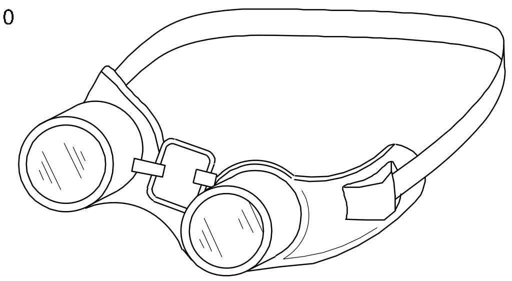
Fig 9



PORTABLE FIREPROOF CANVAS SCREENING

Plain goggles are used to protect the eyes while chipping the slag or grinding the job. Fig, 10

Fig 10



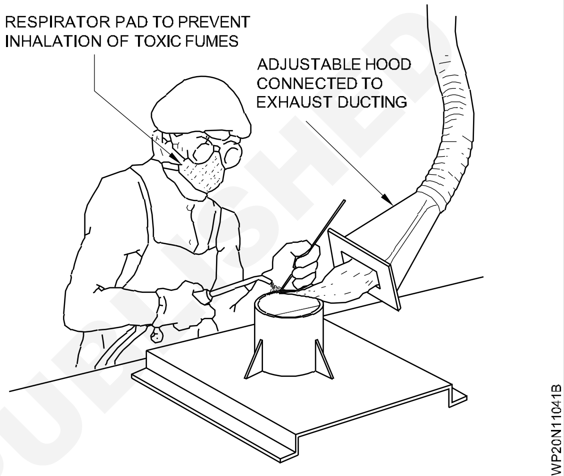
It is made of bakelite frame fitted with clear glasses and an elastic band to hold it securely on the operator's head.

It is designed for comfortable fit, proper ventilation and fullprotection from all sides.

Sometimes toxic fumes and heavy smoke may be liberated (given out) from the weld while welding non-ferrous alloys like brass etc. Use a respirator and use exhaust ducts and fans near the weld area to avoid inhaling the toxic fumes and smoke Fig 11.

Inhaling toxic fumes will make the welder become unconscious and fall on the hot welded job/on the floor. This causes burns or injury.

Fig 11



Safety in Gas cutting process

Objectives: At the end of this lesson you shall be able to
- **describe the safety precautions to be followed by handling gas cutting equipment**
- **explain the safety precautions to be followed by the operator**
- **state the safety required during gas cutting operation.**

Equipment safety: Safety precautions for gas cutting equipment are the same as those adopted in the case of gas welding equipment.

safety for the operator (Fig 1)

Always use safety apparel

Goggles, gloves and other protective clothing must be warn.

Safety during operation: Keep the work area free from flammable materials.

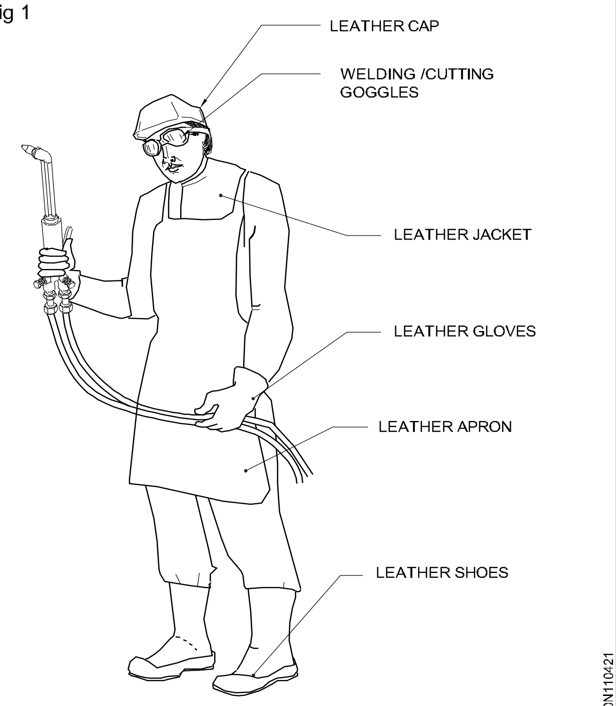
Ensure that the combustible material is at least 3 meters away from the cutting operation area.

In case the flammable material is difficult to remove, suitable fire resisting guards/partitions must be provided.

- protection of your eyes
- protection from burns
- protection of clothing
- protection of inhaling burnt gases.

protect yourself and others from the flying sparks.

Fig 1



WEAR PROTECTIVE CLOTHING

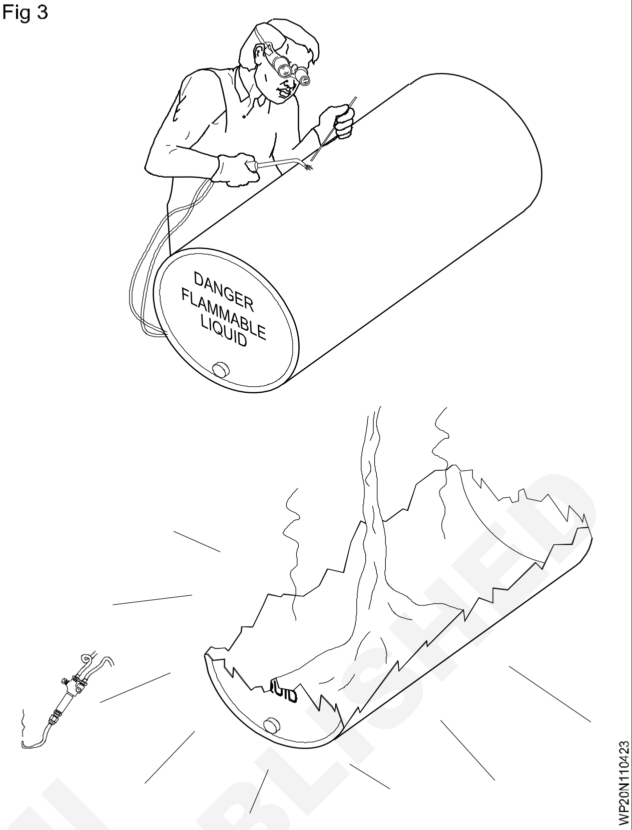
Ensure that the metal being cut is properly supported and balanced so that it will not fall on the feet of the operator or on the hoses.

Keep the space clear underneath the cutting job so as to allow the slag to run freely, and the cutting parts to fall safely.

Be careful about flying hot metal and sparks while starting a cut. Containers which hold combustible substance should not be taken directly for cutting or welding. (Fig 2) Wash the containers with carbon tetrachloride and caustic soda before welding or cutting and fill them with water before repairing. (Fig 3)

Fig 2

Fig 3



Introduction and Definition of Welding

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

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

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

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

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

Welding is a 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.

Definition of Welding:

Welding is a process of Joining two or more, similar or dissimibr metals by heating them to a suitable temperature with or without the application of pressure. Filler material and flux. Welding is used for making permanent Joints.

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

Maintain the cooling oil in the transformer welding set.

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

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

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

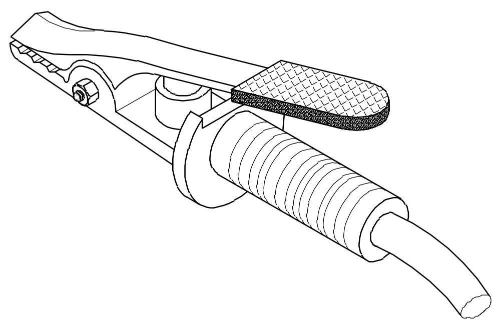
Arc welding accessories: Ensure the welding and earth cables are of standard amperage. The cables are to be joined only by sockets. Use the right capacity electrode holder and earth clamp. Avoid temporary arrangements to join cables or to connect earth clamp with the table or job. Avoid direct contact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

Arc and Gas Welding Equipments, Tools and Accessories

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

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

Fig 1



ELECTRODE HOLDER

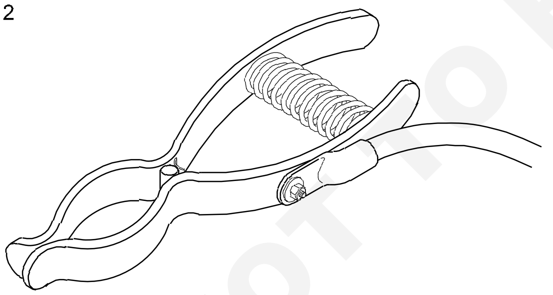
WP20N110611

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

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

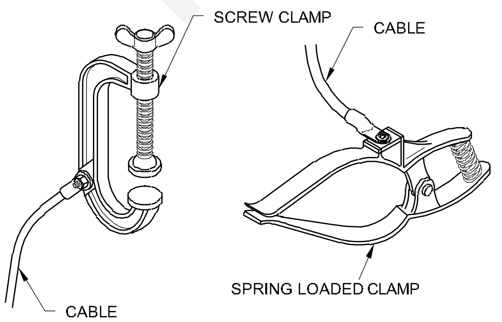
Earth clamp (Fig 2): It is used to connect the earth cable firmly to the job on welding table. It is also made of copper/ copper alloys.

Fig 2



WP20N110612

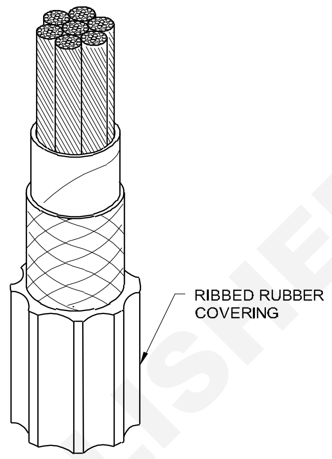
Fig 3



WORK CABLE ATTACHMENTS

WP20N110613

Fig 4



WELDING CABLE WITH HEAVY RIBBED OUTER RUBBER COVERING

WP20N110614

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

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

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

Cables are made of super flexible rubber insulation, having fine copper wires and woven fabric reinforcing layers. (Fig4)

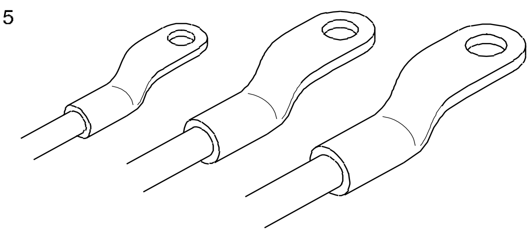
Welding cables are made in various sizes (cross-sections) i.e. 300, 400, 600 amps etc.

Loose joints or bad contacts cause overheating of the cables.

> **The same size welding cables must be used for the electrode and the job.**
>
> **The cable connection must be made with suitable cable attachments (lugs). (Fig 5)**

The length of the cable has considerable effect on the size to be used. (See Table1.)

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

WP20N110615

Table 1

Recommendations of copper cable for arc welding

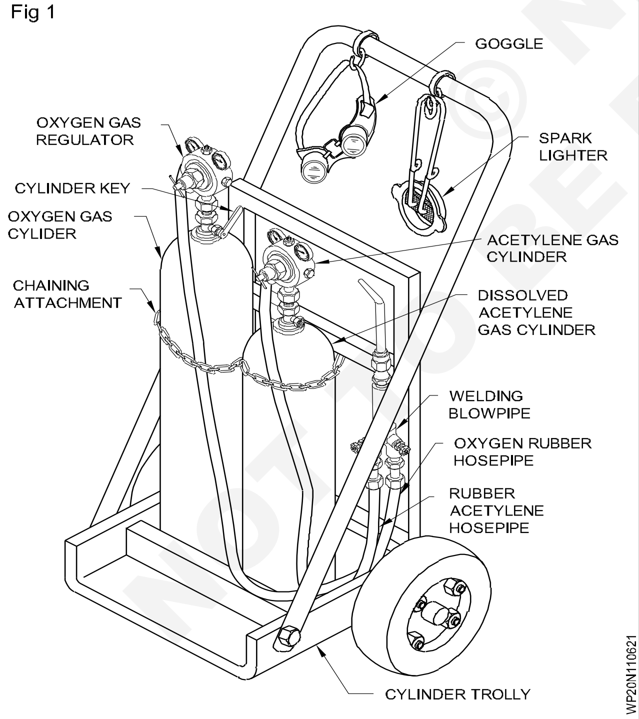
Cable dia.	Lengths of cable in metres current capacity in amperes		
(mm)	0 - 15	15 - 30	30 - 75
24.0	600	600	400
21.0	500	400	300
19.0	400	350	300
18.0	300	300	200
16.5	250	200	175
15.5	200	195	150
14.5	150	150	100
13.5	125	100	75

Oxy-acetylene welding equipment and accessories

Objectives: At the end of this lesson you shall be able to
- **distinguish between the features of oxygen and acetylene gas cylinders**
- **compare the features of oxygen and acetylene gas regulators**
- **distinguish between the house-connectors used in oxygen and acetylene regulators**
- **describe the function of hose-protectors**
- **state the functions of blowpipes and nozzles.**

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

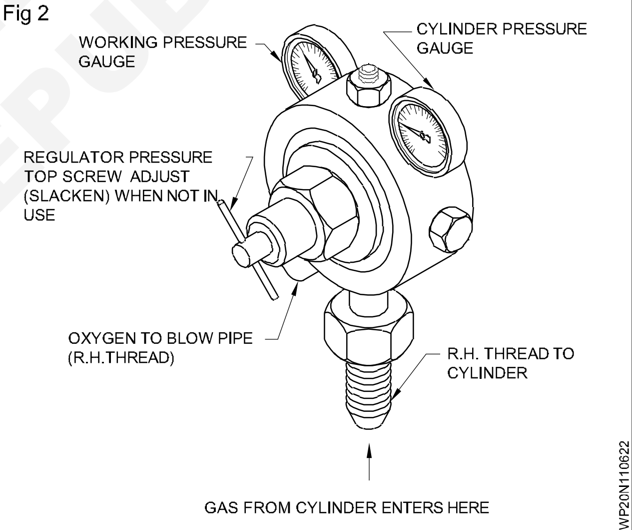
Fig 1



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

Dissolved acetylene cylinders: The acetylene gas used

Fig 2



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

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

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

Fig 3

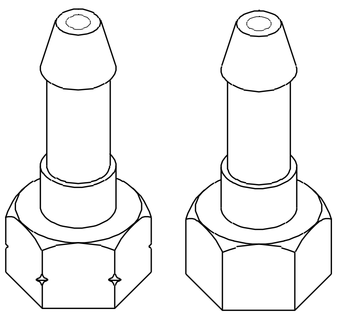
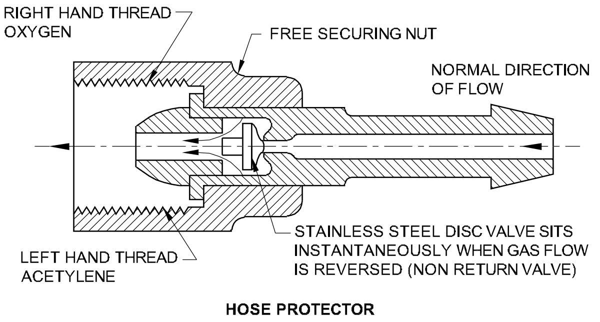


Fig 4



HOSE PROTECTOR

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

Fig 5

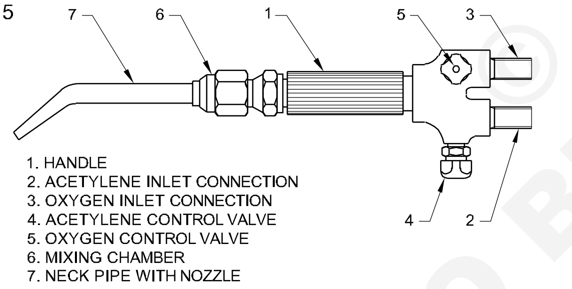
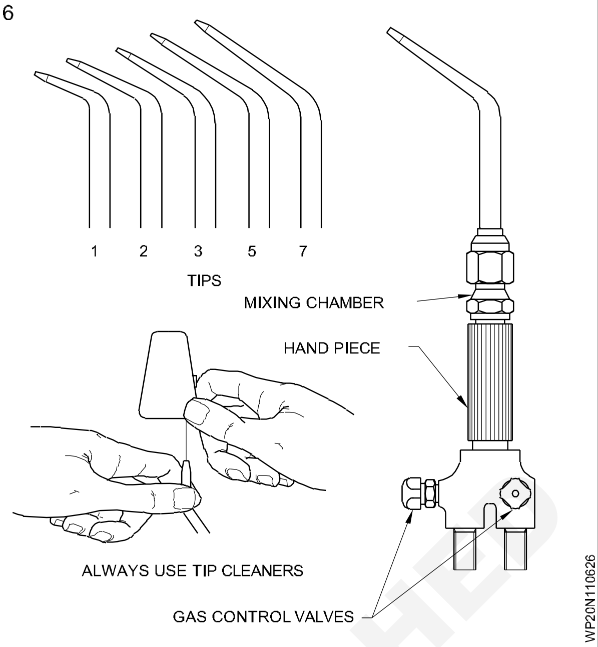


Fig 6



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

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

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

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

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

Gas welding hand tools

Objectives: At the end of this lesson you shall be able to
- **identify and name the hand tools used by a welder**
- **state their uses**

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

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 1 & 2).

Before cleaning the tip, select the correct drill and move it, without turning, up and down through the tip (Fig 3 & 4).

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

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

Chipping hammer: The chipping hammer Fig 8 Is used to remove the slag which covers the deposited weld bead. It is made of medium carbon steel with a mild steel handle.

Care should be taken to maintain the sharp chisel edge and the point for effective chipping of slag (Fig 8 & 9).

Fig 1

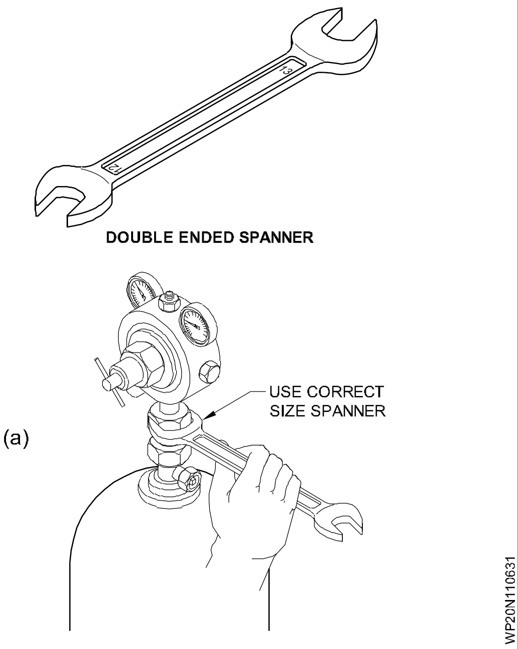


Fig 2

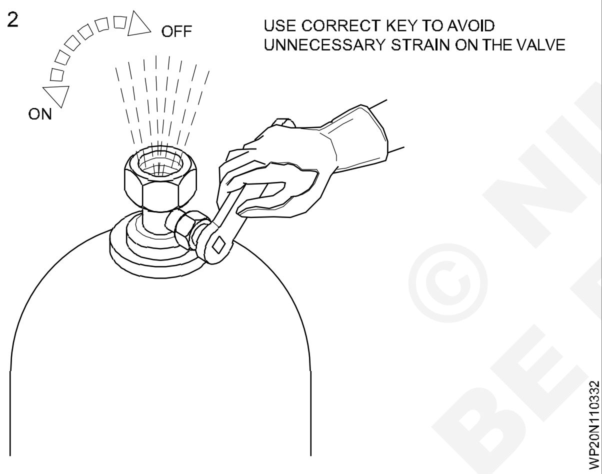


Fig 3

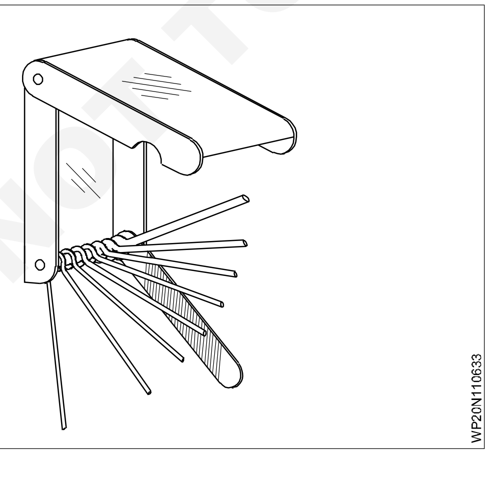


Fig 4

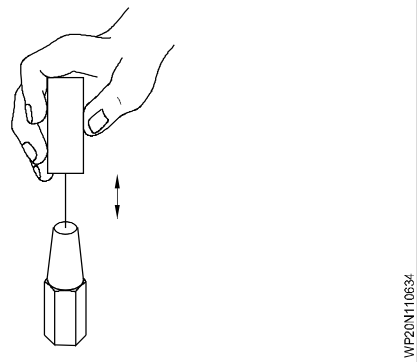


Fig 5

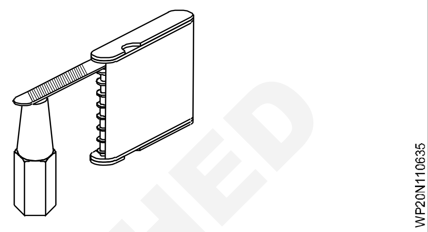


Fig 6

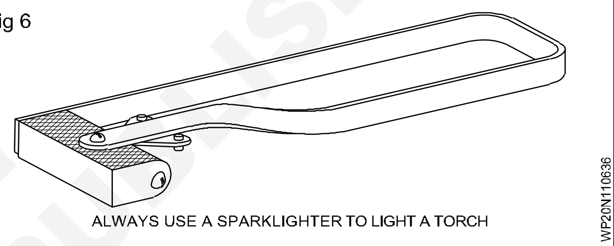


Fig 7

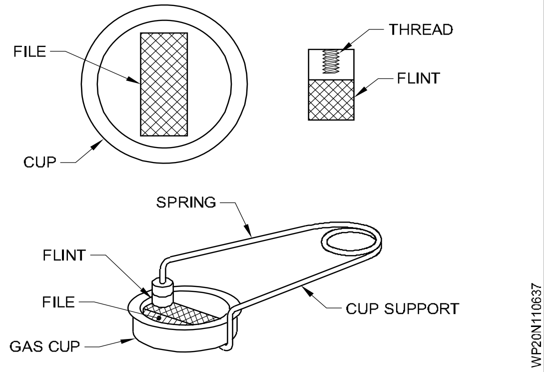


Fig 8

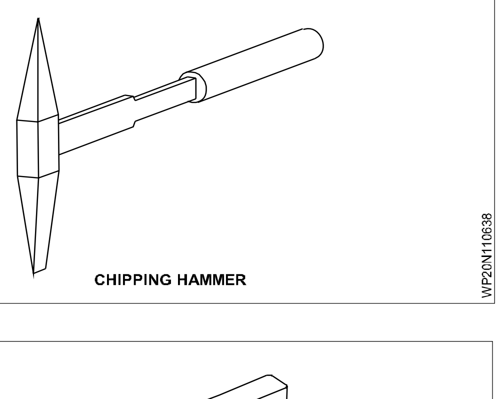


Fig 9

Various Welding Processes and their Applications

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

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

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

Electric welding processes can be classified as:-

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

Electric arc welding can be further classified as:

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

Electric resistance welding can be further classified as:

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

Gas welding processes can be classified as:

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

The other welding processes are:

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

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

Main parts in SMAW

- Welding Machine
- Electrode Holder
- Ground Clamp(Earth)
- Welding Cables

Types of power source

1 AC welding Transformer
2 DC motor Generator
3 Rectifier set
4 Inverter

Welding Terms & Its Definition Arc and Gass

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

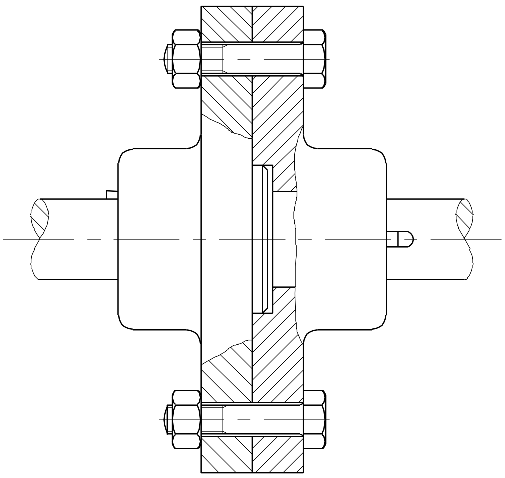
25 **Electrode** (Flux coated) A metal stick which is coated with flux and having parts indicated as stub end, tip, bare/core wire and flux coating. The size of this is determined by size of bare/core wire diameter. (This is used in shielded Metal Arc welding as consumable material).

Different Process of Metal Joining Methods Bolting,Rivelting,Soldering

Objectives: At the end of this lesson you shall be able to
- **state the situations in which bolts and nuts are used**
- **state the advantages of using bolts and nuts**
- **identify the different types of bolts**
- **state the applications of the different types of bolts**
- **state the situations in which studs are used**
- **state the reason for having different pitches of threads on stud ends.**

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.

Rivet joines

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.(Fig 2)

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.

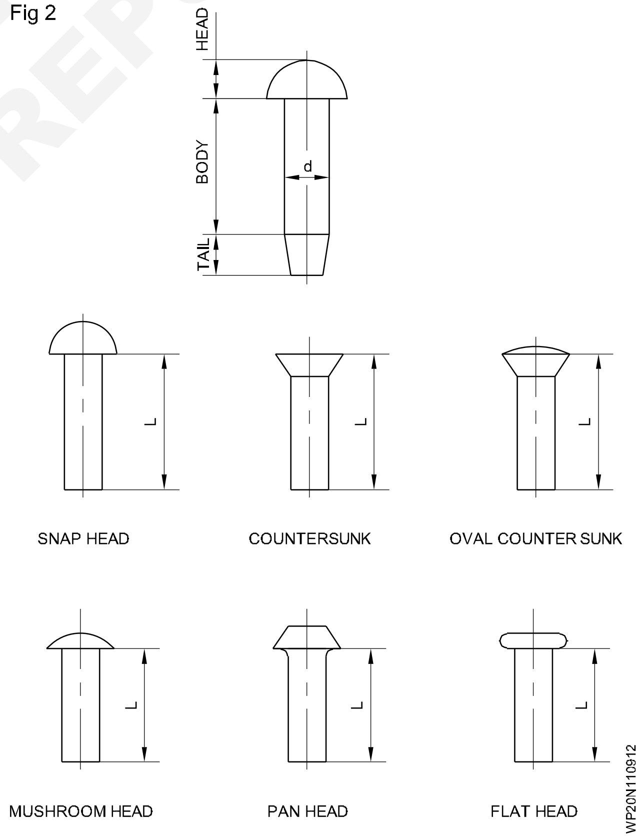
The length of the rivets 'L' is indicated by the shank length.

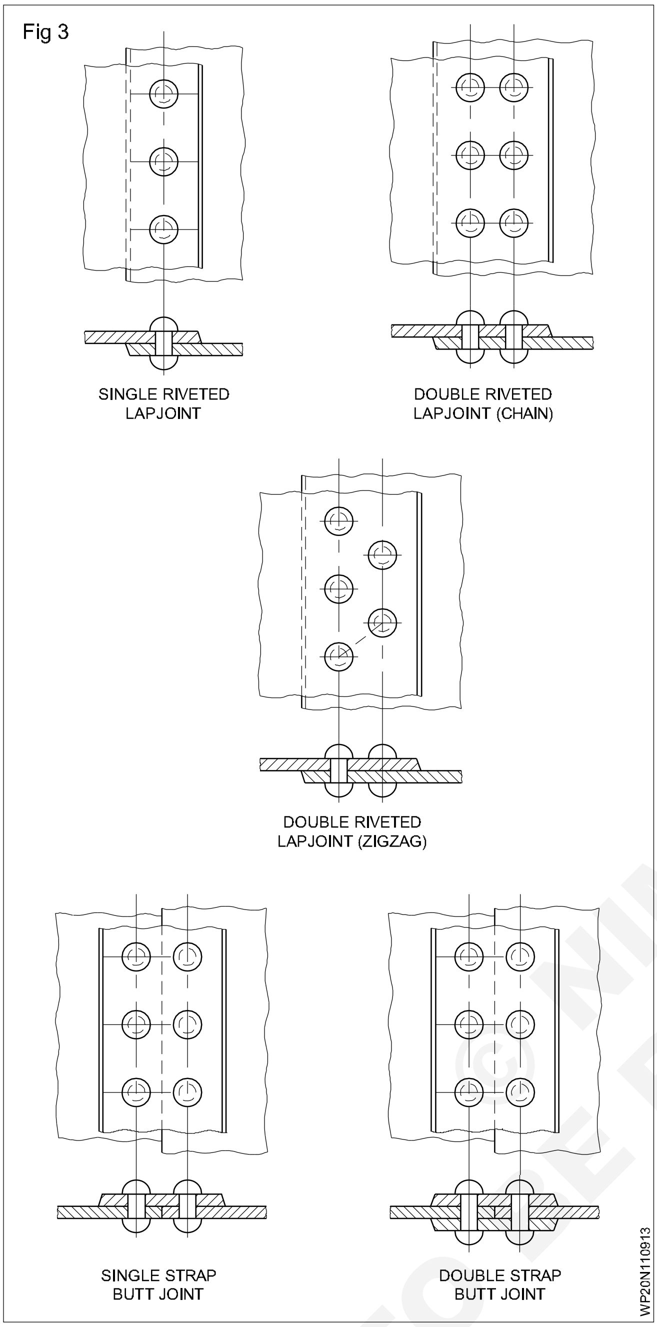
Rivet joints

Rivet joints are classified as lap joints and butt joints.

In the case of butt joints, a plate called a butt strap is used.(Fig 3)

Fig 2





Soldering

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

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

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

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

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

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

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

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

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

Soldering iron (soldering bit)

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

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

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

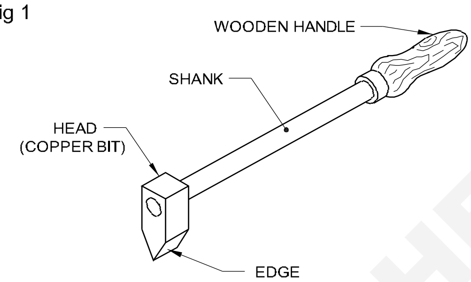
Copper is the preferred material for soldering bit because

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

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

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

Fig 1



SOLDERING IRON (HATCHET TYPE)

Solder

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

Solder is a bonding filler metal using in soldering process

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

Types os solders

There are two types of solders.

- Soft solder
- Hard solder

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

Warning

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

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

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

Soldering flux

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

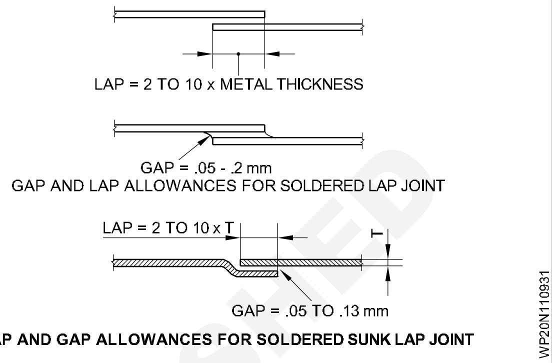
All metal rust to some extent, when exposed to the atmosphere because of oxidation. The layer of the rust must be removed before soldering. For this, a chemical compound applied to the joint is called flux.

- Workpieces must be firmly supported. It is essential to prevent the movement for the control of the solder application, alignment and accuracy of the component assembly.

Sheet metal joints both lapped and folded, are suitable for silver soldering application as shown in Fig 1.

Silver solder effects the union of lapped joints and seals the seam openings of the interlocking folded joints.

Fig 1



Factors considered while soldering

Objectives: At the end of this lesson you shall be able to
- **state the constructional feature of blow lamp**
- **identify the parts of blow lamp**
- **describe the operation of blow lamp.**

Soldering is joining two metal parts with a solder, i.e., a third metal that has a lower melting point.

Before soldering the following conditions must be met.

1 The metal must be clean.

2 The correct soldering device must be used and it must be in good condition.

3 The correct solder and flux or soldering agent must be chosen.

4 Proper amount of heat must be applied. If you follow these conditions, you could get a good solder joint.

Cleanliness: Solder will never stick to a dirty, oil or oxide coated surface. Beginners often ignore this simple point. If the metal is dirty, clean it with a liquid cleaner. If it is black annealed sheet remove the oxide with an abrasive cloth, and clean it until the surface is bright.

A bright metal, such as copper, can be coated with oxide even though you cannot see it. This oxide can be removed with any fine abrasive.

Soft soldering, brazing and silver brazing

Objectives: At the end of this lesson you shall be able to
- **explain soft soldering and hard soldering**
- **describe the method of soft soldering, brazing and sliver brazing**
- **describe the difference between brazing and soldering**
- **explain the various methods of brazing**
- **explain the problems in brazing and the remedies.**

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

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

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

Brazing is employed where a ductile joints is required.

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

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

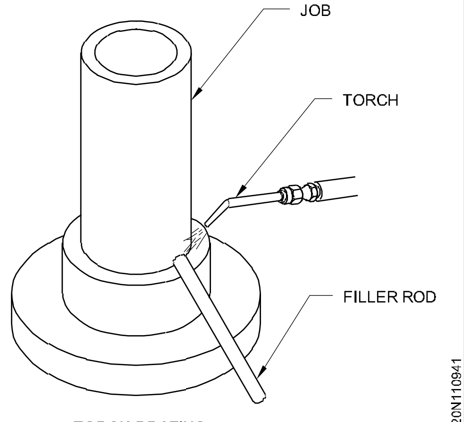
It is applied on the joint in the form of a paste made by mixing up with water.

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

Various methods of brazing

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

Fig 1



TORCH BRAZING

Types of Welding Joints and its Applications Edge Preperation and Fit up for different Thickness.

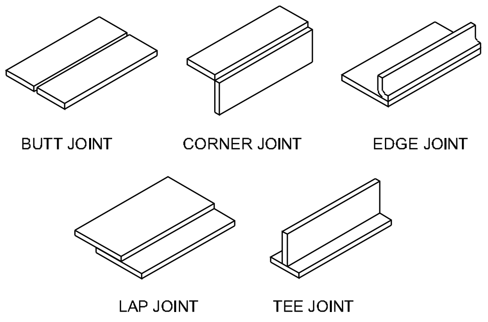
Objectives: At the end of this lesson you shall be able to
- **illustrate and name the basic welding joints.**
- **explain the nomenclature of butt and fillet welds.**

Basic welding joints

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

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

Fig 1

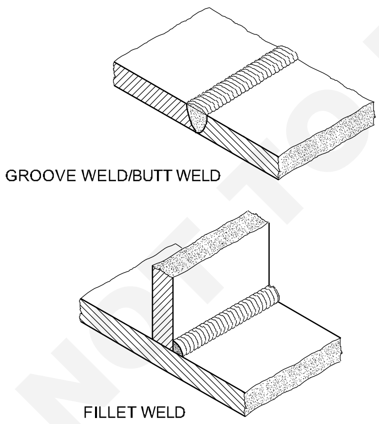


FUNDAMENTAL TYPE OF JOINTS

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

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

Fig 2



TYPE OF WELD

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

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

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

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

Fig 3

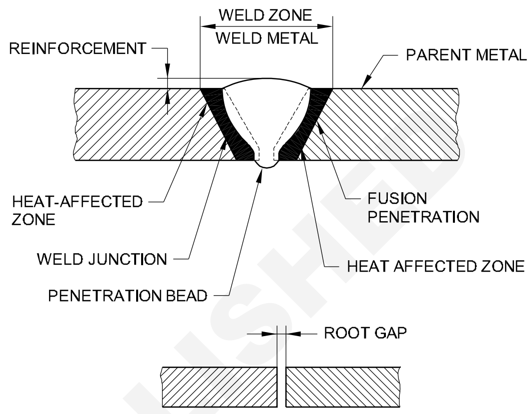


Fig 4

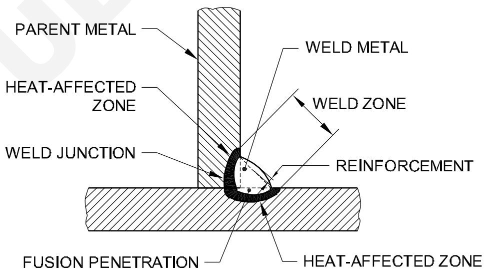
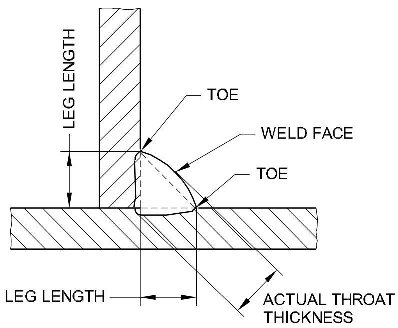


Fig 5



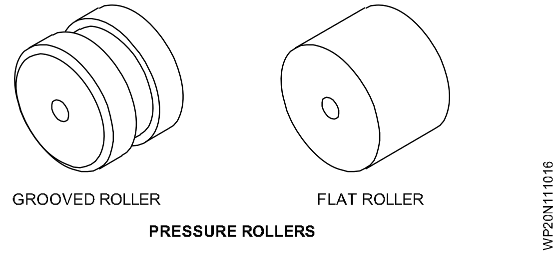
Parent metal: The material or the part to be welded.

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

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

Latch: It holds the horn rigid by when pressure roller is functioning at the time of closing the seam.

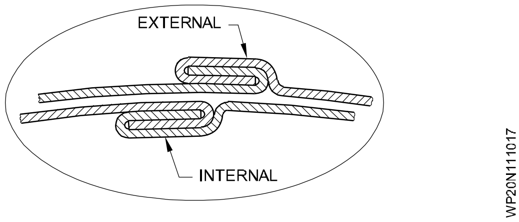
Fig 6



Internal and External locks (Fig 4) can be made by adjusting the horn and changing the pressure rollers on the seam closing machine.

If the seam to be made on the outside of the object, adjust the flat or plain face of the horn on the upper side, and provide suitable grooved pressure roller in the carriage.

Fig 7



If the seam is to be made from inside of the object, adjust the suitable groove on the horn upper side and provide flat pressure roller in carriage as shown in Fig 5.

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

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

Different methods used to cut metals

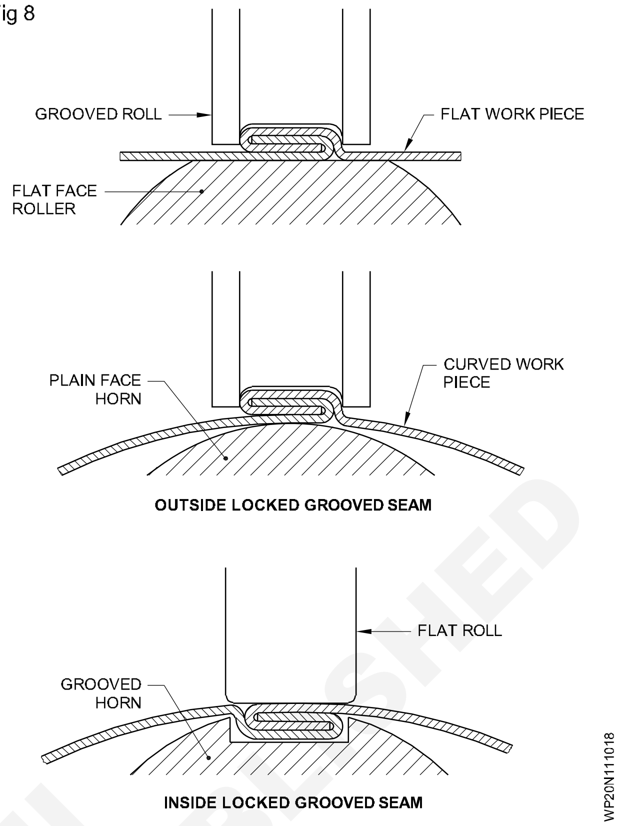
1 By chiseling the sheets

2 By hack sawing

3 By shearing using hand lever shear

4 By using guillotine shear

Fig 8



5 By gas cutting

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

Tools and equipments used to cut metals

1 Cold chisel

2 Hacksaw with frame

3 Hand lever shear

4 Guillotine shear

5 Oxy-acetylene cutting torch

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

Edge preparation

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

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

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

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

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

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

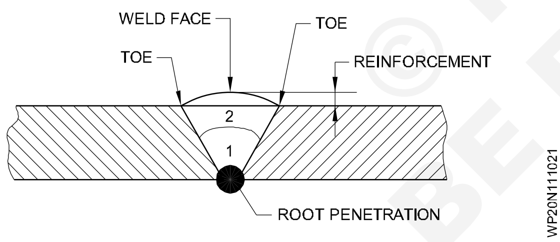
Method of edge preparation: The joining edges may be prepared for welding by any one of the methods mentioned below.

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

Types of edge preparation and setup

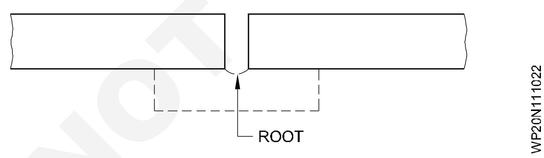
Different preparation generally used in arc welding are shown in Fig 1 below.

Fig 1



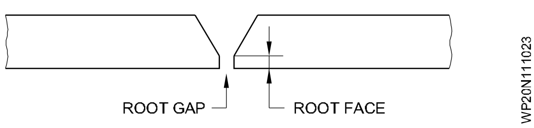
Root: The parts to be joined that are nearest together. (Fig 7)

Fig 2



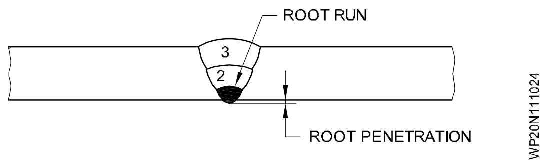
Root face: The surface formed by squaring off the root edge of the fusion face to avoid a sharp edge at the root. (Fig 8)

Fig 3



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

Fig 4

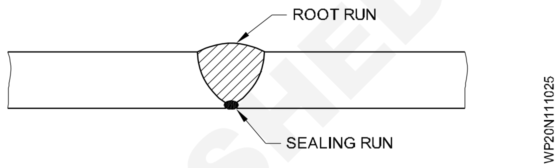


Root penetration: It is the projection of the root run at the bottom of the joint (Fig. 6 and 9)

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

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

Fig 5



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

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

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

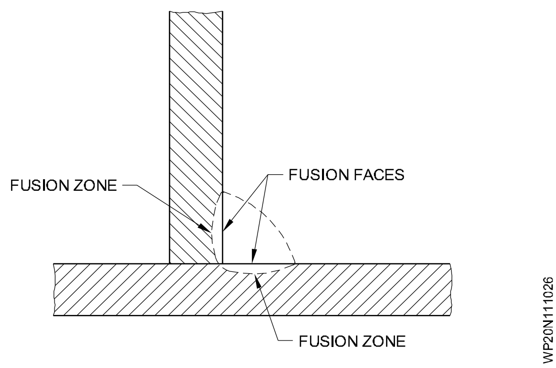
Toe of weld: The point where the weld face joins the parent metal. (Fig 5&6.)

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

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

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

Fig 6



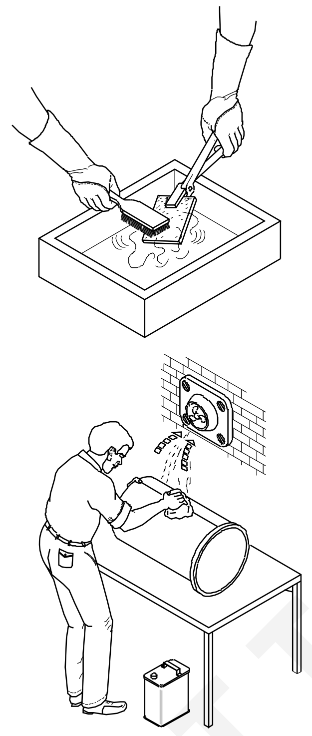
Surface Cleaning

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

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

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

Fig 1

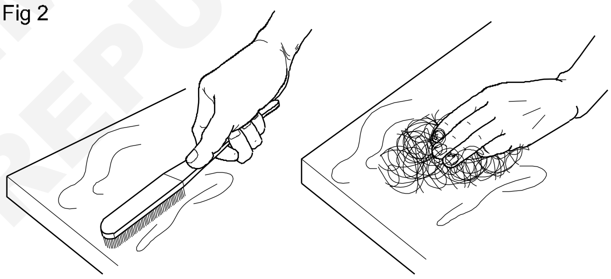


Methods of cleaning: Chemical cleaning includes washing the joining surface with solvents of diluted hydrochloric acid to remove oil, grease, paint etc (Fig. 1)

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 2



Basic Electricity as Applied to Welding

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

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

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

It is dangerous to play with electricity.

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

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

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

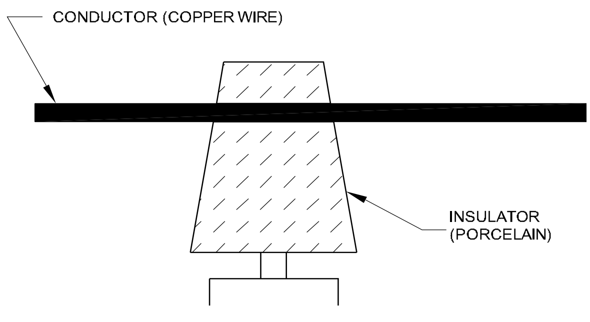
Electric resistance; It is the property of a substance to oppose the flow of electric current passing through it.

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

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

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

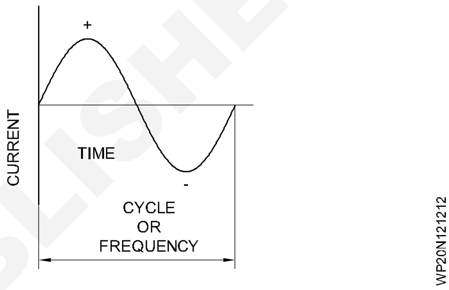
Fig 1



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

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

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 means it changes its direction 50 times per second. Its rate of change is called frequency i.e. hertz (Hz). (Fig.2)

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

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

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

Fig 3

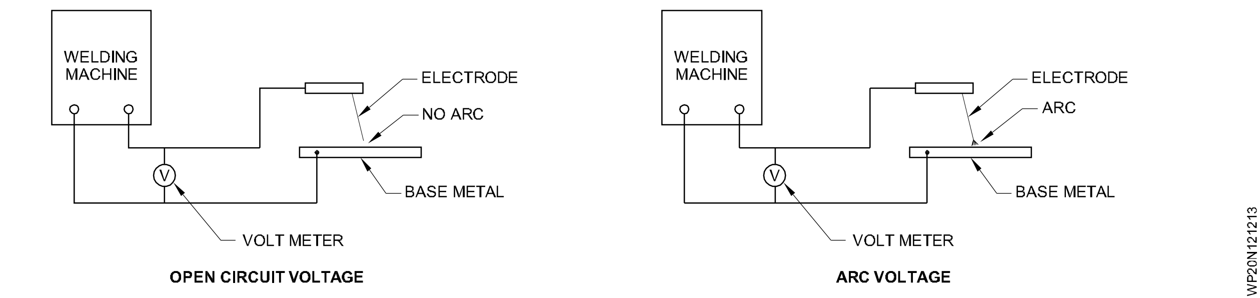
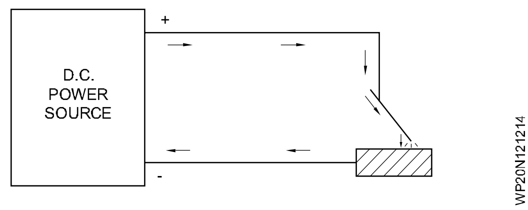


Fig 4



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.

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".

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

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

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

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 passig 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 workpiece (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

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

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

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

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

- Centigrade scale
- Fahrenheit scale

In both systems there are two fixed points which indicate:

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

Temperature is measured by a unit called 'degree'.

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

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

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

Conversion of temperature from °C to °F

The formula used for temperature conversion is

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

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

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

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

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

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

Heat and temperature should not be confused with each other.

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

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

Example

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

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

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

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

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

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

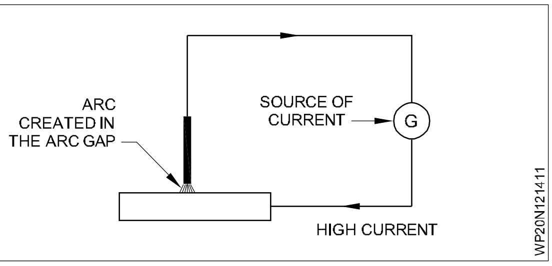
Given below is a chart showing welded plate thickness, nozzle size used and volume of gasses used.

Principle of Arc Welding and Characteristic of ARC

Objectives : At the end of this lesson you shall be able to
- **define principle of one welding**
- **state carbon are welding principle.**

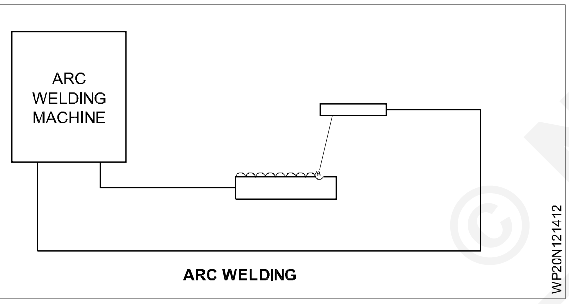
When high current passes through an air gap from one conductor to another, it produces very intense and concentrated heat in the form of a spark. The temperature

Fig 1



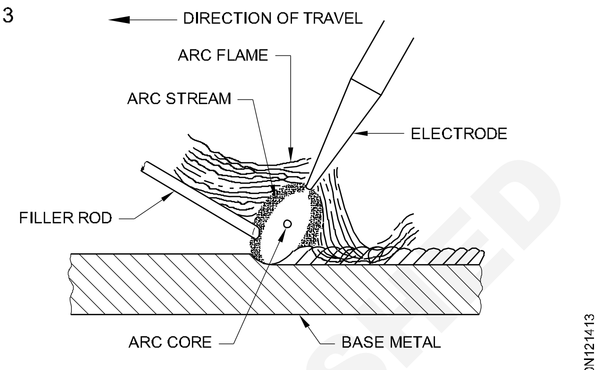
of this spark (or arc) is app. 3600°C, which can melt and fuse the metal very quickly to produce a homogeneous weld. (Fig 1)

Fig 2



ARC WELDING

Fig 3



CARBON ARC WELDING

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.

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

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

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

Metal transfer across the arc (Characteristics of arc)

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

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

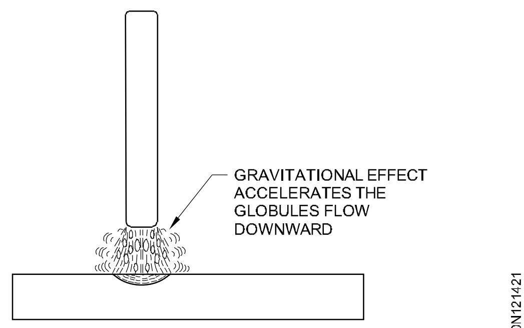
- gravity force
- gas expansion force
- surface tension
- electromagnetic force.

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

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

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

Fig 1



GRAVITY FORCE

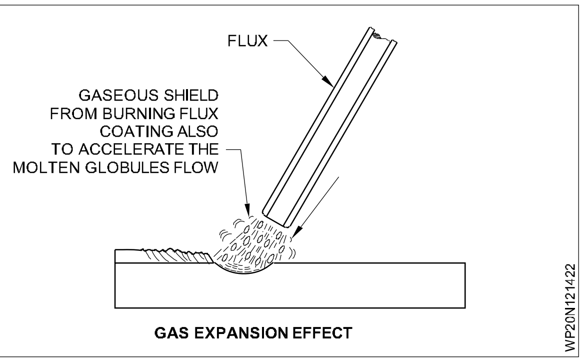
- Production of carbon monoxide and hydrogen mainly
- Formation of a sleeve of the flux at the arcing end due to a little higher melting point of the flux coating than the core wire.

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

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

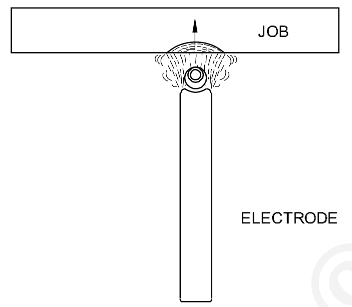
Surface tension (Fig 3): It is the characteristic (Force) of the base metal to attract and retain the molten metal in it. This effect is more useful in the case of positional welding.

Fig 2



GAS EXPANSION EFFECT

Fig 3



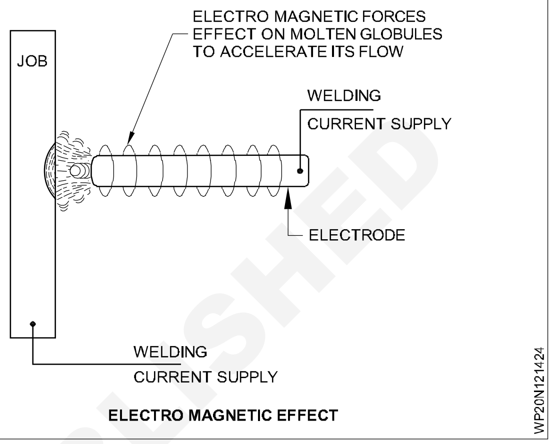
SURFACE TENSION EFFECT

The short arc promotes more surface tension effect.

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

This effect is more useful in positional welding.

Fig 4



ELECTRO MAGNETIC EFFECT

Common Gases used for Welding & Cutting, Flame Temperature and Uses

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

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

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

Comparison of different gas flame combinations and their uses

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

Types of Oxy - Acetylene Flames Uses

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

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

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

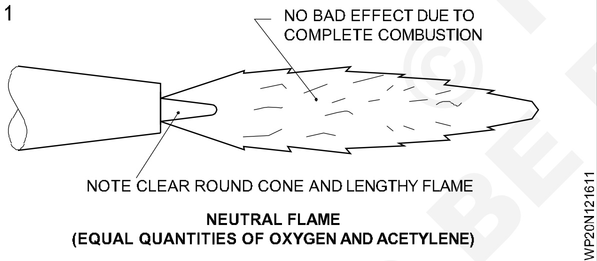
Three different types of oxy-acetylene flames as given below can be set.

- Neutral flame
- Oxidising flame
- Carburising flame.

Characteristics and uses

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

Fig 1



NEUTRAL FLAME
(EQUAL QUANTITIES OF OXYGEN AND ACETYLENE)

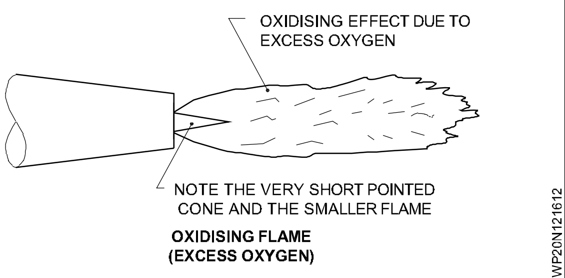
Complete combustion takes place in this flame.

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

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

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

Fig 2



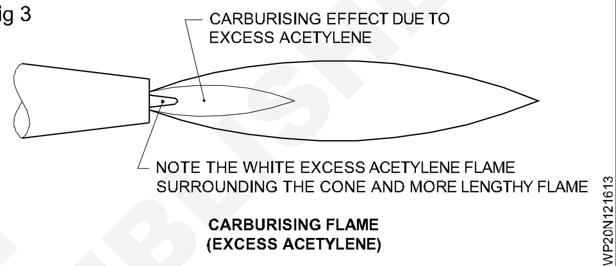
OXIDISING FLAME
(EXCESS OXYGEN)

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

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

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

Fig 3



CARBURISING FLAME
(EXCESS ACETYLENE)

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

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

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

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

Oxy Acetylene Cutting Equipment Principle Parameter and Application.

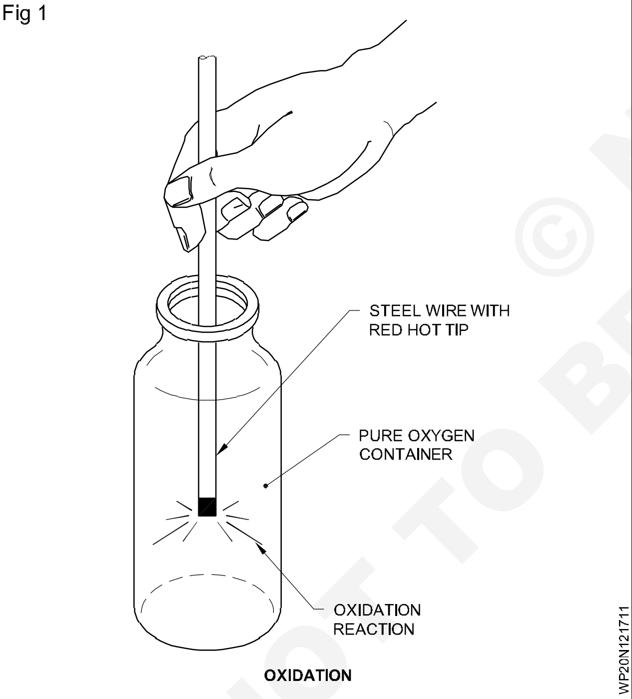
Objectives: At the end of this lesson you shall be able to
- **explain the principle of gas cutting**
- **describe the cutting operation and its application.**

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.

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.

Fig 1



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 1 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.

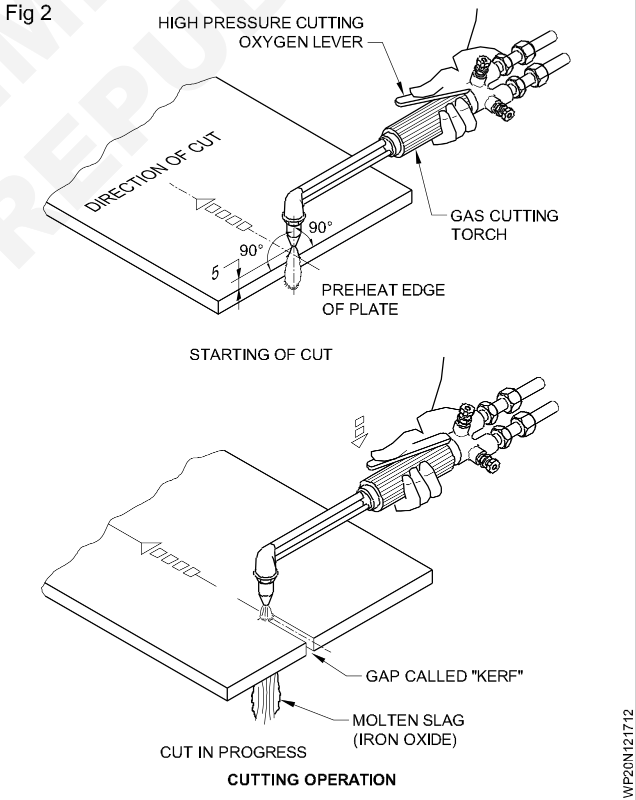
Also the iron oxide is in molten condition called slag. So the jet of oxygen coming from the cutting torch will blow the molten slag away from the metal making a gap called 'Kerf'. Fig.2

Cutting operation (Fig 2**):** There are two operations in oxy-acetylene gas cutting. A preheating flame is directed on the metal to be cut and raises it to bright red hot or ignition point (900° C app.). Then a stream of high pressure pure oxygen is directed on to the hot metal which oxidizes and cuts the metal.

The two operations are done simultaneously with a single torch.

The torch is moved at a proper travel speed to produce a smooth cut. The removal of oxide particles from the line of cut is automatic by means of the force of oxygen jet during the progress of cut**.**

Fig 2



300 litres of oxygen are required to oxidize one kilogram of iron completely. The ignition temperature of steel for gas cutting is 875°C to 900°C

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

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

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

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

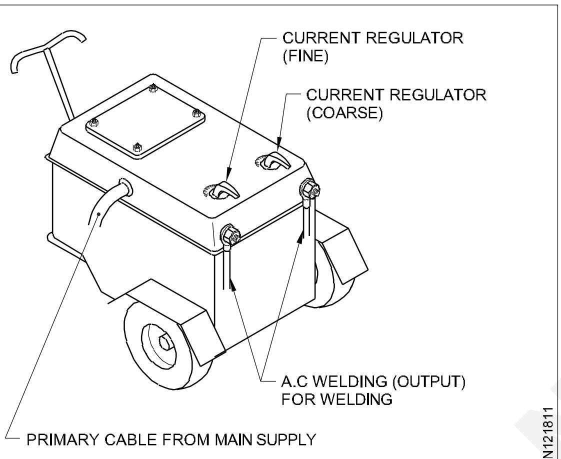
Cutting nozzle size-mm	Thickness of plate (mm)	Cutting oxygen Pressure kgf/cm^2
0.8	3-6	1.0 - 1.4
1.2	6-9	1.4 - 2.1
1.6	19-100	2.1 - 4.2
2.0	100-150	4.2 - 4.6
2.4	150-200	4.6 - 4.9
2.8	200-250	4.9 - 5.5
3.2	250-300	5.5 - 5.6

ARC Welding Power sourses Transformer, Rectifier, and Inverter type Welding m/c and its cane maintanance.

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

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

Fig 1



AC WELDING TRANSFORMER

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

It is a step down transformer, which:

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

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

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

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

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

Two welding cables are attached with the output terminals.

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

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

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

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

This action is called the principle of mutual induction.

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

Not suitable for:

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

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

- 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.

D.C welding generator

Necessity of DC welding generator

DC welding generators are used to:

- generate DC welding supply with the help of AC main supply
- generate welding supply where electricity (main supply) is not available, with the help of engine driven sets
- get relative advantages of polarity i.e. heat distribution between the electrode and the base metal and welding of non-ferrous metals.

Lubricate the shaft bearings after six months with good quality grease.

Guard the rotating parts with suitable covers.

Do not cover the air ventilation ducts.

Do not operate the polarity switch during arcing.

Ensure a proper working of the cooling fan.

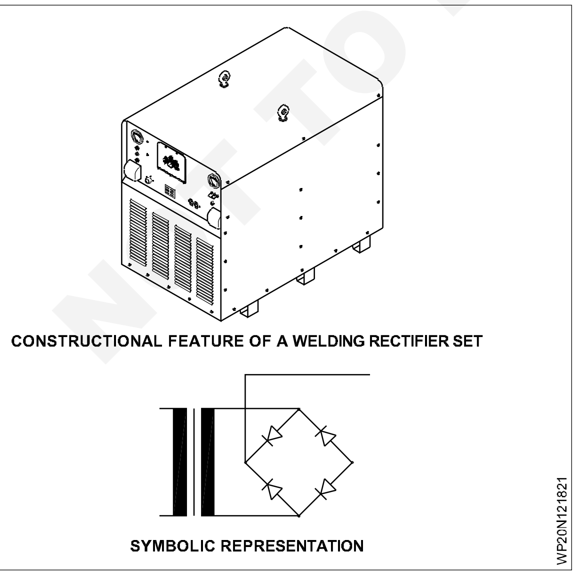
Check the electrical connections and avoid loose connections.

Never run the motor on a weak phase.

Ensure the electric motor is properly earthed.

AC/DC welding rectifier its construction

Fig 1



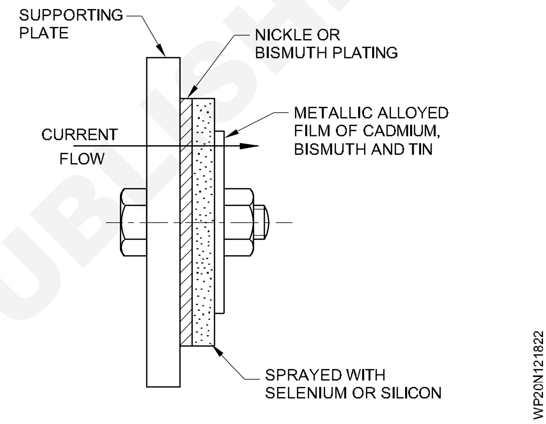
CONSTRUCTIONAL FEATURE OF A WELDING RECTIFIER SET

SYMBOLIC REPRESENTATION

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

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

Fig 2



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

Care and maintenance of rectifier welding set

Keep all the connections in tight condition.

Lubricate the fan shaft once in 3 months.

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

Keep the rectifier plates clean.

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

Keep the air ventilation system in good order.

Never run the machine without the fan.

Inverters

Objectives: At the end of this lesson you shall be able to
- **describe the inverters**
- **state the advantage & disadvantage of inverter**

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

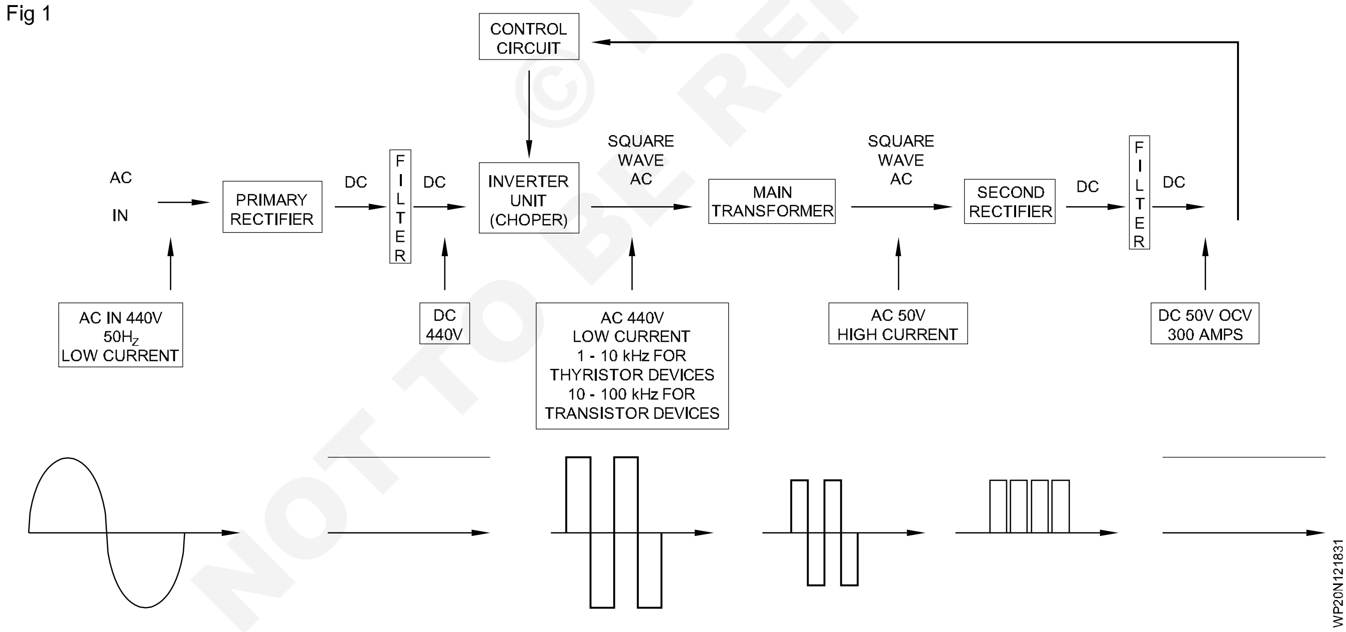
Advantage

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

Disadvantage

- expensive
- difficult to repair
- sensitive to high currents

Fig 1



Advantages and Disadvantages of AC and DC Welding.

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

Advantages of AC welding

A welding transformer has:

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

Disadvantages of AC welding

It is not suitable for bare and light coated electrodes.

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

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

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

Advantages of DC welding

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

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

Bare wires and light coated electrodes can be easily used.

Positional welding is easy due to polarity advantage.

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

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

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

It is easy to strike and maintain a stable arc.

Remote control of current adjustment is possible.

Disadvantages of DC welding

DC welding power source has:

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

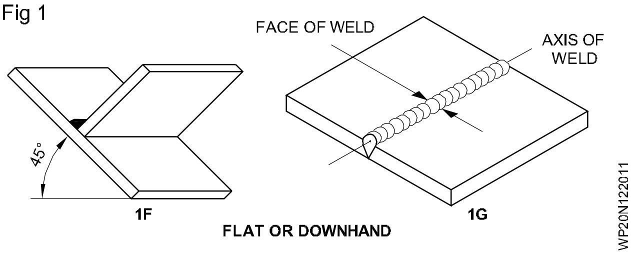
Welding Positions as per EN & ASME : Flat, Horizontal, Vertical and Overhead position.

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

Basic welding positions

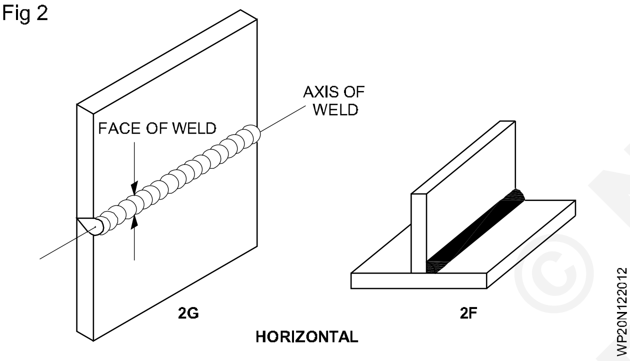
- Flat or down hand position (Fig 1)

Fig 1



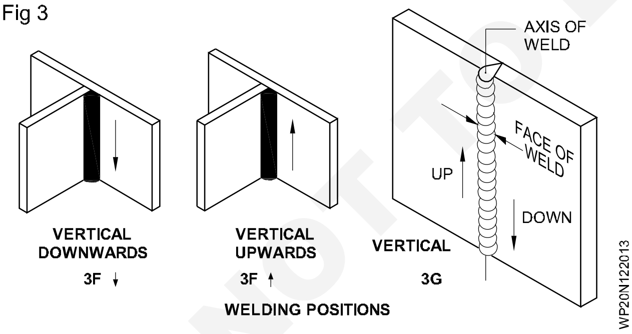
- Horizontal position (Fig 2)

Fig 2



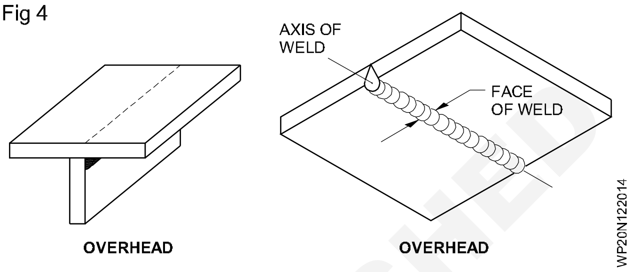
- Vertical position (Vertical up and down) (Fig 3)

Fig 3



- Overhead position (Fig 4)

Fig 4



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

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

All joints may be welded in all positions.

Plate welding position:

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

Pipe welding position:

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

Weld Slope and Rotation.

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

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

1 Flat or down hand

2 Horizontal

3 Vertical

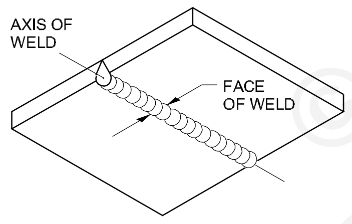
4 Overhead

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

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

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

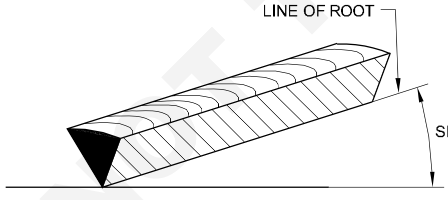
Fig 1



OVERHEAD

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

Fig 2



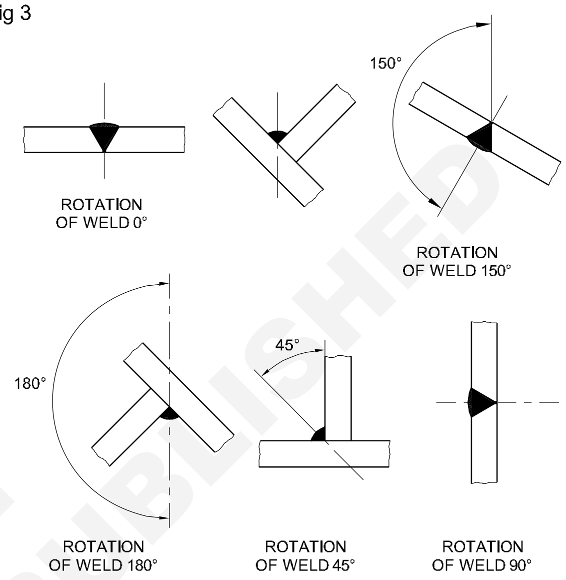
WELD SLOPE

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

Slope and rotation (Fig 4)

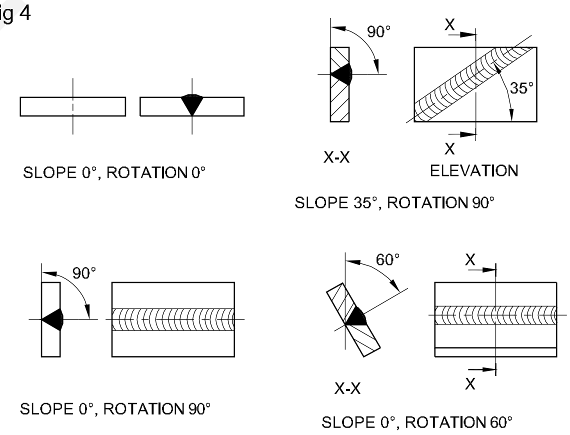
Weld in flat position. (Fig 5)

Fig 3



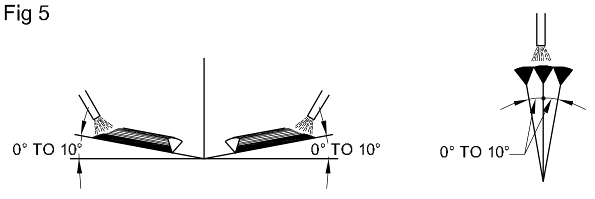
WELD ROTATION

Fig 4



SLOPE AND ROTATION

Fig 5



WELD IN FLAT POSITION

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

Fig 6

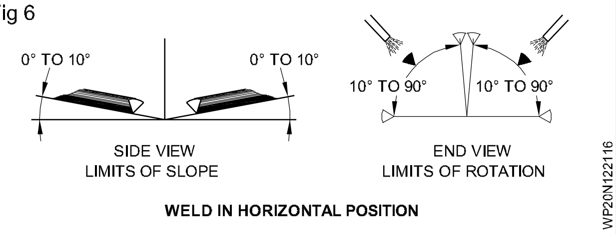
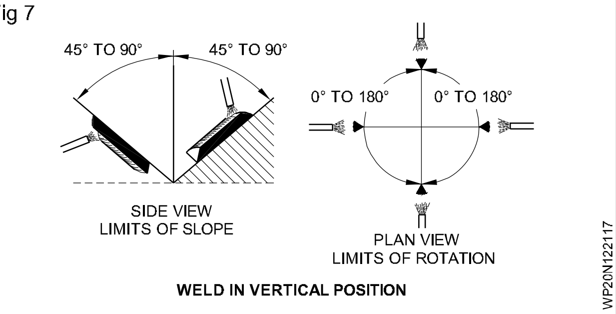
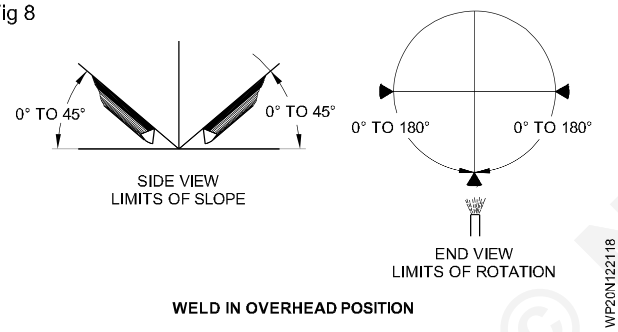


Fig 7



Weld in overhead position. (Fig 8)

Fig 8



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

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

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 & AWS

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

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

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

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

TABLE 1

Elementary symbols

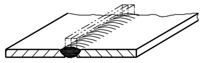
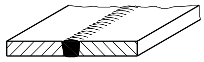
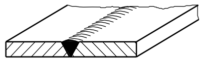
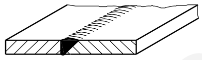
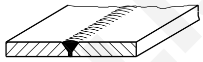
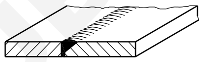
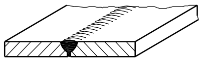
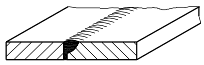
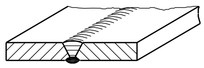
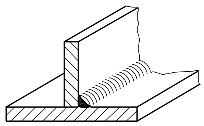
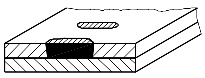
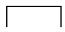
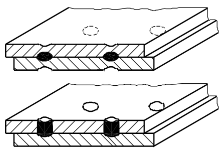
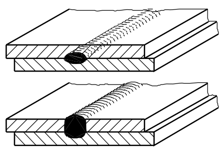
Sl. No.	Designation	Illustration	Symbol
1	Butt weld between plates with raised edges (the raised edges being melted down completely)		
2	Square butt weld		
3	Single V butt weld		
4	Single bevel butt weld		
5	Single V butt weld with broad root face		
6	Single bevel butt weld with broad root face		
7	Single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

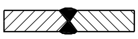
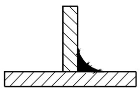
TABLE 2

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

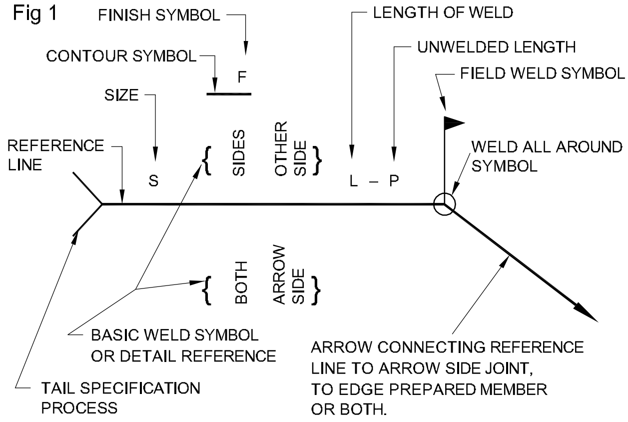
4 Dimensions and other details

5 Supplementary symbols

6 Finish symbols

7 Tail (Specification, process)

Fig 1

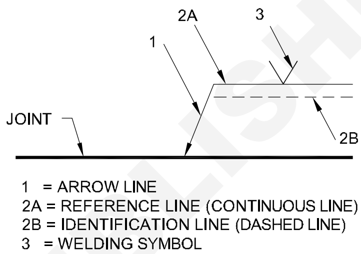


STANDARD LOCATION OF ELEMENTS OF A WELDING SYMBOL

WP20N122131

Methods of representation (Fig 2 and 3)

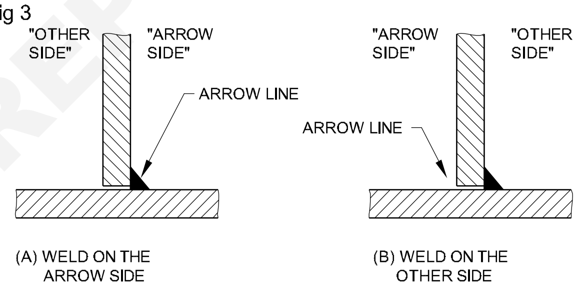
Fig 2



METHOD OF REPRESENTATION

WP20N122132

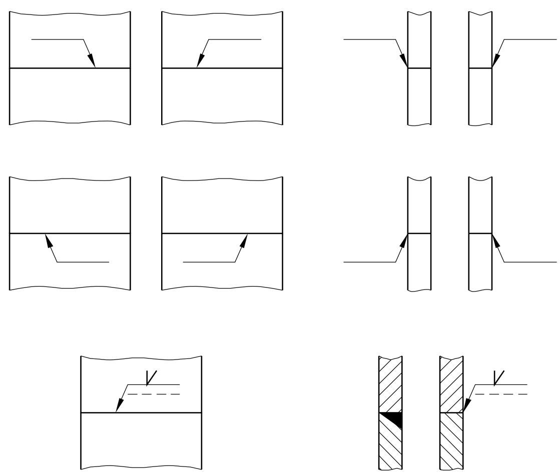
Fig 3



T-JOINT WITH ONE FILLET WELD

WP20N122133

Fig 4



POSITION OF THE ARROW LINE

WP20N122134

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.

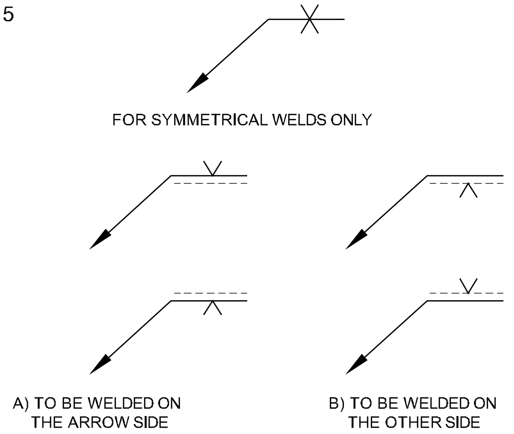
Arrow: The arrow may be drawn from either end of the reference line. The arrow always touches the line which represents the welded joint.

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.

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

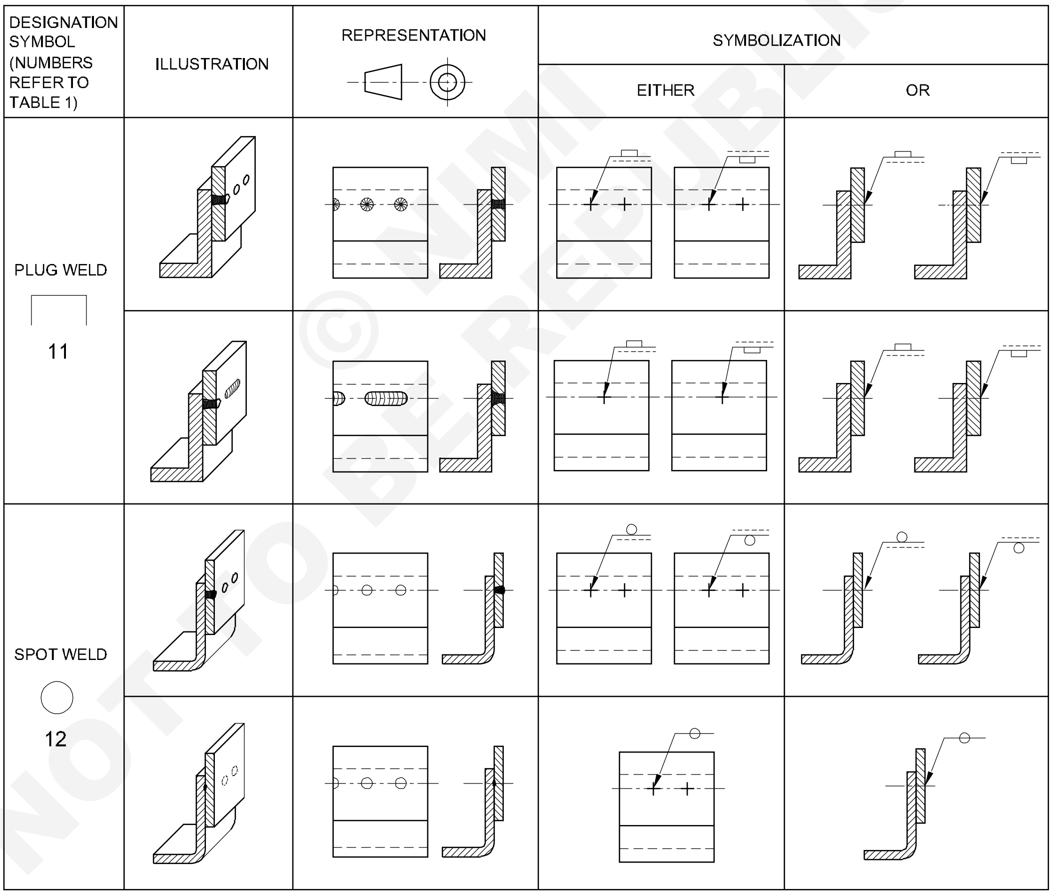
Fig 5



POSITION OF SYMBOLS ACCORDING TO THE REFERENCE LINE

WP20N122135

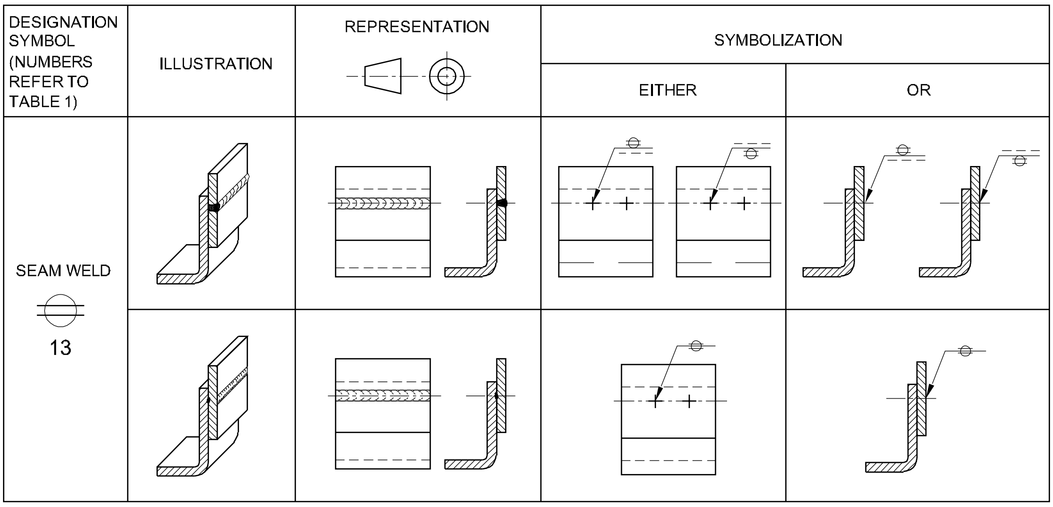
Fig 6



EXAMPLES OF USE OF ELEMENTRY SYMBOLS

WP20N122136

Fig 7

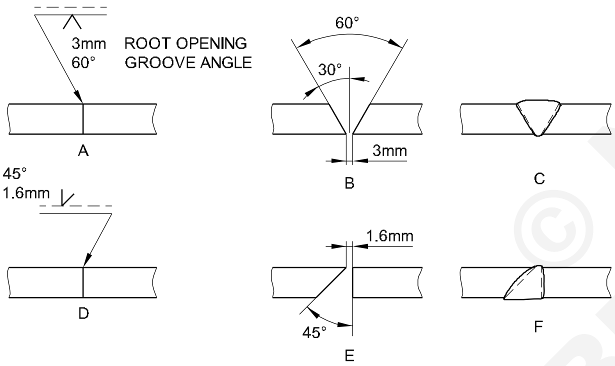


EXAMPLES OF USE OF ELEMENTRY SYMBILS

WP20N122137

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 aroove weld is shown above the basic weld symbol. (Fig 8)

Fig 8

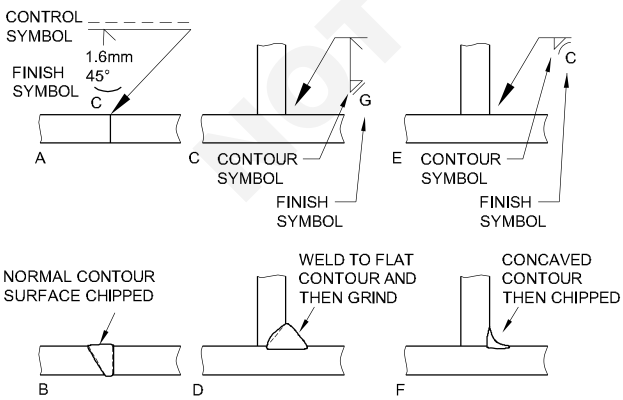


A AND D SHOW THE WELD SYMBOL FOR A GROOVE WELD
B AND E SHOW THE PIECES CUT AND SET UP FOR WELDING
C AND F SHOW THE COMPLEETED WELD

ROOT OPENING AND GROOVE ANGLE

WP20N122138

Fig 9

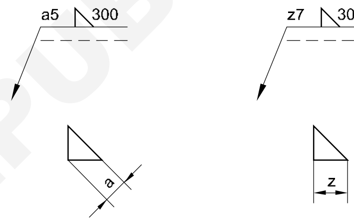


WELD CONTOUR AND FINISH SYMBOLS IN A,C AND FINISH E
CONTOUR AND FINISH SYMBOLS ARE SHOWN ON WELDING SYMBOL
B,D AND F ILLUSTRATE SHAPE AND FINISH OF COMPLETED WELD

WP20N122139

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

Fig 10



METHOD OF INDICATING DIMENSIONS
FOR FILLET WELDS

WP20N12213A

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

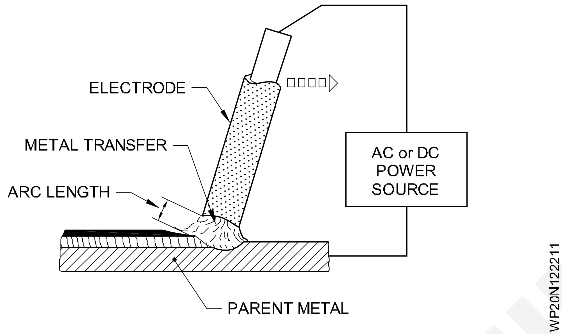
Arc Length and its Effects of are Length.

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

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

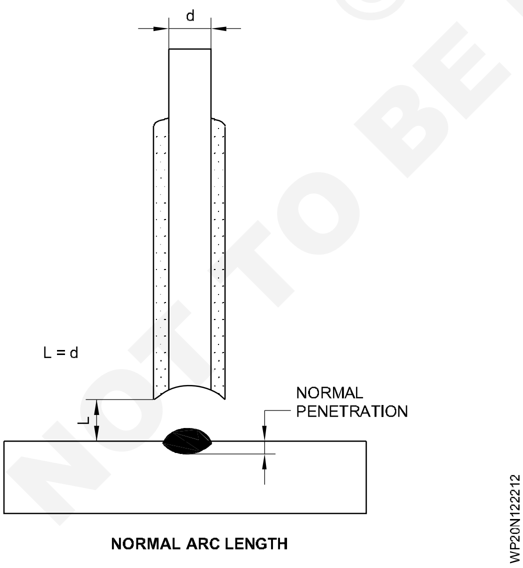
- Medium or normal
- Long
- Short

Fig 1



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

Fig 2



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

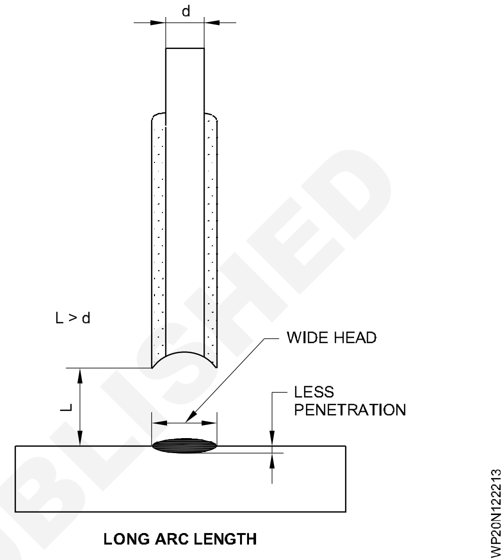
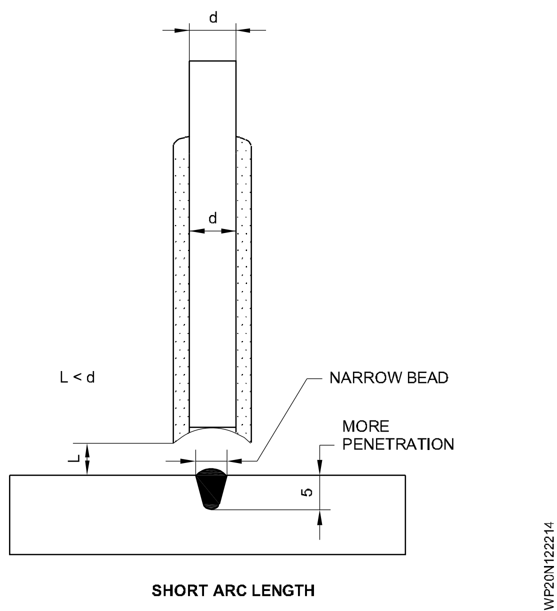


Fig 4



Effects of different arc length

Long arc

It makes a humming sound causing:

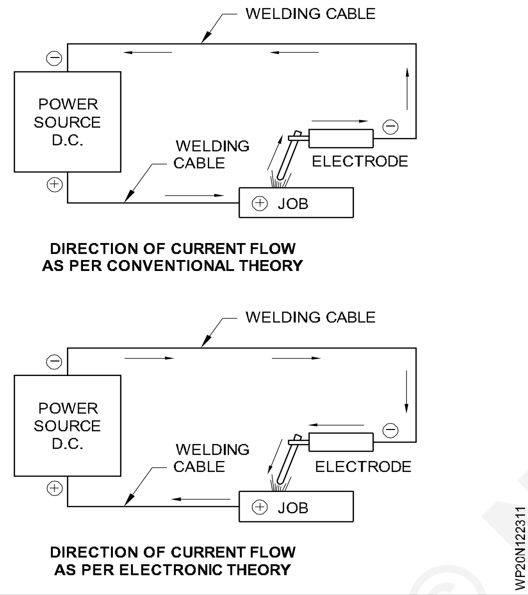
- Unstable arc
- Oxidation of weld metal
- Poor fusion and penetration
- Poor control of molten metal
- more spatters, indicating wastage of electrode metal.

Polarity types and Applications.

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

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

Fig 1



Direct current (DC) Always flows from:

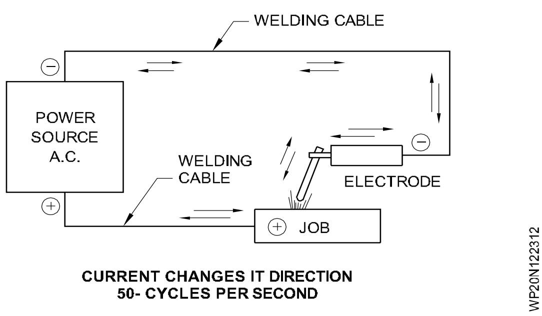
- the positive (higher potential) terminal to the negative (lower potential) terminal, as per the conventional theory
- negative terminal to positive terminal as per electronic theory.

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

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

> **Flow of electrons is always from negative to the positive.**
>
> **In AC we cannot utilize polarity as the power source changes its poles frequently. (Fig 2)**

Fig 2



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

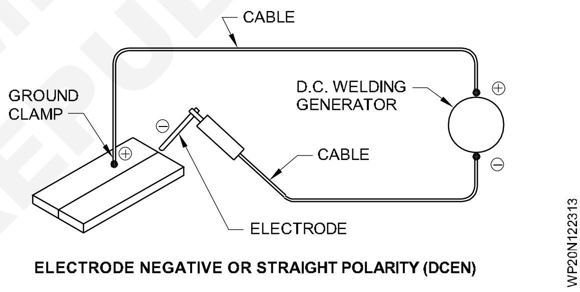
To have this advantage of unequal heat distribution in the electrode and base metal, the polarity is an important factor for successful welding.

Kinds of polarity

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

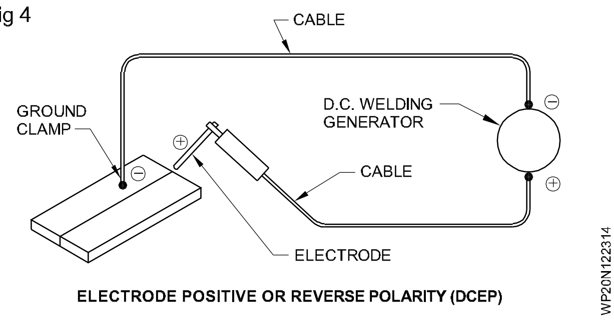
Straight polarity: In straight polarity the electrode is connected to the negative and the work to the positive terminal of the power source. (Fig 3)

Fig 3



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

Fig 4



Straight polarity is used for:

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

Reverse polarity is used for:

- Welding of non-ferrous metals

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

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

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

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

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

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

Indication of wrong polarity

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

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

Calcium Carbide uses and Hazards

Objectives : At the end of this lesson you shall be able to
- **state the ingredients and grades of calcium carbide**
- **describe the properties of calcium carbide**
- **explain the method of production of calcium carbide**
- **explain the safe storage and handling of calcium carbide.**

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

Properties of calcium carbide: It is a solid chemical compound of dark-grey colour. It is brittle. Its density is 2.22 to 2.26 g/cc. It easily absorbs moisture from the atmosphere and gradually changes into slaked lime. It is not soluble in kerosene. If it is allowed to come into contact with water (or any mixture containing water), it produces acetylene gas.

Uses of Calcium Carbide

1 It is used in the production of calcium hydroxide and acetylene.

2 It is used in the production of polyviyl chloride as acetylene the derivative of calcium carbide can be used as a raw material for the production of PVC.

3 It is used produce calcium cyanamide.

4 It is used in the removal for sulphur from iron. The removal of sulphur from any materail is called desulphurization.

5 It is used in lamps such as carbide lamps. In the early days, it was used as headlights of automobiles.

6 Used as a ripening agent like ethylene.

7 It is used in bamboo cannons as well as big-bang cannons.

8 It is used as a deoxider i.e it helps in the removal of oxygen during the manufacturing of steel.

Hazards

1 Calcium carbide can effect you when inhaled.

2 Calcium carbide can irritate the skin causing a rash,

3 edness and burning feeling on contact.

4 Contact can severely irritate and burn the eyes with possible permanent damage (corneal opacities).

5 Exposure can irritate the mouth, nose and throat.

6 Inhalling calcium carbide can irritate the lungs, higher exposures may cause a build -up of fluid in the lungs.

7 (pulmonary edema), a medical emergency.

8 Calcium carbide is FLAMMABLE and REACTIVE and a DANGEROUS FIRE and EXPLOSION HAZARD.

9 When Calcium Carbide is exposed to WATER or MOISTURE it forms flammable Avetylene gas.Consult the Right to Know Hazardous Substance Fact sheet on ACETYLENE.

10 Calcium Carbide can irritate the lungs. Repeated exposure may cause bronchitis to develop with coughing, phlegm, and/or shortness of breath.

Personal protective Equipment

Wear Gloves Clothing

11 Avoid skin contact with Calcium carbide. Wear personal protective equipment made from materail which can not be permeated or degraded by this substance.

12 Safety equipment manufacturers recommend Nitrile and Natural Rubber gor gloves, and Tyvek, or the equivalent, as a protective material for clothing.

All protective clothing (suits,gloves,footwear,headgear)

should be clean, availble each day, and put on before work.

Eye Protection

1 Wear eye protection with side shields or goggles.

2 If additional protection is needed for the entire face, use in combination with a face shield. A face shield should not be used without another type of eye protection.

Acetylene Gas - Properties

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

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

Composition of acetylene gas: Acetylene is composed of:

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

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

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

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

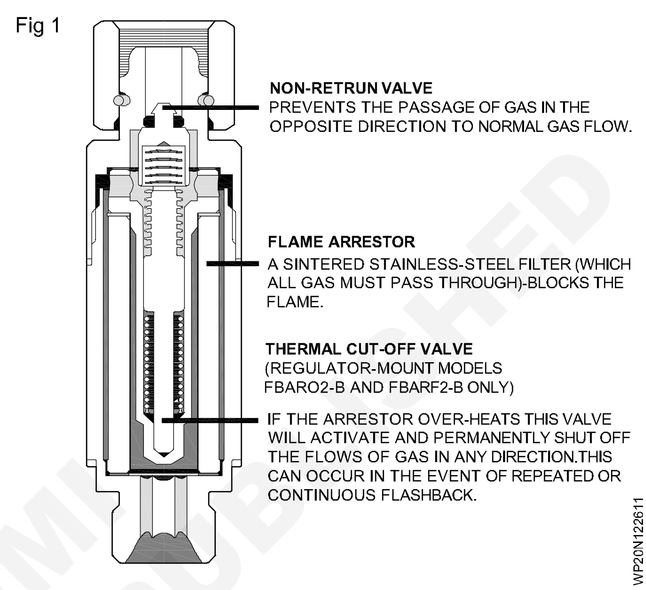
Flash Back Arrestor

Objectives : At the end of this lesson you shall be able to
- **state working principle of flash back arrestor**
- **state how flash back arrestor protect from fire hazards.**

Working principle in normal stage: The acetylene gas from the carbide to water acetylene generator enters through the inlet connection of the flash back arrestor and goes to water compartment through non, return space valve and baffle plate, filter wool. Baffle plate reduces the velocity of acetylene gas whereas the purifying materials purify the generated acetylene gas that goes to outlet through the regulator and gas controlling tap.

Accidental condition: Flash back from the blow pipe enters through the outlet connection in flashback arrestor and goes to the non-return valve through the filter wool, baffle plate and water. Flash back creates the pressure and pushes the water downwards when the ball of non-return valve comes down and closes the inlet acetylene gas with the help of the disc. With the result, no more gas enters inside the flash back arrestor. The acetylene gas which is already in the flask back arrestor burns due to this pressure, the bursting disc bursts remaining gas in the flash back arrestor.So the damages of flash back arrestor outside the water acetylene generator is prevented from the accident. Thereafter water and the carbon particle are taken out through thr drain plug and fresh water is filled in the flash back arrestor for further use.(Fig 1)

Fig 1



Oxygen Gas and its Properties

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

- **explain the composition and properties of oxygen gas**
- **describe the method of producing oxygen by air liquefaction process and by electrolysis of water.**

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

Properties of oxygen gas

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

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

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

Liquid oxygen has a pale blue colour.

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

Iron + oxygen = Iron oxide

Copper + oxygen = Cuprous oxide

Aluminium + oxygen = Aluminium oxide

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

Charging Process of Oxygen and Acetylene Gases.

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

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

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

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

The cylinders are filled with porous substances such as:

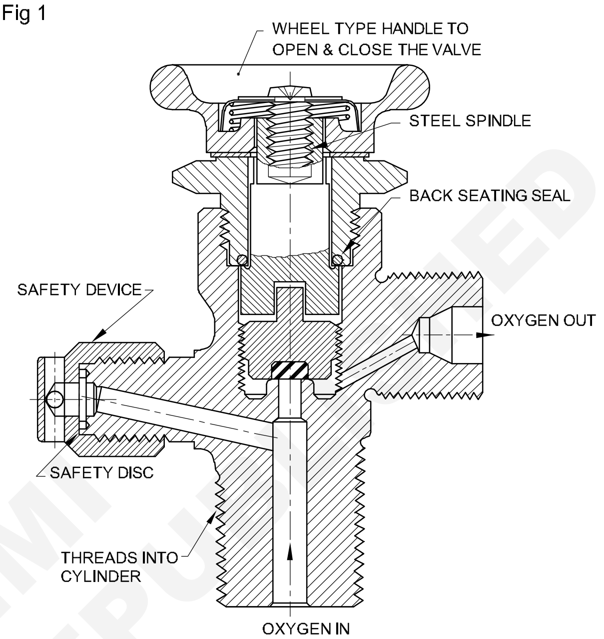
- pith from corm stalk
- fullers earth
- lime silica
- specially prepared charcoal
- Fiber asbestos.

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

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

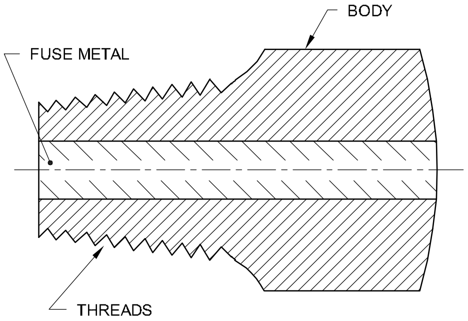
The liquid acetone dissolves the acetylene gas in large quantity as safe storage medium: hence, it is called dissolved acetylene. One volume of liquid acetone can.

Fig 1



CONSTRUCTIONAL FEATURES OF A CYLINDER VALVE

Fig 2



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

Oxygen and DA Gas Cylinder and Colour Coding and Uses of Single Stage and Double Stage Gas Regulator

Objectives : At the end of this lesson you shall be able to
- **state the different types of regulators**
- **describe the working principle of a single and double stage regulator**
- **explain the parts of each type of regulator**
- **explain the care and maintenanace of the regulators.**

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)

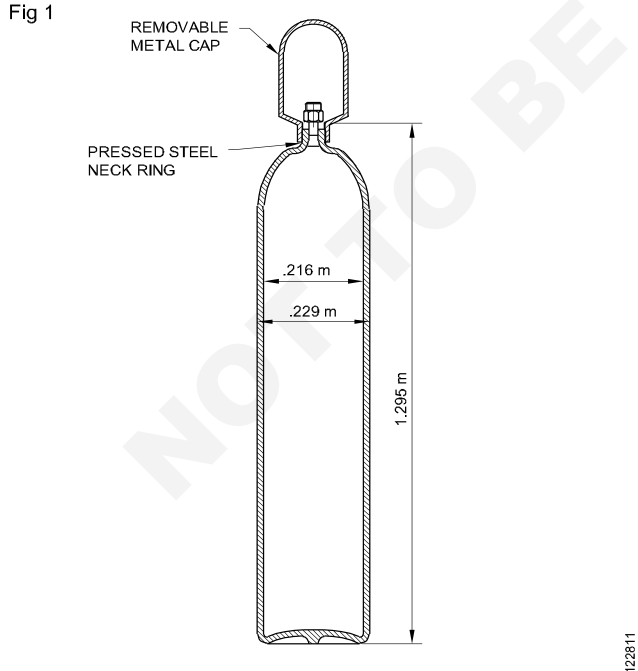
Gas cylinders are identified by their body colour marks and valve threads. (Table 1)

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.

Constructional features of oxygen gas cylinder (Fig 1)

It is made from seamless solid drawn steel and tested with a water pressure of 225kg/cm^2. The cylinder top is fitted with a high pressure valve made from high quality forged bronze. (Fig 1)

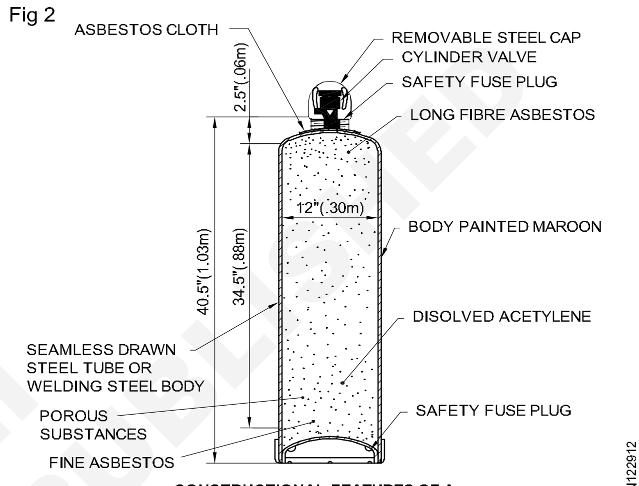
Fig 1



CONSTRUCTIONAL FEATURE OF OXYGEN GAS CYLINDER

Constructional features (Fig 3): The acetylene gas cylinder is made from seamless drawn steel tube or welded steel container and tested with a water pressure of 100kg/

Fig 2



CONSTRUCTIONAL FEATURES OF A DISSOLVED ACETYLENE GAS CYLINDER

cm^2. The cylinder top is fitted with a pressure valve made from high quality forged bronze. The cylinder valve outlet socket has standard left hand threads to which acetylene regulators of all makes may be attached. The cylinder valve is also fitted with a steel spindle to operate the valve for opening and closing. A steel cap is screwed over the valve to protect it from damage during transportation. The body of the cylinder is painted maroon. The capacity of the DA cylinder may be 3.5m^3-8.5m^3.

The base of the D A cylinder (Curved inside) is fitted with fuse plugs which will melt at a temperature of app. 100°C. (Fig 4) 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.

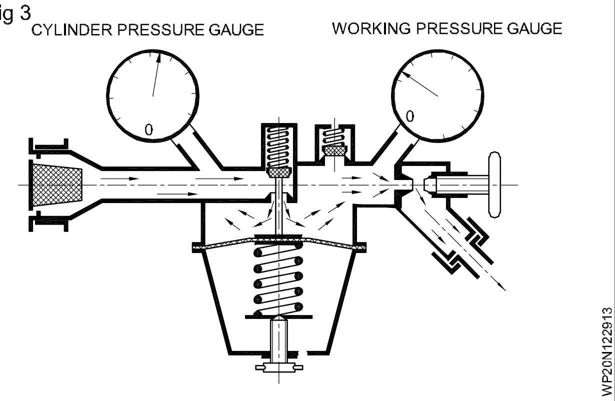
Table 1

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	Right hand

	black neck)	
Air	Grey	Right hand
Propane	RED (with larger diameter and name propane)	Left hand
Argon	Blue	Right hand
Carbon-di-	Black (With	Right hand

Fig 3



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)

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

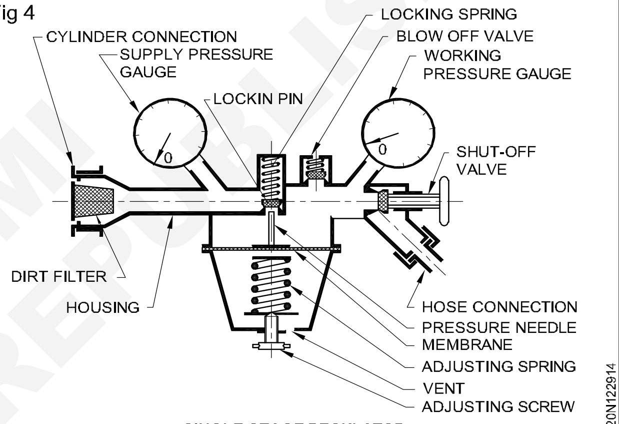
The outlet side is fitted with a pressure gauge which indicates the working pressure on the blowpipe. Upon the gas being drawn 'off from the outlet side, the pressure inside the regulator body falls, the diaphragm is pushed back by the spring and the valve opens, letting more gas 'in' from the cylinder.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

Welding regulator (double stage)

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

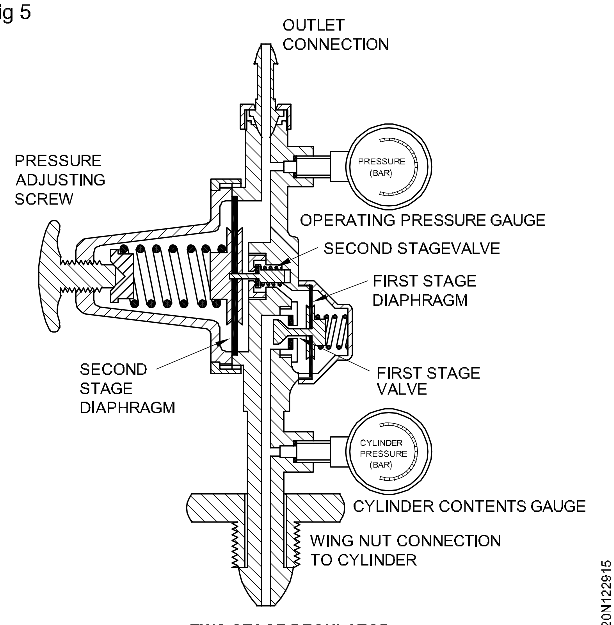
Single stage regulators may be used with pipelines and cylinders. Two stage regulators are used with cylinders and manifolds.

Fig 4



SINGLE STAGE REGULATOR

Fig 5



TWO STAGE REGULATOR

Systems of Oxy-Acetylene Gas Welding System(Low pressure and high pressure)Difference between by welding blow pipe and gas cutting blow pipe

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

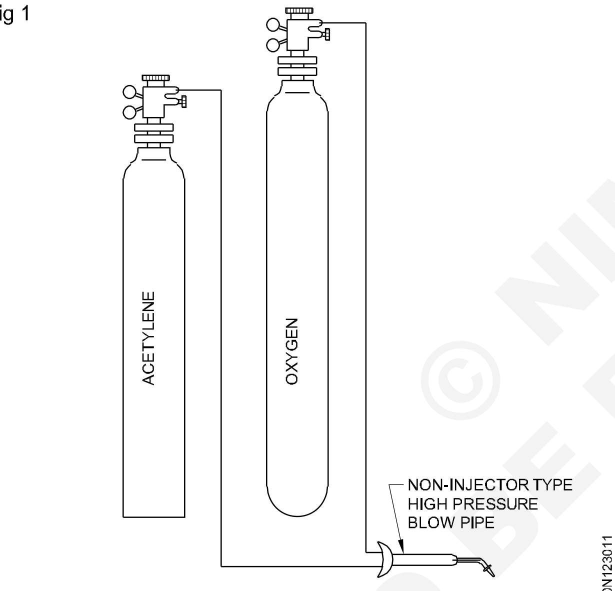
- **explain the low pressure and the high pressure systems of oxy-acetylene plants and systems**
- **distinguish between low pressure and high pressure blowpipes**
- **state the advantages and disadvantages of both systems.**

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.

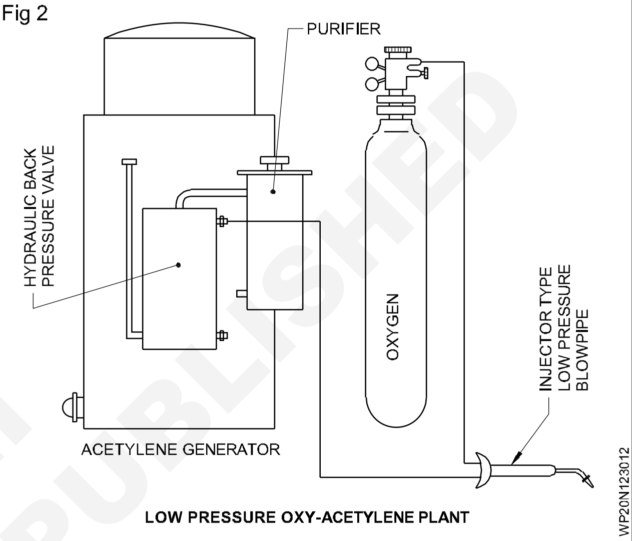
A low pressure plant utilizes acetylene under low pressure (0.017 kg/cm^2) produced by the acetylene generator only. (Fig 2)

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.

Types

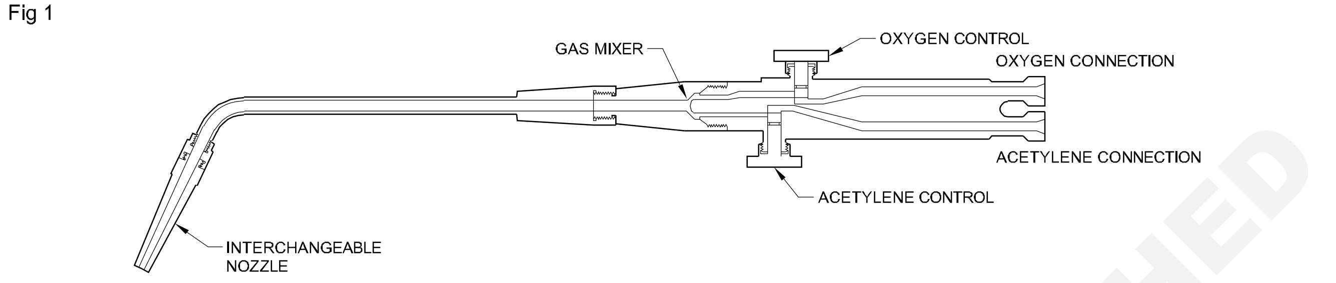
There are two types of blowpipes.

- High pressure blowpipe or non-injector types blowpipe
- Low pressure blowpipe or injector type blowpipe.

Uses of blow pipes: Each type consists of a variety of designs depending on the work for which the blowpipe is required, i,e., gas welding, brazing, very thin sheet welding, heating before and after welding, gas cutting.

Equal or high pressure blowpipe (Fig 1): The H.P. blowpipe is simply a mixing device to supply approximately equal volume of oxygen and acetylene to the tip, and is fitted with valves to control the flow of the gases as required i.e, the blow pipes/gas welding torches are used for welding of ferrous and non-ferrous metals, joining thin sheets by fusing the edges, preheating and post heating of jobs, brazing, for removing the dents formed by distortion and for gas cutting using a cutting blow pipe.

Fig 1



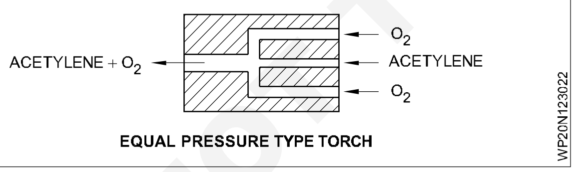
EQUAL OR HIGH PRESSURE BLOWPIPE

The equal pressure blow pipe (Fig.1) consists of two inlet connections for acetylene and oxygen gases kept in high pressure cylinders. Two control valves to control the quantity of flow of the gases and a body inside which the gases are mixed in the mixing chamber (Fig.2). The mixed gases flow through a neck pipe to the nozzle and then get ignited at the tip of the nozzle. Since the pressure of the oxygen and acetylene gases are set at the same pressure of 0.15 kg/cm^2 they mix together at the mixing chamber and flows through the blow pipe to the nozzle tip on its own. This equal pressure blow pipe/torch is also called as high pressure blow pipe/torch because this is used in the high pressure system of gas welding.

A set of nozzles is supplied with each blowpipe, the nozzles having holes varying in diameters, and thus giving various sized flames. The nozzles are numbered with their consumption of gas in litres per hour.

Fig 2

GAS PASSAGE IN THE GAS MIXING SECTION



EQUAL PRESSURE TYPE TORCH

Important caution: A high pressure blowpipe should not be used on a low pressure system.

Low pressure blowpipe (Fig 3)

This blowpipe has an injector (Fig 3) inside its body through which the high pressure oxygen passes. This oxygen draws the low pressure acetylene from an acetylene generator into a mixing chamber and gives it the necessary helps to prevent backfiring.

The low pressure blow pipe is similar to the equal pressure blow pipe except that inside its body an injector with a very small (narrow) hole in its center through which high pressure oxygen is passed. This high pressure oxygen while coming out of the injector creates a vacuum in the mixing chamber and sucks the low pressure acetylene from the gas generator (Fig 4)

It is usual for the whole head to be interchangeable in this type, the head containing both the nozzle and injector. This is necessary, since there is a corresponding injector size for each nozzle.

The L.P. blowpipe is more expensive than the H.P. blowpipe but it can be used on a high pressure system, if required.

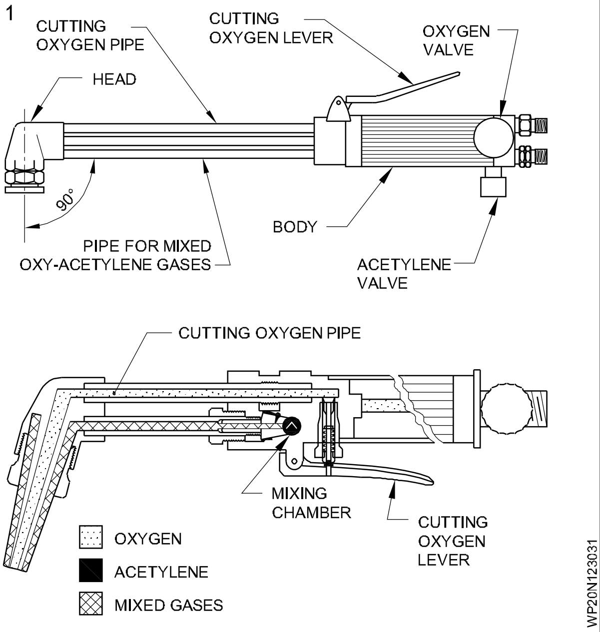
Oxy-acetylene cutting equipment

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

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.

Fig 1



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

A welding blowpipe has only two control valves to control the heating flame (Fig 2).

The nozzle of the cutting blowpipe has one hole in the center for cutting oxygen and a number of holes around the circle for the preheating flame. (Fig 3)

The nozzle of the welding blowpipe has only one hole in the center for the heating flame. (Fig 4)

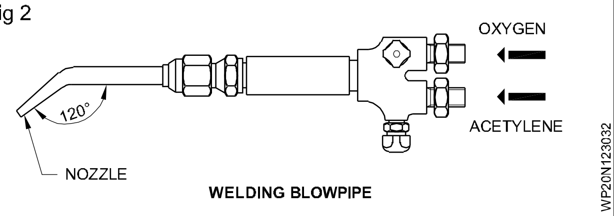
The angle of the cutting nozzle with the body is 90°

The angle of the welding nozzle with the neck is 120°

The cutting nozzle size is given by the diameter of the cutting oxygen orifice in mm.

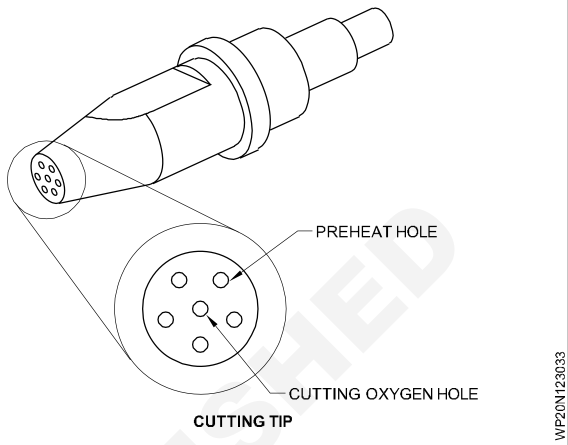
The welding nozzle size is given by the volume of oxy-acetylene mixed gas coming out of the nozzle in cubic meter per hour.

Fig 2



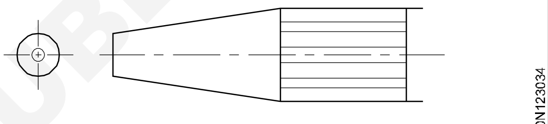
WELDING BLOWPIPE

Fig 3



CUTTING TIP

Fig 4



WELDING NOZZLE

Operating data for cutting mild steel **Care and maintenance**

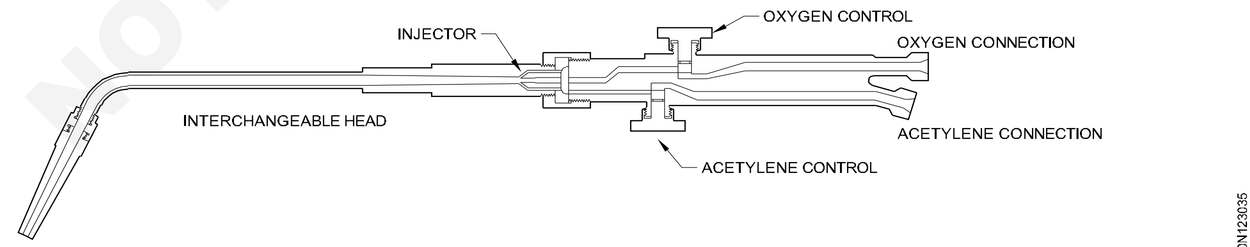
Welding tips made of copper may be damaged by careless handling.

Nozzles should never be dropped or used for moving or holding the work.

The nozzle seat and threads should be absolutely free from foreign matter in order to prevent any scoring/scatter on the fitting surfaces when tightening on assembly.

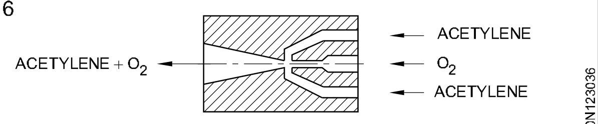
The nozzle orifice should only be cleaned with a tip cleaner specially designed for this purpose. (Fig5,6 &7)

Fig 5



LOW PRESSURE BLOWPIPE

Fig 6



INJECTOR TYPE TORCH

Gas Welding Technique Rightward and Leftward & Technique

Objectives: At the end of this lesson you shall be able to
- **name the different gas welding techniques and explain the leftward welding techniques**
- **describe the edge preparation and application of leftward techniques.**

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

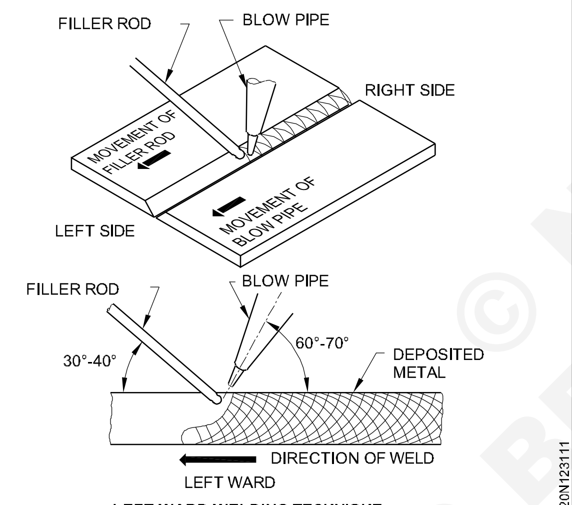
1 Leftward welding technique (Forehand technique)

2 Rightward welding technique (Backhand technique)

The leftward technique is explained below. For details of rightward technique refer Related Theory for exercise 2..6.

Leftward welding technique: It is the most widely used oxy-acetylene gas welding technique in which the welding commences at the right hand edge of the welding job and proceeds towards the left. It is also called forward or forehand technique. (Fig 1)

Fig 1



LEFT WARD WELDING TECHNIQUE

In this case welding is started at the right hand edge of the job and proceeds towards the left. The blowpipe is held at an angle of 60°-70° with the welding line. The filler rod is held at an angle of 30°-40° with the welding line. The welding blowpipe follows the welding rod. The welding flame is directed away from the deposited weld metal.

The blowpipe is given a circular or side-to-side motion to obtain even fusion on each side of the joint.

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

If the flame is used to melt the welding rod itself into the pool, the temperature of the molten pool will be reduced and consequently good fusion cannot be obtained.

Table 1

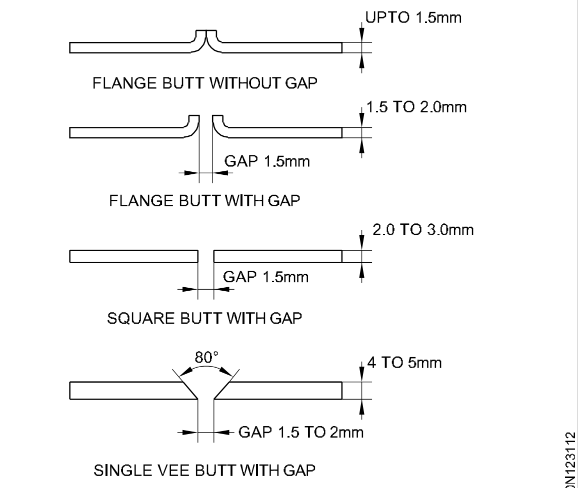
The table given below shows the details for welding mild steel by leftward technique (For Butt joints)

Metal thickness in mm	C.C.M.S filler rod diameter in mm	Blow pipe nozzle size	Edge preparation	Root gap in mm	Flux to be used
0.8	1.6	1	Flange	NIL	
1.6 to 2	1.6	3	Square	2	For gas welding of mild steel no flux is required to be used
2.5	2	5	Square	2	
3.15	2.5	7	Square	3	
4	3.15	7	80°Vee	3	
5	3.15	13	80°Vee	3	

Edge preparation for leftward technique: For fillet joints square edge preparation is done.

For butt joints the edges are prepared as shown in Fig 2. the table given below gives the details for welding mild steel by leftward technique for butt joints.

Fig 2



EDGE PREPARATION FOR LEFTWARD TECHNIQUE

For fillet joints one size larger nozzle is to be used.

Above 5.0 mm thickness, the rightward technique should be used.

Application

This technique is used for the welding of:

- mild steel up to 5mm thick
- all metals both ferrous and non-ferrous.

Rightward technique of oxy-acetylene gas welding

Objectives: At the end of this lesson you shall be able to
- **explain rightward welding technique and its advantages.**
- **describe edge preparation and the application of rightward technique.**

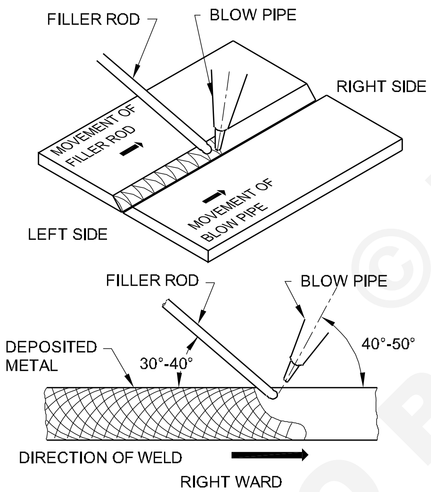
Rightward welding technique: It is an oxy-acetylene gas welding technique, in which the welding is begun at the left hand edge of the welding job and it proceeds towards the right.

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 1)

Fig 1



FEATURE OF RIGHTWARD WELDING TECHNIQUE

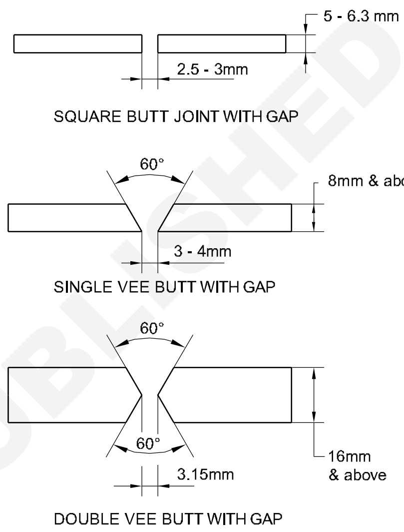
WP20N123121

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 2)

Fig 2



EDGE PREPARATION FOR RIGHTWARD WELDING

WP20N123122

For butt joints the edges are prepared as shown in Fig 2.

The table given below gives the details for welding mild steel by rightward welding technique for Butt joints.

Application: This technique is used for the welding of steel above 5mm thickness and 'LINDE' WELDING PROCESS of sheet pipes.

Advantage: Less cost per length run of the weld due to less bevel angle, less filler rod being used, and increased speed. Welds are made much faster.

It is easy to control the distortion due to less expansion and contraction of a smaller volume of molten metal. The flame being directed towards the deposited metal, is allowed to cool slowly and uniformly. Greater annealing action of the flame on the weld metal as it is always directed towards the deposited metal during welding.

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

Table 1 (For Butt joints)

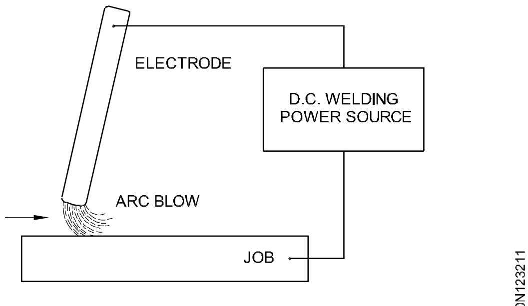
Metal thickness in mm	C.C.M.S filler rod diameter in mm	Blow pipe nozzle size	Edge preparation	Root gap in mm	Flux to be used
5	3.15	10	Square	2.5	For gas welding of mild steel no flux is required to be used
6.3	4.0	13	Square	3.0	
8	5.0	18	60° Vee	3.0	
10 to 16	6.3	18	60° Vee	4.0	
Above 16	6.3	25	60° double Vee	3.0	

Arc Blow Causes and Methods of Controlling

Objectives : At the end of this lesson you shall be able to
- **explain the arc blow in DC welding**
- **explain the effects of arc blow on welds**
- **describe the various methods used to control the arc blow.**

Arc blow in dc welding: When the arc deviates from its regular path due to the magnetic disturbances it is called 'Arc blow'. (Fig 1)

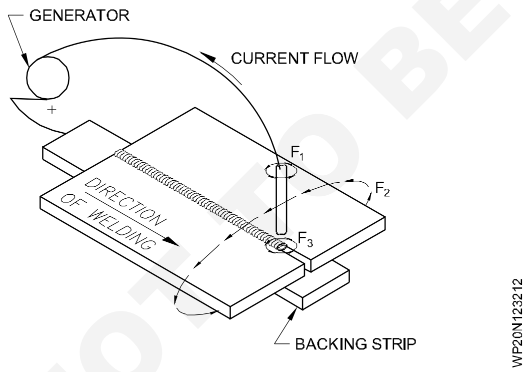
Fig 1



ARC BLOW IN DC ARC WELDING

Causes and effects of arc blow: Whenever a current flows in the electrode a magnetic field is formed around the electrode and the arc F_1 and F_3 (Fig 2). Likewise a similar magnetic field is also formed around the base metal F_2 (Fig 2). Due to the interaction of these two magnetic fields, the arc is blown to one side of the joint. At the starting of the weld there will be forward blow and at the end backward blow. (Fig 3)

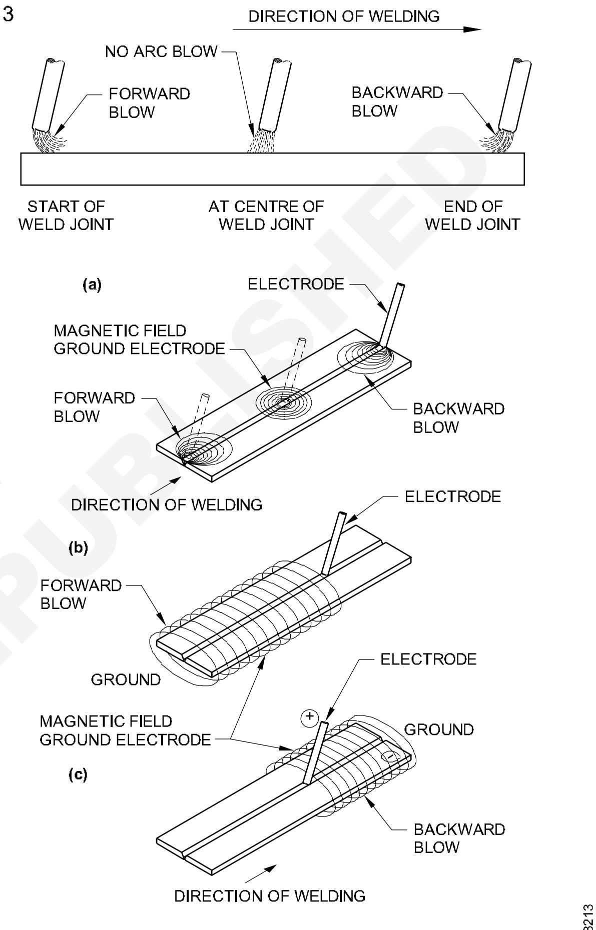
Fig 2



Due to this the following effects occur.

- more spatters with less deposition of weld metal.
- poor fusion/penetration.
- weak welds.
- Difficulty in depositing weld metal at the required place in the joint.
- The bead appearance will be poor and slag inclusion defect will also take place.

Fig 3



MAGNETIC FIELDS THAT RESULT IN FORWARD OR BACKWARD ARC BLOW (A) AROUND THE ELECTRODE/ARC (B) AND (C) AROUND THE WORK

Methods used to control the arc blow

The arc blow can be controlled by:

- Place the earth connection as far from the weld joint as possible. (Fig 4)
- changing the position of the earth connection on the work.
- Changing the position of the work on the welding table.
- wrapping the electrode cable around the work. (Fig 5)
- welding towards a heavy welding tack or a weld already made.

Fig 4

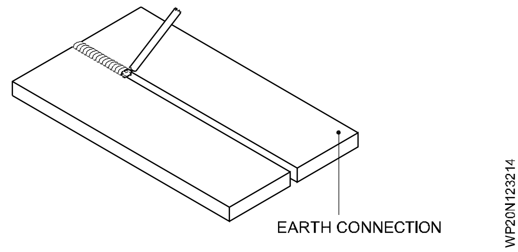
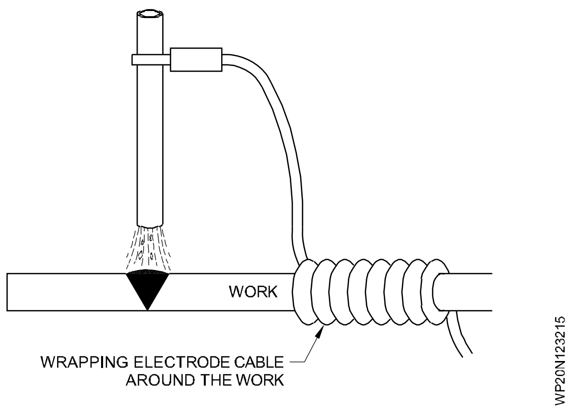


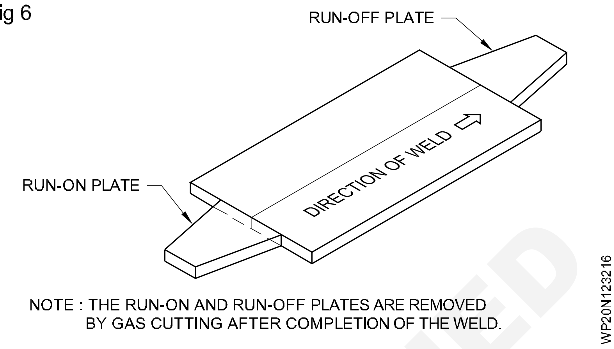
Fig 5



- keeping a magnetic bridge on the top of the groove joint.
- holding the correct electrode angle with a short arc. use 'run on' and 'run off plates. (Fig 6)

If all the above methods fail to control the 'arc blow', change to AC supply.

Fig 6

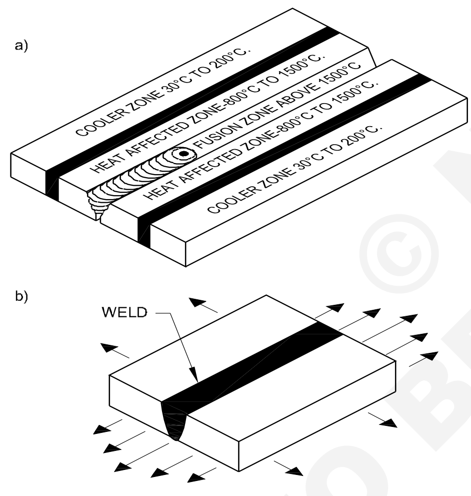


Distortion in Arc & Gas Welding and Methods Employed to Minimize Distortion.

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

Causes of distortion: In arc welding, the temperature at different areas of the joint are different. (Fig 1a). The expansions in these areas are also different depending on the temperature (Fig 1b). In the same way after welding, different areas of the joint contract differently, But in a solid body (i.e., the parent metal) it cannot expand or contract differently at different areas. This uneven expansion and contraction of the welded joint due to uneven heating and cooling in welding creates stresses in the joint. These stresses make the welded job to change its size and shape permanently (i.e. deformation) and this is called distortion of the welded joint. (Fig 2)

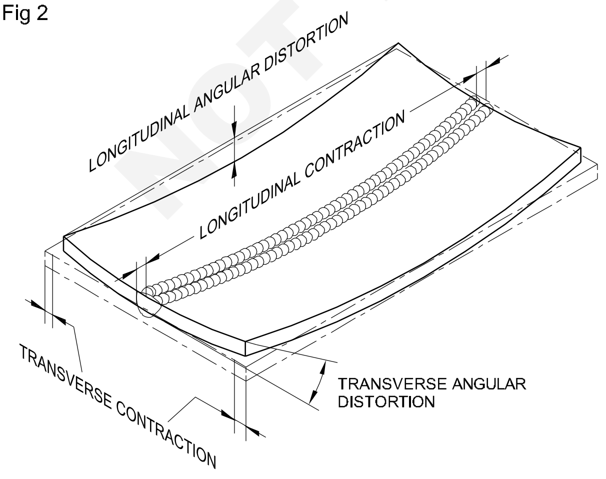
Fig 1



EXPANSION OF A PLATE DURING WELDING (MILD STEEL)

WP20N123311

Fig 2



DISTORTION IN SINGLE-SIDED WELDING OF AN UNRESTRAINED BUTT JOINT WITH SEVERAL SMALL RUNS

WP20N123312

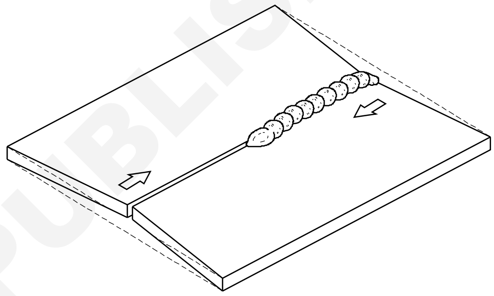
Types of distortion

The 3 types of distortion are:

- longitudinal distortion
- transverse distortion
- angular distortion.

The figures (3,4,5) illustrate the different types of distortion.

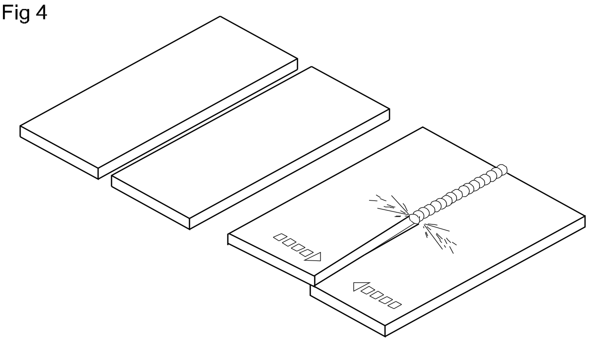
Fig 3



LONGITUDINAL DISTORTION

WP20N123313

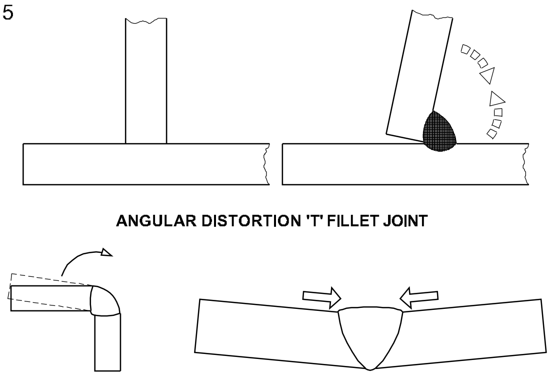
Fig 4



TRANSVERSE DISTORTION

WP20N123314

Fig 5



WP20N123315

Factors affecting distortion

Design

Parent metal

Joint preparation and set up

Assembly procedure

Welding process

Deposition technique

Welding sequence

Unbalanced heating about the neutral axis

Restraint imposed

Either one or more of these above factors are responsible for distortion, in a welded job. To avoid or reduce the distortion in a welding job these factors are to be taken care of-before, during and after welding. The methods adopted to avoid or reduce distortion are as follows.

Prevention of distortion: The following methods are used to prevent and control distortion.

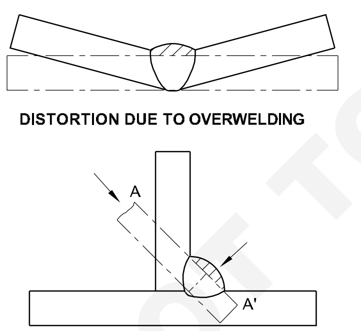
- Reducing the effective shrinkage force.
- Making the shrinkage forces to reduce distortion.
- Balancing the shrinkage force with another shrinkage force.

Methods of reducing the effective shrinkage forces

Avoiding over-welding/Excessive reinforcement: Excessive build up in the case of butt welds and fillet welds should be avoided. (Fig 6)

The permissible value of reinforcement in groove and fillet welds is T/10 where "T" is thickness of parent metal.

Fig 6



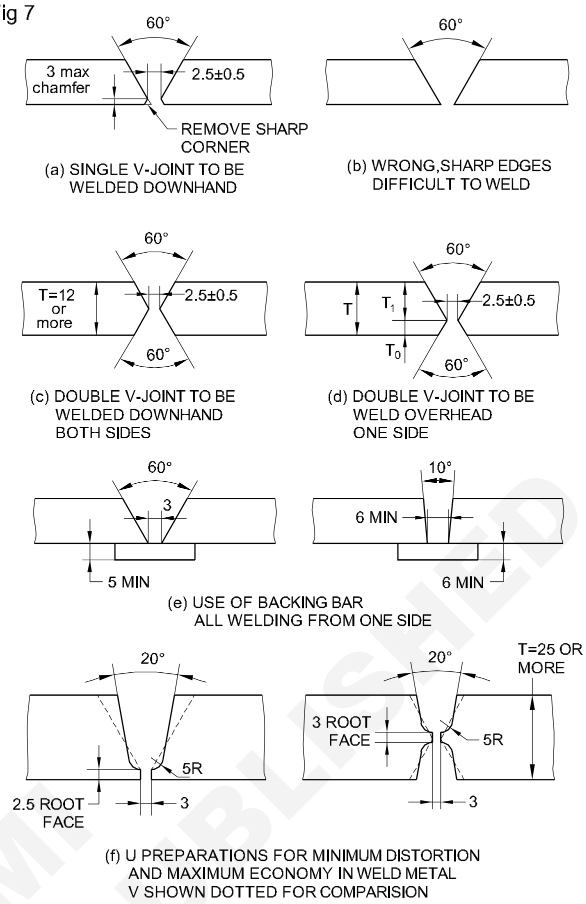
EXCESS WELD METAL ABOVE THE LINE A A' OF CONVENTIONAL FILLET WELD

WP20N123316

Use of proper edge preparation and fit up: It is possible to reduce the effective shrinkage force by correct edge preparation. This will ensure proper fusion at the root of the weld with a minimum of weld metal. (Fig 7)

Use of few passes: Use of fewer passes with large dia. electrodes reduces distortion in the lateral direction. (Fig8)

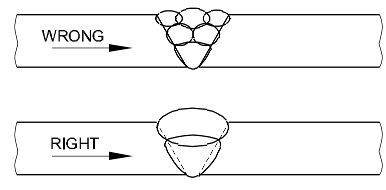
Fig 7



PREPARATION OF PLATES FOR BUTT WELDING

WP20N123317

Fig 8

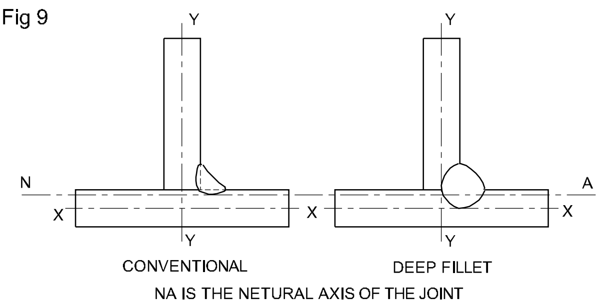


COMPARISION OF PASSES OF WELD

WP20N123318

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

Fig 9

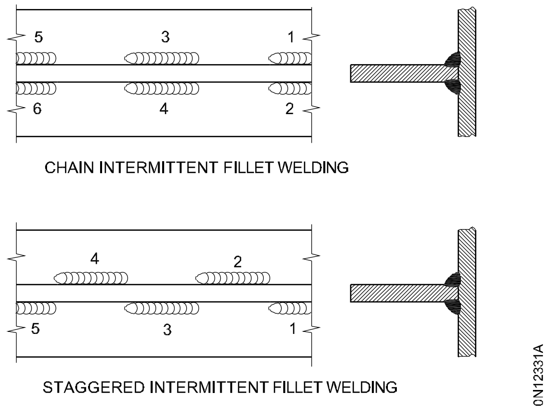


DEEP PENETRATION FILLET WELD

WP20N123319

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)

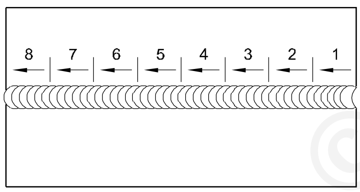
Fig 10



INTERMITTENT WELDING

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

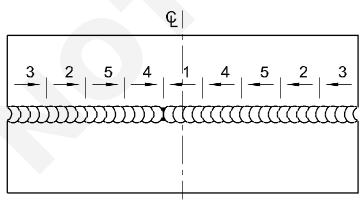


BACK STEP WELDING METHOD

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)

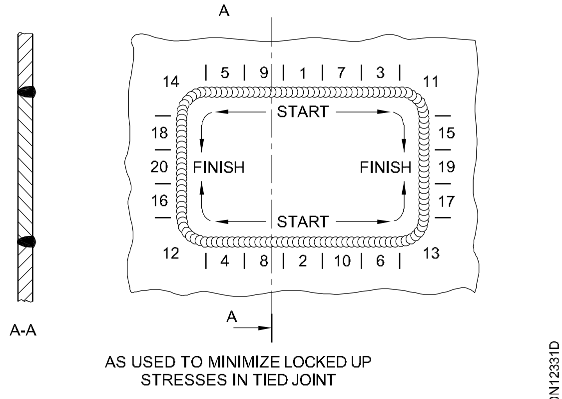
Fig 12



PLANNED WANDERING METHOD

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

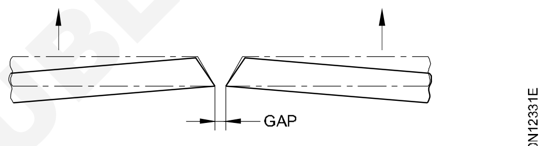


SKIP WELDING

Methods used for making the shrinkage forces work to reduce distortion

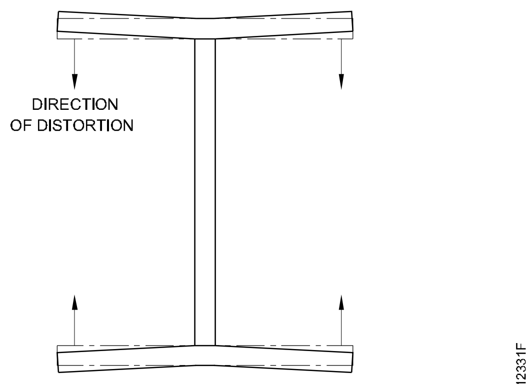
Locating parts out of position: Distortion may be allowed for by pre-setting the plates in the opposite way so that the weld pulls them to the desired shape. When the weld shrinks it will pull the plate to its correct position (Fig 14 & 15)

Fig 14



PRE-SETTING TO COMPENSATE FOR ANGULAR DISTORTION

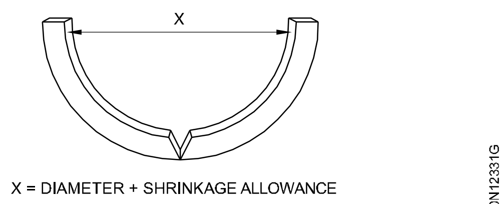
Fig 15



PRE-CAMBERING TO COMPENSATE FOR ANGULAR DISTORTION

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)

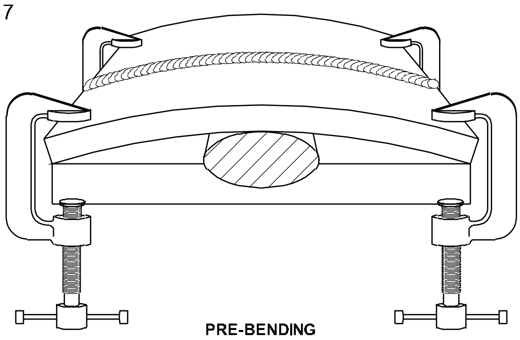
Fig 16



SPACING OF PARTS TO ALLOW FOR SHRINKAGE

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

Fig 17

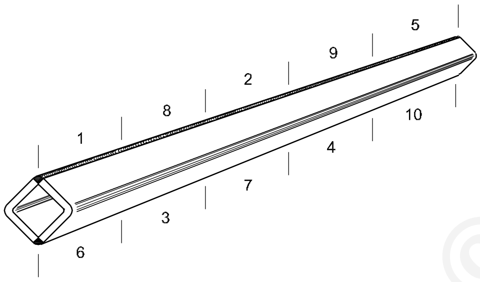


PRE-BENDING

Methods of balancing of one shrinkage force with another shrinkage force

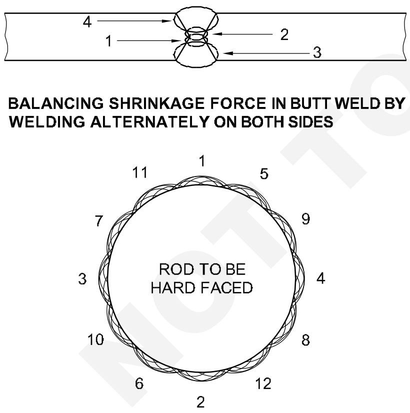
Use of proper welding sequence: This places the weld metal at different points about the structure. In this method, welds are made from each side alternately so that when a second run of weld metal shrinks it will counteract the shrinkage forces of the first weld. (Figs 18, 19 a and 19b)

Fig 18



AS USED WHEN FABRICATING SQUARE SECTIONS FROM ANGLES OR CHANNELS

Fig 19

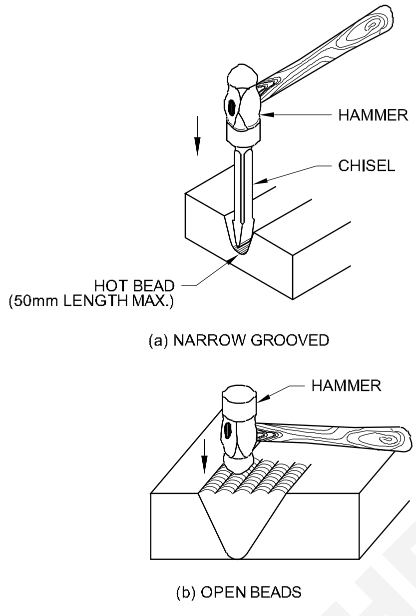


a) BALANCING SHRINKAGE FORCE IN BUTT WELD BY WELDING ALTERNATELY ON BOTH SIDES

b) SEQUENCE WELDING USED TO CONTROL DISTORTION IN HARD FACING OPERATION

Peening: This is light hammering of the weld metal immediately after it is deposited. By peening the bead, it is actually stretched counteracting its tendency to contract as it cools. Fig 20.

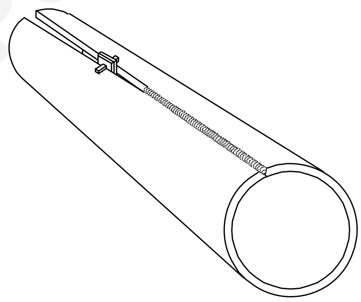
Fig 20



PEENING

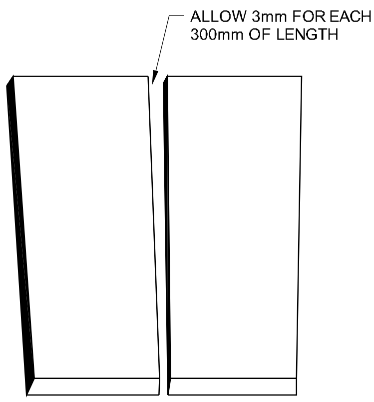
Divergence allowance: As there is a tendency of the plates to extend & converge along the seam during welding, this technique is used to diverge the plates from the point where welding commences by placing a wedge or an alignment clamp between the plates ahead of the weld. (Fig 21& 22)

Fig 21



DIVERGENCE ALLOWANCE

Fig 22



PROVIDE SPACE BETWEEN THE EDGES TO BE WELDED

DIVERGING ALLOWANCE

The spacing allowances are as follows.

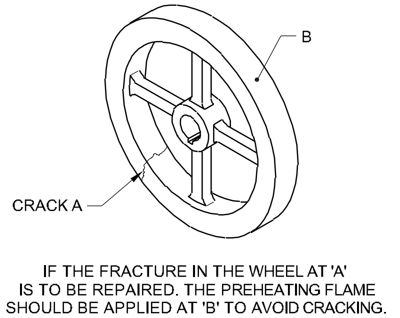
3mm/m for (mild steel) Ferrous metals

10 mm/m for non ferrous metals

While cooling, the shrinkage stresses will pull the plate in correct alignment.

Preheating: Some metals would normally fracture if welded in the cold state. They may be welded successfully by preheating and subsequent controlled cooling. (Fig 23)

Fig 23

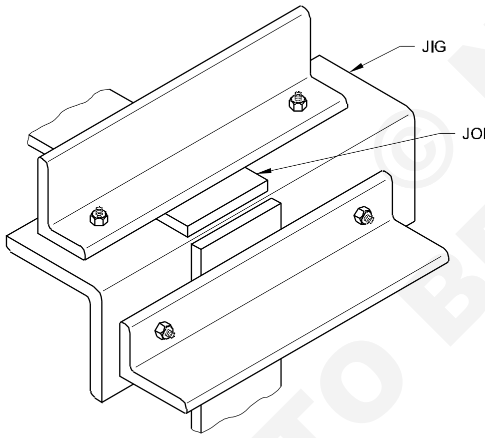


TECHNIQUE OF LOCAL PREHEATING

WP20N12331N

Jigs and fixtures: Jigs and fixtures are used to hold the work in a right position during welding. By using them the shrinkage forces of the weld are balanced with sufficient counter force of the jigs and fixtures. (Fig 24)

Fig 24



USE OF JIGS AND FIXTURES TO AVOID DISTORTION

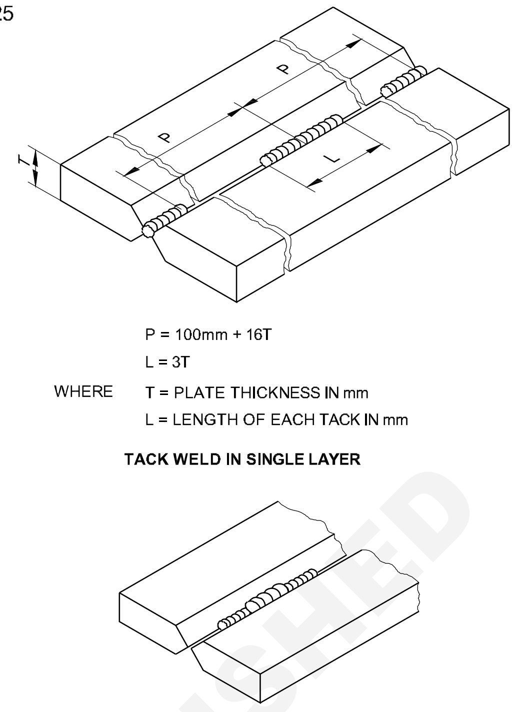
WP20N12331O

Tack-welding: A tack weld is a short weld made prior to welding to hold the plates in perfect alignment and with uniform root gap. Tack welds are made at regular intervals along the joint with high current to obtain proper penetration. (Fig 25) They are necessary where the plates cannot be held by a fixture. (Fig 26)

Methods of correcting distortion: Distortion may take place even after following a planned procedure as it is difficult to control distortion to the full extent. So some mechanical means and application of heat are used to remove distortion after it occurs.

Mechanical methods: Small parts, deformed by angular distortion can be straightened by using a press. If the parts of the assembly are not restrained, they can be brought into alignment by hammering, drifting or jacking without giving excessive force (stress}.

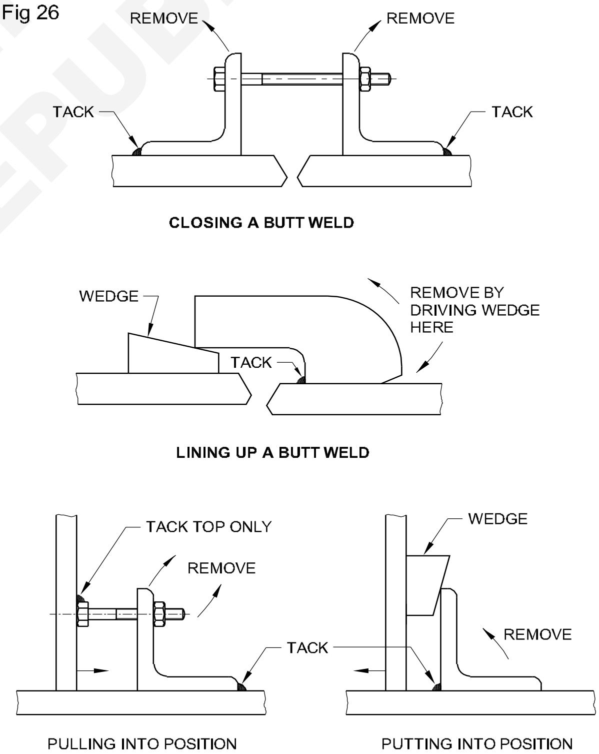
Fig 25



TACK WELD IN TWO LAYERS.
TOP WELD IS SHORTER IN LENGTH THAN BOTTOM LAYER.

WP20N12331P

Fig 26



TACK WELDING ERECTION CLEATS AND AIDS TO ASSEMBLY

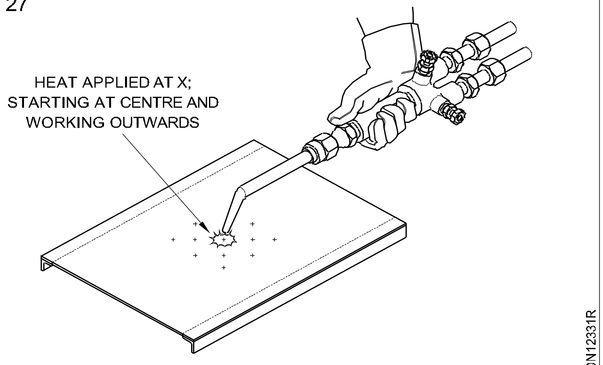
WP20N12331Q

Heating methods: The distorted part is heated locally and rapidly keeping the surrounding metal reasonably cool.

Heat small areas at a time. It should not exceed bright red hot condition.

If thin plates are buckled they can be corrected by local spot heating on the convex side. Starting at the center of the buckled area heat symmetrically outwards as shown in Fig 27.

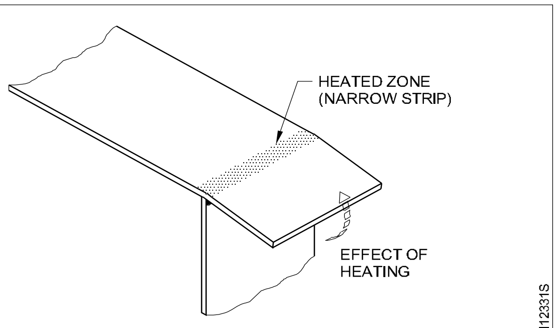
Fig 27



SPOT HEATING TO CORRECT BUCKING OF THIN SHEET

Correction of distortion caused by fillet welds is done by local heating on the underside of the plate in a narrow strip following the line of the joint. (Fig 28)

Fig 28



CORRECTION OF DISTORTION CAUSED BY FILLET WELD

Straightening by flame heating: The most common distortion-removal technique is to use a flame and heat the part at selected spots or along certain lines and then to aircool it. The area to be straightened is heated to between 600 and 650°C for plain carbon and low alloy steels and suddenly cooled in air, or if necessary with a spray of water in low carbon steels.

The methods of flame straightening are shown in Fig 29.

In Line heating (Fig 29a) heat from the torch is applied along a line or a set of parallel lines. This method is frequently used for removing the angular distortion produced by the fillet welds attaching a plate to its stiffener.

In pipe-needle (Fig 29b) heating, heat is applied along two short lines crossing each other. This method is half way between line heating and spot heating. Since the shrinkage and angular distortion occur in two directions, this method produces a uniform distortion-removal effect.

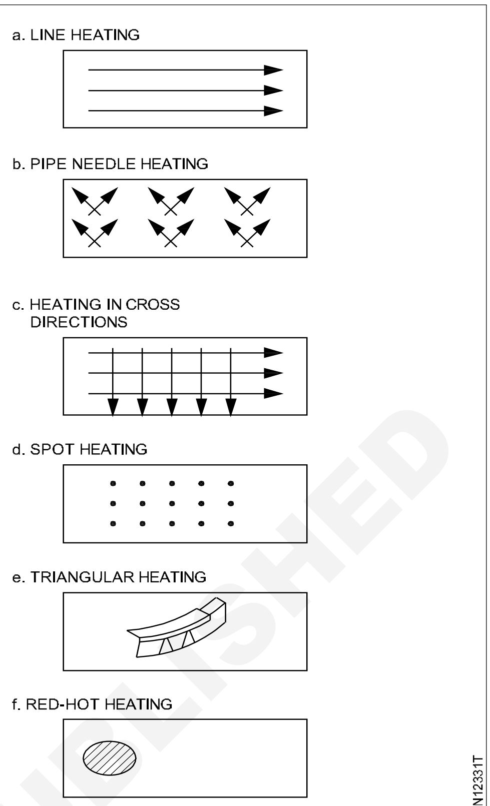
In checker board (cross-directions) heating, (Fig 29c) heat is applied along a pair of two lines crossing each other. This method is used to remove severe distortion.

In spot heating. (Fig 29e) heat is applied on a wedge shaped area, and this method is useful for the removal of bending distortion in frames.

In triangular heating (Fig 29e) heat is applied on a wedge shaped area, and this method is useful for the removal of bending distortion in frames.

Red hot heating (Fig 29f) is used when severe distortion has occurred in a localised area, and it may be necessary to heat the area to a high temperature and beat it with a hammer. This method can cause metallurgical changes.

Fig 29



METHODS OF FLAME-STRAIGHTENING

Thermal treatments: To reduce distortion, various thermal treatments are done. They include preheat and post weld thermal treatments.

Preheating: Weld shrinkage is generally reduced by preheating. Actual measurements across welds during cooling have shown that less than 30% total contraction occurred in joints preheated to 200°C, compared to non-preheating joints.

Stress relief: In many cases thermal stress relief is necessary to prevent further distortion being developed before the weldment is brought to its finished state. Residual tensile stress in welds are always balanced by compressive residual stresses. If a considerable portion of the stressed material is machined out, a new balance of residual stress will result, causing new distortion. Weld stress-relieving prior to machining is thus very important for prolonged dimensional accuracy of sliding and rotating parts.

Vibration stress relieving: This technique reduces distortion by means of vibrating the weldments. The equipment consists of a variable speed vibrator, which is clamped to the work piece, and an electronic amplifier, by varying the speed of the vibrating motor, the frequency can be varied until a resonant frequency has been reached for the work piece. The piece is then allowed to vibrate for a period which varies in relation to the weight of the work piece. Usually it ranges from 10 to 30 minutes. 30 to even 50% of the residual stresses are relieved using vibrating methods. The component thus balances roughly its residual stresses, and it remains undistorted.

Arc Welding Defects Causes and Remadies

Objectives: At the end of this lesson you shall be able to
- **name different weld defects in arc welded joints**
- **define weld defect**
- **state the effect of defects on the welded joints**
- **differentiate between external and internal defects.**

Introduction: The strength of a welded joint should be more than or equal to the strength of the base metal. If any weld defect is in a welded joint, then the joint becomes weaker than the base metal. This is not acceptable.

So a strong or good weld should have uniformly rippled surface, even contour, bead width, good penetration and should not have defect.

Definition of a weld defect/fault: A defect or fault is one which does not allow the finished joint to withstand or carry the required load.

Effects of weld defect/fault: Always a defective welded joint will have the following bad effects.

- The effective thickness of the base metal is reduced.
- The strength of the weld is reduced
- The effective throat thickness is reduced
- The joint will break, when loaded, causing accident.
- The properties of base metal will change.
- More electrodes are required which will also increase the cost of welding.
- Waste of labour and materials.
- The weld appearance will be poor.

Since the weld defects will give bad effects on the joint, always proper care and action has to be taken before and during welding to avoid/prevent the defects. If the defects have already taken place then proper action has to be taken to correct/rectify the defect after welding.

The action/measure taken to avoid/prevent and correct/rectify a weld defect is also called as a remedy.

So some remedies may help to avoid/prevent a weld defect and some remedies may help to correct/rectify a weld defect which has already taken place.

Weld defect may be considered under two heads.

- External defects
- Internal defects

The defects which can be seen with bare eyes or with a lens on the top of the weld bed, or on the base metal surface or on the root side of the joint are called external defects.

Those defects, which are hidden inside the weld bead or inside the base metal surface and which cannot be seen with bare eyes or lens are called internal defects.

Some of the weld defects are external defects, some are internal defects and some defects like crack, blow hole and porosity, slag inclusion, lack of root penetration in fillet joints, etc. will occur both as external and internal defects.

External defects

1. Undercut
2. Cracks
3. Blow hole and porosity
4. Slag inclusions
5. Edge plate melted off
6. Excessive convexity/Oversized weld/Excessive reinforcement
7. Excessive concavity/insufficient throat thickness/insufficient fill
8. Incomplete root penetration/lack of penetration
9. Excessive root penetration
10. Overlap
11. Mismatch
12. Uneven/irregular bead appearance
13. Spatters

Internal defects

1. Cracks
2. Blow hole and porosity
3. Slag inclusions
4. Lack of fusion
5. Lack of root penetration
6. Internal stresses or locked-up stresses or restrained joint.

Defects in arc Welding - Definition, Causes and Remedies

Objectives: At the end of this lesson you shall be able to
- **define common weld defects in arc welded joints**
- **describe the causes, remedies and corrections of weld defects.**

A sound or good weld will have uniformly rippled surface, even contour, bead width, good penetration and no defects.

Definition of a defect: A defect is one which does not allow the finished joint to withstand the required strength (load).

Causes for weld defects means wrong actions taken which creates the defect.

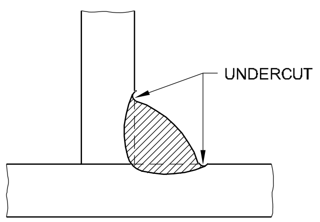
A remedy can be

a Preventing the defect by taking proper actions before and during welding.

b Taking some corrective actions after welding to rectify a defect which has already taken place.

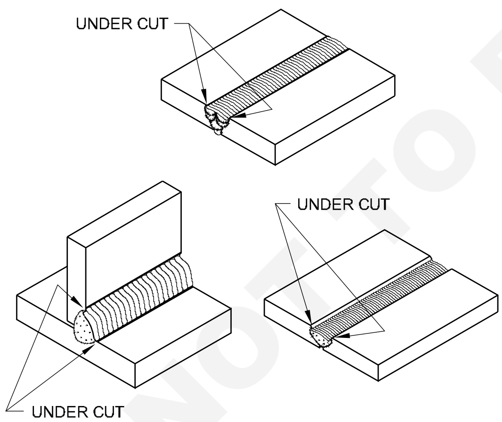
Undercut: A grooved or channel formed in the parent metal at the toe of the weld. (Figs 1, 2 & 3)

Fig 1



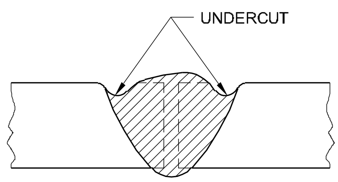
TEE-JOINT FILLET WELD

Fig 2



A SCHEMATIC DIAGRAM OF UNDERCUTS IN FILLET AND BUTT WELDS.

Fig 3



SQUARE-BUTT WELD

Causes

- Current too high
- Use of a very short arc length
- Welding speed too fast
- Overheating of job due continuous welding
- Faulty electrode manipulation
- Wrong electrode angle

Remedies

a Preventive action

Ensure

- proper current is set
- correct welding speed is used
- correct arc length is used
- correct manipulation of electrode is followed

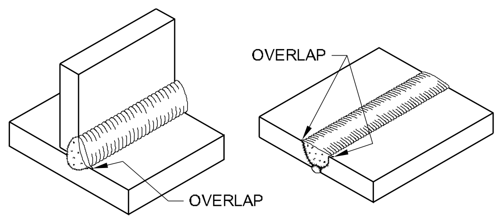
b Corrective action

- deposit a thin stringer bead at the top of the weld using a 2mm ø electrode to fill up the undercut.

Overlap

An overlap occurs when the molten metal from the electrode flows over the parent metal surface without fusing into it. (Fig 4)

Fig 4



SCHEMATIC DIAGRAM OF OVERLAP IN FILLET AND BUTT WELDS

Causes

- Low current.
- Slow arc travel speed.
- Long arc.
- Too large a diameter electrode.
- Use of wrist movement for electrode weaving instead of arm movement.

Remedies

a Preventive actions

- Correct current setting.
- Correct arc travel speed.

– Correct arc length.

– Correct diameter electrode as per metal thickness.

– Proper manipulation of electrode.

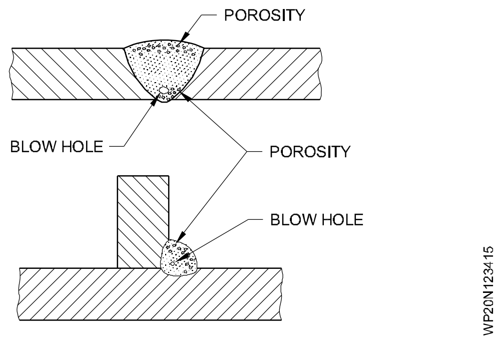
b Corrective actions

– Remove the overlap by grinding without an undercut.

Blowhole and porosity

Blow hole or gas pocket is a large diameter hole inside a bead or on the surface of the weld caused by gas entrapment. Porosity is a group of fine holes on the surface of the weld caused by gas entrapment. (Fig 5)

Fig 5



Causes

Presence of contaminants/impurities on the job surface or on electrode flux, presence of high sulphur in the job or electrode materials. Trapped moisture between joining surfaces. Fast freezing of weld metal. Improper cleaning of the edges.

Remedies

a Preventive actions

– Remove oil, grease, rust, paint, moisture, etc. from the surface. Use fresh and dried electrodes. Use good flux-coated electrodes. Avoid long arcs.

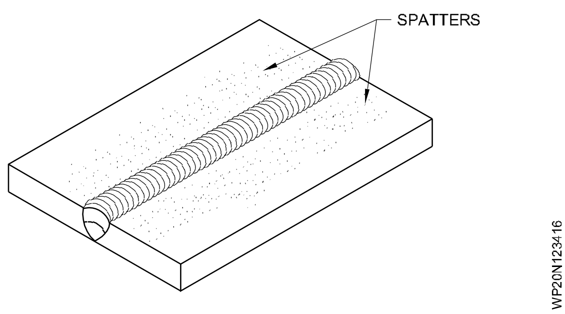
b Corrective action

– If the blowhole or porosity is inside the weld then gouge the area and re-weld. If it is on the surface then grind it and re-weld.

Spatter

Small metal particles which are thrown out of the arc during welding along the weld and adhering to the base metal surface. (Fig 6)

Fig 6



Causes

Welding current too high. Wrong polarity (in DC). Use of long arc. Arc blow. Uneven flux coated electrode.

Remedies

a Preventive actions

– Use correct current.

– Use correct polarity (DC).

– Use correct arc length.

– Use good flux-coated electrode.

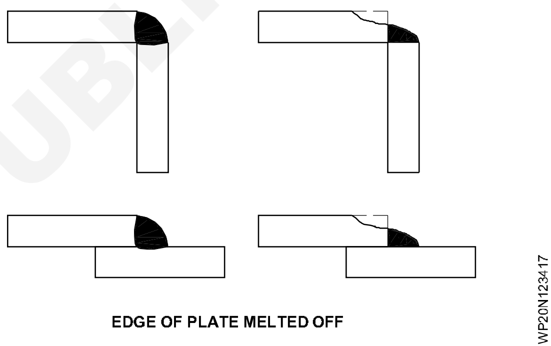
b Corrective actions

– Remove the spatters using a chipping hammer and wire brush.

Edge of plate melted off

Edge of plate melted off defect takes place in lap and corner joints only. If there is excess melting of one of the plate edges resulting in insufficient throat thickness then it is called edge of plate melted off defect. (Fig 7)

Fig 7



Causes

– Use of oversize electrode.

– Use of excessive current.

– Wrong manipulation of the electrode i.e. excessive weaving of electrode.

Remedies

a Preventive action

– Select correct size electrode.

– Set correct current.

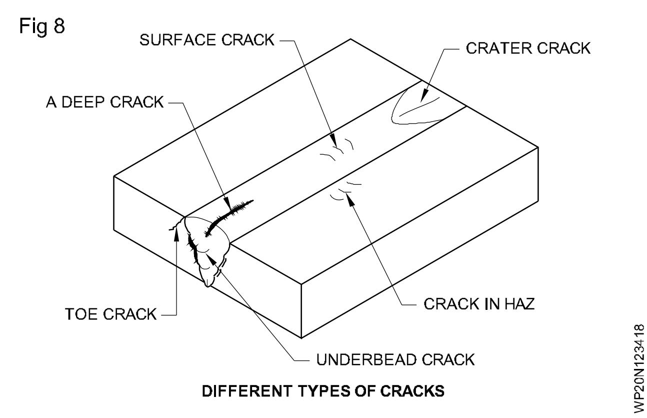
– Ensure correct manipulation of electrode.

b Corrective action

– Deposit additional weld metal to increase throat thickness.

Crack

A hairline separation exhibits in the root or middle or surface and inside of the weld metal or parent metal. (Fig 8)



DIFFERENT TYPES OF CRACKS

Causes

- Wrong selection of electrode.
- Presence of localized stress.
- A restrained joint.
- Fast cooling.
- Improper welding techniques/sequence.
- Poor ductility.
- Absence of preheating and post-heating of the joint.
- Excessive sulphur in base metal.

Remedies

a Preventive actions

- Preheating and post-heating to be done on copper, cast iron, medium and high carbon steels.
- Select low hydrogen electrode.
- Cool slowly.
- Use fewer passes.
- Use proper welding technique/sequence.

Cracks

b Corrective actions

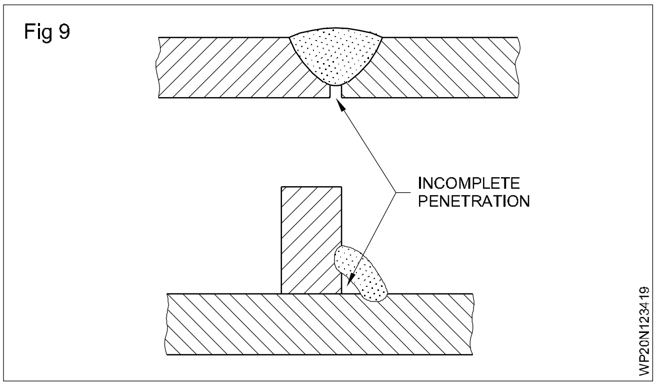
- For all external cracks to a smaller depth, take a V groove using a diamond point chisel upto the depth of the crack and re-weld (with preheating if necessary) using low hydrogen electrode. Cool the job slowly.
- For internal/hidden cracks gouge upto the depth of the cracks and re-weld (with preheating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

Incomplete penetration

Failure of weld metal to reach and fuse the root of the joint. (Fig 9)

Causes

- Edge preparation too narrow - less bevel angle.
- Welding speed too much.



- Key-hole not maintained during welding the root run of a grooved joint.
- Less current.
- Use of larger dia. electrode.
- Inadequate cleaning or gouging before depositing sealing run.
- Wrong angle of electrode.
- Insufficient root gap.

Remedies

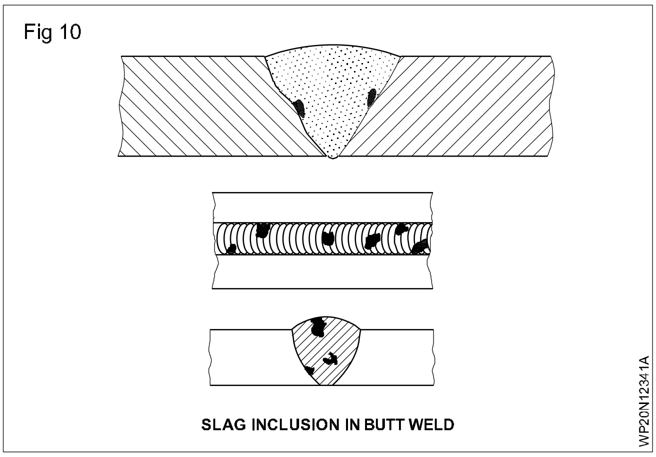
a Preventive actions

- Correct edge preparation is required.
- Ensure correct angle of bevel and required root gap.
- Use correct size of electrode.
- Correct welding speed is required.
- Maintain a keyhole throughout the root run.
- Correct current setting is required.

b Corrective actions

- For butt welds and open corner welds gouge the root of the joint and deposit the root run from the bottom side of the joint. For a Tee & lap fillet welds blow off the full weld deposit and reweld the joint.

Slag inclusion: Slag or other non-metallic foreign materials entrapped in a weld. (Fig 10)



SLAG INCLUSION IN BUTT WELD

Causes

- Incorrect edge preparation.
- Use of damaged flux coated electrode due to long storage.
- Excessive current.
- Long arc length.
- Improper welding technique.
- Inadequate cleaning of each run in multi-run welding.

Remedies

a Preventive actions

- Use correct joint preparation.
- Use correct type of flux coated electrode.
- Use correct arc length.
- Use correct welding technique.
- Ensure thorough cleaning of each run in multi-run welding.

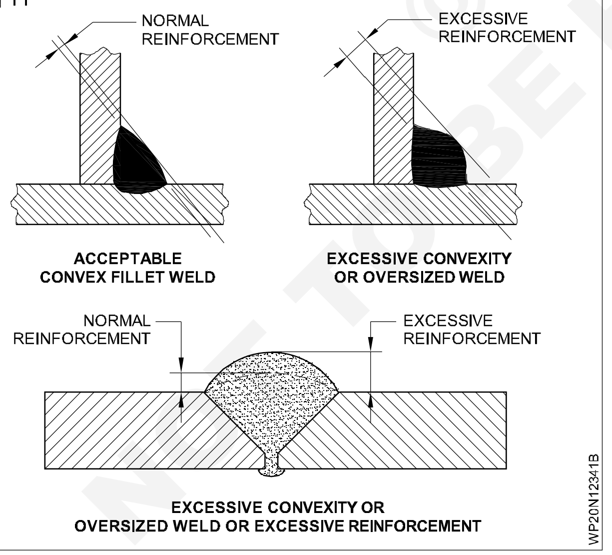
b Corrective actions

- For external/surface slag inclusion remove them using a diamond point chisel or by grinding and re-weld that area. For internal slag inclusions use gouging upto the depth of the defect and re-weld.

Excessive convexity (Fig 11)

This defect is also called as oversize weld or excessive reinforcement. It is the extra weld metal deposited in the final layer/covering run.

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)

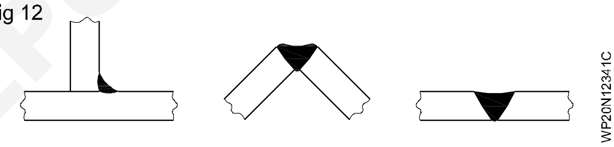
Causes

- 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.

Fig 12



Specification of Pipe Various Type of Pipe Joints pipe Welding, Positions and Procedure.

Objectives: At the end of this lesson you shall be able to
- **explain the advantages of welded pipes**
- **state different methods of pipes welding**
- **explain the types of pipe joint and pipe welding position.**
- **describe the methods of welding pipes in '1G' position.**

Specification of Pipes

- In a pipe its size is measured by nominal diameter (or) nominal outside diameter (OD).
- It is also mentioned as nominal pipe size (NPS).
- Pipe is normally used to transport gases or liquids in a process.

Pipe is normally used for standard purpose and it is mentioned as outside diameter and its wall thickness as Pipe.

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.

Refer Table 1 as per IS 1161:1998.

Table 1

Sizes and Properties of Steel Tubes for Structural Purposes

(*Clauses* 3.1, 6.1, 6.1.1 *and* 6.1.2)

Nominal Bore	Outside Diameter	Class	Thickness	Mass	Area of Cross Section	Internal Volume	Surface		Moment of Inertia	Modulus of Section	Radius of Gyration	Square of Radius of Gyration
							External	Internal				
mm (1)	mm (2)	(3)	mm (4)	kg/m (5)	cm^2 (6)	cm^3/m (7)	cm^3/m (8)	cm^3/m (9)	cm^4 (10)	cm^3 (11)	cm (12)	cm^2 (13)
15	21.3	Light	2.0	0.947	1.21	235		543	0.57	0.54	0.69	0.47
		Medium	2.6	1.21	1.53	203	669	506	0.69	0.64	0.66	0.44
		Heavy	3.2	1.44	1.82	174		468	0.75	0.70	0.55	0.42
20	26.9	Light	2.3	1.38	1.78	390		700	1.36	1.01	0.87	0.76
		Medium	2.6	1.56	1.98	370	845	681	1.48	1.10	0.86	0.74
		Heavy	3.2	1.87	2.38	330		644	1.70	1.26	0.84	0.71
25	33.7	Light	2.6	1.98	2.54	638		895	3.09	1.83	1.10	1.21
		Medium	3.2	2.41	3.06	585	1 059	857	3.61	2.14	1.08	1.17
		Heavy	4.0	2.93	3.73	518		807	4.19	2.48	1.05	1.11
32	42.4	Light	2.6	2.54	3.25	1 086		1 168	6.47	3.05	1.41	1.98
		Medium	3.2	3.10	3.94	1 017	1 332	1 130	7.62	3.59	1.39	1.93
		Heavy	4.0	3.79	4.82	929		1 080	8.99	4.24	1.36	1.86
40	48.3	Light	2.9	3.23	4.13	1 418		1 335	10.70	4.43	1.61	2.59
		Medium	3.2	3.56	4.53	1 378	1 517	1 316	11.59	4.80	1.59	2.54
		Heavy	4.0	4.37	5.56	1 275		1 265	13.77	5.70	1.57	2.47
50	60.3	Light	2.9	4.08	5.23	2 332		1 711	21.59	7.16	2.03	4.13
		Medium	3.6	5.03	6.41	2 213		1 667	25.88	8.58	2.00	4.02
		Heavy	4.5	6.19	7.88	2 066		1 611	30.90	10.2	1.98	3.92
65	76.1	Light	3.2	5.17	7.32	3 814		2 189	48.79	12.82	2.58	6.66
		Medium	3.6	6.42	8.20	3 727	2 391	2 163	54.02	14.20	2.57	6.60
		Heavy	4.5	7.93	10.1	3 534		2 107	65.12	17.1	2.54	6.43
80	88.9	Light	3.2	6.72	8.61	5 343		2 591	79.23	17.82	3.03	9.19
		Medium	4.0	8.36	10.7	5 138	2 793	2 540	96.36	21.68	3.00	9.00
		Heavy	4.8	9.90	12.7	4 936		2 490	112.52	25.31	2.98	8.88
90	101.6	Light	3.6	8.70	11.1	6 995		2 964	133.27	26.23	3.47	12.03
		Medium	4.0	9.63	12.3	6 877	3 192	2 939	146.32	28.80	3.45	11.91
		Heavy	4.8	11.5	14.6	6 644		2 889	171.44	33.75	3.43	11.76

Nominal Bore	Outside Diameter	Class	Thickness	Mass	Area of Cross Section	Internal Volume	Surface		Moment of Inertia	Modulus of Section	Radius of Gyration	Square of Radius of Gyration
							External	Internal				
mm (1)	mm (2)	(3)	mm (4)	kg/m (5)	cm^2 (6)	cm^3/m (7)	cm^3/m (8)	cm^3/m (9)	cm^4 (10)	cm^3 (11)	cm (12)	cm^2 (13)
100	114.3	Light	3.6	9.75	12.5	9 004		3 363	192.03	33.60	3.92	15.36
		Medium	4.5	12.2	15.5	8 704	3 591	3 306	234.3	41.0	3.89	15.10
		Heavy	5.4	14.5	18.5	8 409		3 250	274.5	48.0	3.85	14.86
110	127.0	Light	4.5	13.6	17.3	10 930		3 705	325.3	51.2	4.33	18.78
		Medium	4.8	14.5	18.4	10 819	3 990	3 686	344.58	54.27	4.32	18.69
		Heavy	5.4	16.2	20.6	10 599		3 649	382.0	60.2	4.30	18.52
125	139.7	Light	4.5	15.0	19.1	13 410		4 104	437.2	62.6	4.78	22.87
		Medium	4.8	15.9	20.3	13 287	4 389	4 085	463.44	66.35	4.77	22.76
		Heavy	5.4	17.9	22.8	13 043		4 047	514.5	73.7	4.75	22.58
135	152.4	Light	4.5	16.4	20.9	16 142		4 503	572.2	75.1	5.23	27.37
		Medium	4.8	17.5	22.2	16 008	4 788	4 484	606.92	79.65	5.22	27.25
		Heavy	5.4	19.6	25.0	15 740		4 446	674.5	88.5	5.20	27.05
150	165.1	Light	4.5	17.8	22.7	19 128		4 902	732.6	88.7	5.68	32.27
		Medium	4.8	18.9	24.2	18 981	5 187	4 883	777.32	94.16	5.67	32.14
		Heavy	5.4	21.3	27.1	18 690		4 845	864.7	105.0	5.65	31.92
150	168.3	Light	4.5	18.2	23.1	19 921		5 002	777.2	92.4	5.79	33.56
		Medium	4.8	19.4	24.7	19 771	5 287	4 983	824.78	98.01	5.78	33.42
		Heavy 1	5.4	21.7	27.6	19 473		4 946	917.7	109.0	5.76	33.21
		Heavy 2	6.3	25.2	32.0	19 030		4 889	1 053	125.0	5.73	32.85
175	193.7	Light	4.8	22.4	28.5	26 606		5 781	1 271.71	131.31	6.68	44.63
		Medium	5.4	25.1	32.0	26 260	6 085	5 743	1 417	146	6.66	44.36
		Heavy	5.9	27.3	34.8	25 974		5 712	1 535.2	158.65	6.64	41.11
200	219.1	Light	4.8	25.4	32.3	34 454		6 578	1 856.51	169.47	7.58	57.45
		Medium	5.6	29.5	37.5	33 930	6 883	6 528	2 141	195	7.55	57.02
		Heavy	5.9	31.0	39.5	33 734		6 509	2 247	205	7.54	56.86
225	244.5	Heavy	5.9	34.7	44.2	42 507	7 681	7 307	3 149	258	8.44	71.21
250	273.0	Heavy	5.9	38.9	49.5	53 557	8 578	8 202	4 412	323	9.45	89.30
300	323.9	Heavy	6.3	49.3	62.8	76 073	10 177	9 775	7 992	493	11.2	125.44
350	355.6	Heavy	8.0	68.6	87.3	90 533	11 173	10 663	13 111	737	12.3	151.29

Welded pipe joints

Pipes of all types and sizes are used in great deal today in transporting oil, gas, water etc. They are also used extensively for piping systems in building, refineries and industrial plants.

Advantages of welded pipe

Pipes are mostly made of ferrous and non-ferrous metals and their alloys. They possess the following advantages.

- Improved overall strength.
- Ultimate saving in cost including maintenance.
- Improved flow characteristics.
- Reduction in weight due to its compactness.
- Good appearance.

Method of pipes welding

The following are the methods of pipe welding by arc.

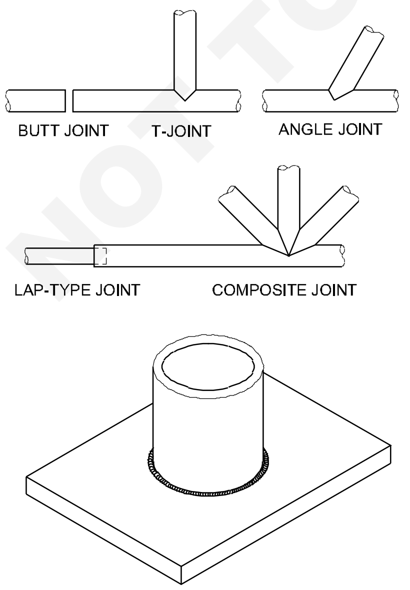
- Metallic arc welding
- Gas metal arc welding
- Tungsten inert gas welding
- Submerged arc welding
- Carbon arc welding

All these methods, except carbon arc welding are commonly used and the choice of welding depends upon the size of the pipe and its application.

Types of pipe joints

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

Fig 1



6 Pipe flange joint
7 Y joint (Fig 2)
8 Elbow joint (Fig 3)

Fig 2

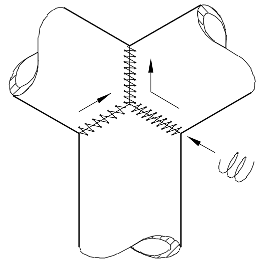
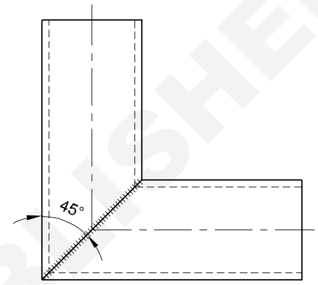


Fig 3

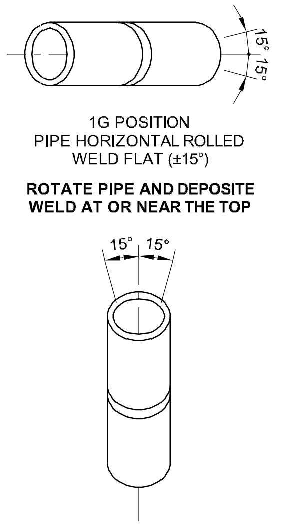


Welding of pipe butt joints: Normally joints in pipes and tubes cannot be welded from the inside of the bore. Hence before starting to learn pipe welding, a person should be proficient in welding in all positions i.e. flat, horizontal, vertical and overhead.

All these positions are used to weld pipes.

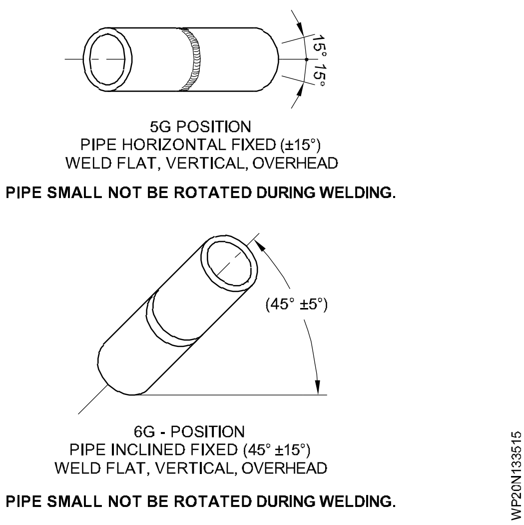
Pipes welding positions (Figs 4 and 5)

Fig 4



1 G - Pipe weld in flat (roll) position i.e. pipe axis is parallelto the ground.

Fig 5



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.

Fig 6

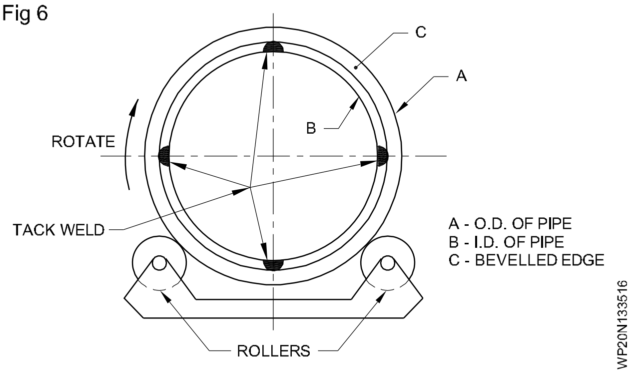
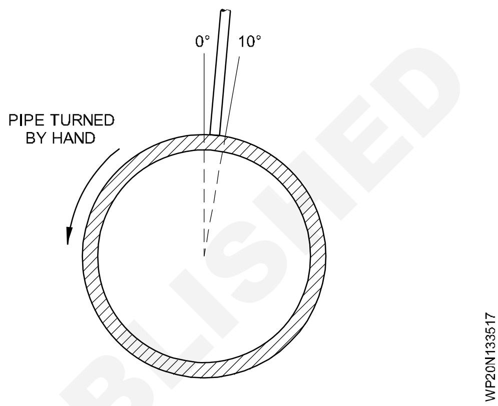


Fig 7



(Use a helmet type screen).

– 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)

– Strike the arc at 10° from Top Dead Centre (TDC) and deposit the root run. Use a small weaving motion to achieve fusion of the root faces. Adjust travel speed to control root penetration. (Fig 9)

- When a segment equivalent to 60° has been welded, terminate/stop the weld run. Avoid the formation of a crater.
- Move the pipe until the end of the segment is at 10° before TDC.
- Strike the arc on the end of the previous weld run and establish a weld pool.
- Weld a further 60° segment. (Fig10)
- Continue welding in segments until the root run has been completed.
- Move the pipe until the mid point of the segments is at TDC.
- Strike the arc and deposit the second (filling) run, use a side-to-side weaving position to fill the preparation and to achieve fusion of the pipe edges.
- Complete the filling run in 60° segments.

Fig 8

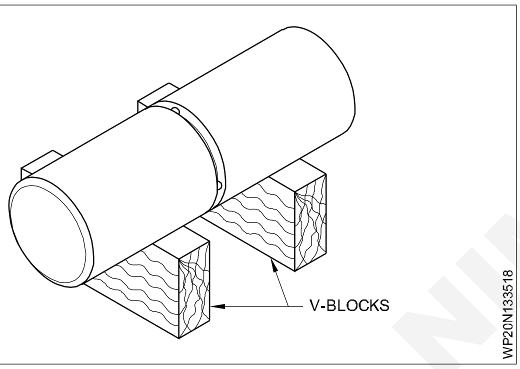
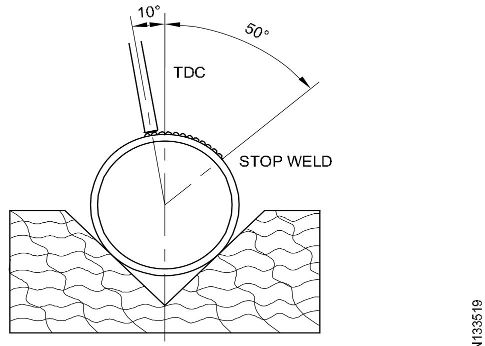
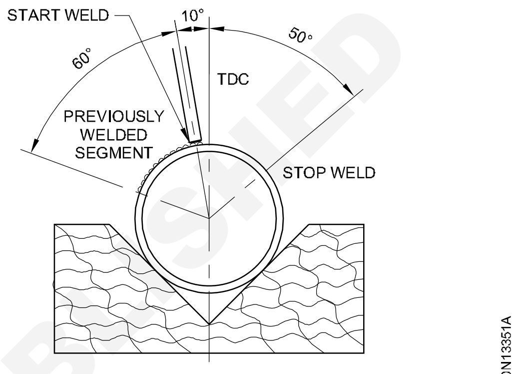


Fig 9



WELDING FIRST SEGMENT

Fig 10



WELDING SECOND SEGMENT

Pipe welding and Procedure

Objectives: At the end of this lesson you shall be able to
- **state different fixed pipe welding positions**
- **explain different methods of pipe welding in 5G position**
- **explain the welding producer of M.S. pipe butt joint by arc in fixed (5G) position.**

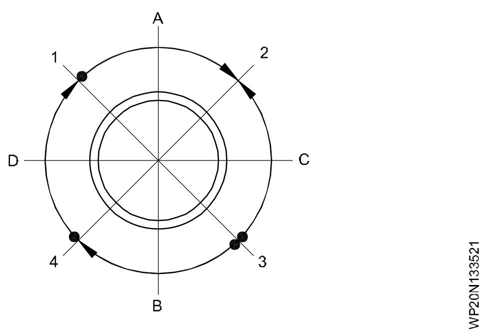
Whenever the pipes to be welded cannot be rotated or whenever the pipes are to be welded in the field i.e. at work site, then they are welded in fixed position. If the fixed pipe axis is horizontal, then the welding position is called 5G position.

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

In 5G position, a pipe butt joint can be welded by the following method.

Method 1: The pipe joint circumference is divided into four positions as A, B, C and D. First portion 'A' is welded from 1 to 2 in more or less in flat position. Then portion B is welded from 3 to 4 in overhead position. Next portion C from 3 to 2 and then portion D from 4 to 1 are welded in vertical up position. (Fig 1)

Fig 1

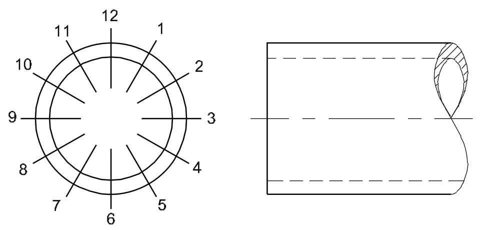


It is important that a key hole is maintained throughout the welding operation to ensure proper root penetration. Also the electrode position is continuously changed as the joint surface is curved. In addition, the starting and ending of each weld portion i.e. A, B, C and D properly done so that they merge with the previous portion.

Method 2: The pipe outer circumference is divided into 12 equal divisions as in a clock.

The top of the pipe is 12 O'clock position and the bottom is in 6 O'clock position. (Fig 2)

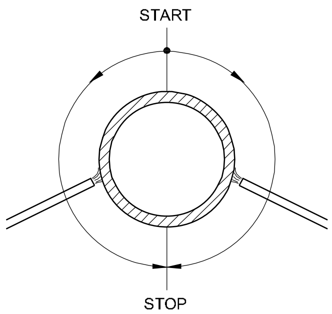
Fig 2



THE IDENTIFICATION OF THE WELDING POSITION AROUND THE THE PIPE JOINT BYTHE NUMBERS ON THE FACE OF A CLOCK.

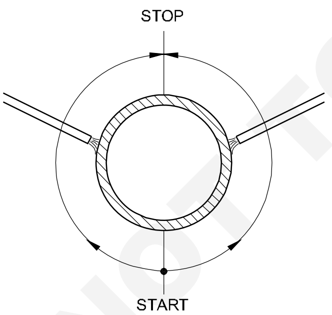
The weld is started from 12 O'clock position to 6 O'clock position on the right side vertically downwards. Then welding is done again from 12 O'clock to 6 O'clock position on the left side (Fig 3). This method is called down hill method and is normally used for thin walled pipes with wall thickness of 3 to 4 mm.

Fig 3



Method 3: The weld is started from 6 O'clock to 12 O'clock position on the right side first and then again from the 6 O'clock to 12 O'clock position on the left side (Fig 4). This method is called uphill method or vertical up method. This uphill method is used to weld pipes of 5 mm and above wall thickness.

Fig 4



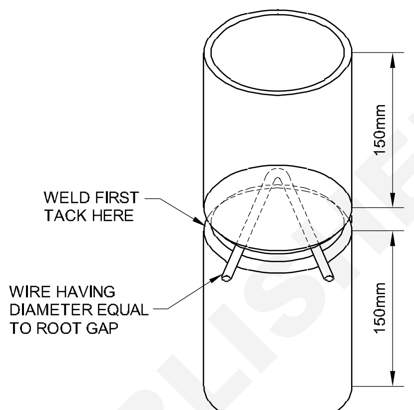
Welding in 2G and 6G positions are done based on the position of the pipe axis.

In the 2G position, the horizontal pipe welding with its axis being vertical, the weld joint connecting the two pipes is in the horizontal position. The weld must be made around the pipe. (Fig 5)

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

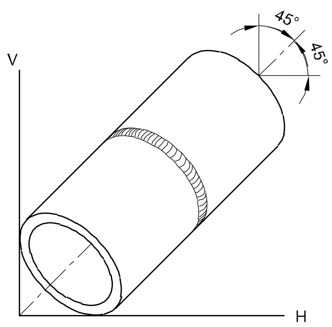
Use electrodes specially manufactured for pipe welding to get good penetration, appearance and strength, (low the

Fig 5



USE OF BEND WIRE OF SPACER TO SET ROOT GAP

Fig 6



POSITION 6 G

Difference between Pipe Welding and Plate Welding

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

Plate welding: Plate welding is a fusion welding process. It joins plate metals using the combustion of oxygen and fuel gas. The intense heat that is produced melts and fuses together the edges of the parts to be welded generally with the help of a filler metal.

Plate welding by gas can be done in two ways. One is leftward welding and the other rightward welding.

All the-position rightward welding is used for all position of welding. (Fig 1) The path travelled by the flame and the filler rod varies with the welding position. The angles at which the flame and the filler rod are held also vary.

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.

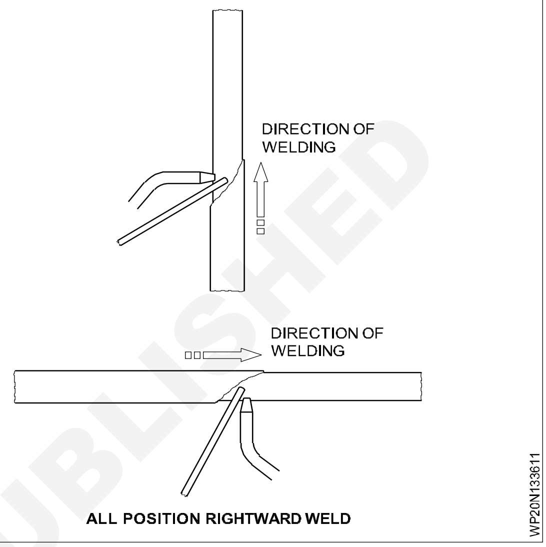
Pipe welding: When welding the circumference of a mild steel pipe, the angles of the rod and the blowpipe are given in relation to the tangent to the pipe at the point of welding.

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.

Fig 1



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

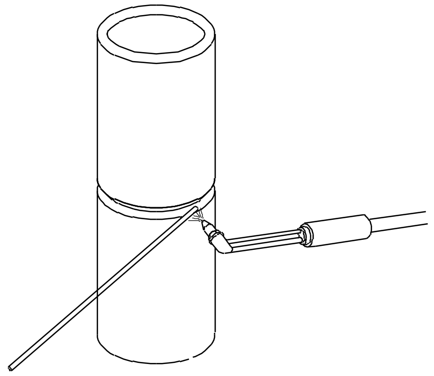
The techniques used for the positional welding of plates are also applied when welding pipes.

For thin walled pipes up to 5 mm, the leftward technique is used in any position. (Fig 2)

The leftward, rightward or all-position rightward techniques are used as appropriate on sections of 5 mm and above. (Fig 3)

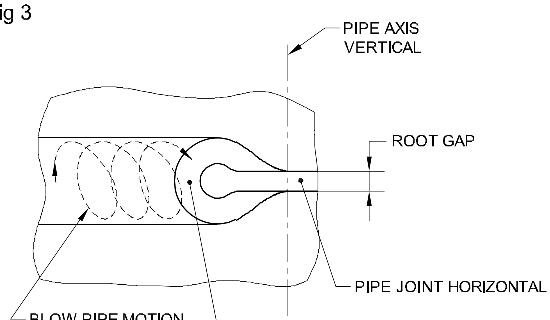
Pipe welding in 2G position (Pipe axis is vertical): In a pipe butt joint if the axis of the pipes is vertical and the weld joint is in the horizontal plane then it is called pipe welding in 2G position. (Fig 20) It is a fixed position welding and the blowpipe and filler rod are to be moved around the pipe surface. The position of blowpipe and the filler rod are given in Fig 20. To avoid sagging of weld metal the blowpipe is given a motion as shown in Fig 21 and the filler rod is fed at the top half of the molten pool.

Fig 2



2G POSITION
SINGLE "V" GROOVE PIPE JOINT
(PIPE AXIS VERTICAL)

Fig 3



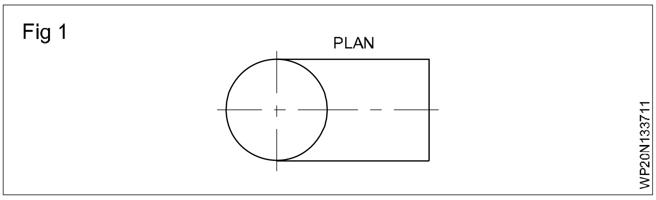
Pipe Development for Elbow joint and Branch Joint.

Objectives: At the end of this lesson you shall be able to
- **develop and layout the pattern for 90° elbow joining two equal diameter pipe by parallel line method.**

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

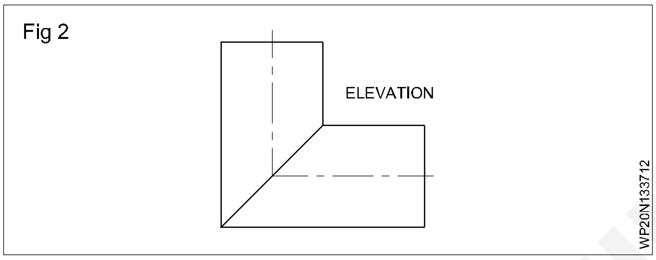
Draw plan as shown in Fig 1.

Fig 1



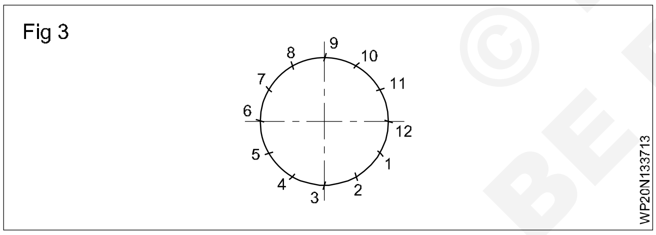
Below this, draw the front elevation as shown in Fig 2.

Fig 2



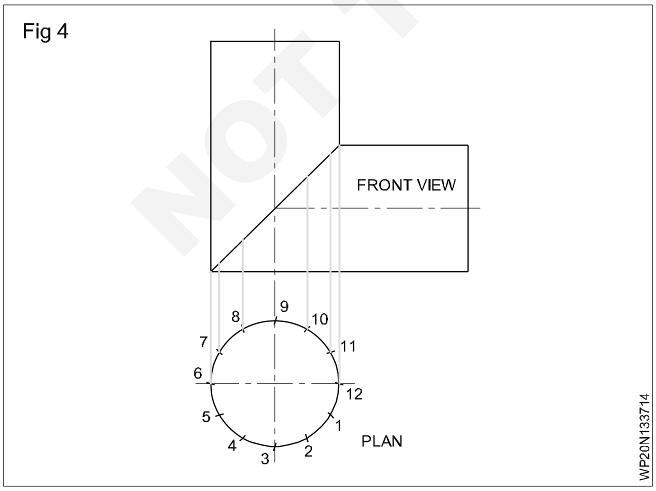
Divide the circle in the plan into twelve equal parts and number the points 0 to 12 as shown in Fig 3.

Fig 3



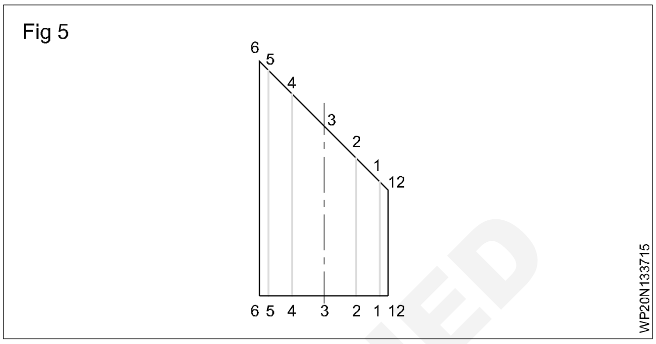
Draw the perpendicular line from these points towards the front view and number 1 to 12 as shown in Fig 4.

Fig 4



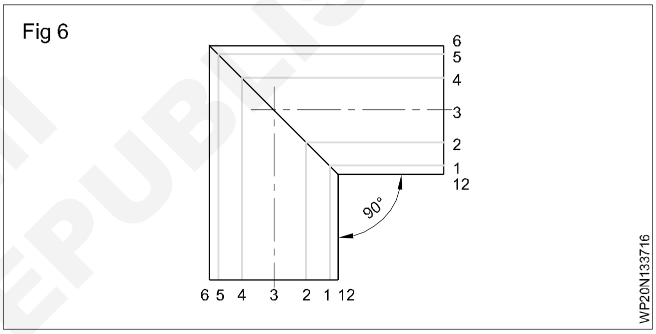
Now you find that the vertical lines are cutting at six different points top and bottom in the elevation line. Number them as shown in Fig 5.

Fig 5



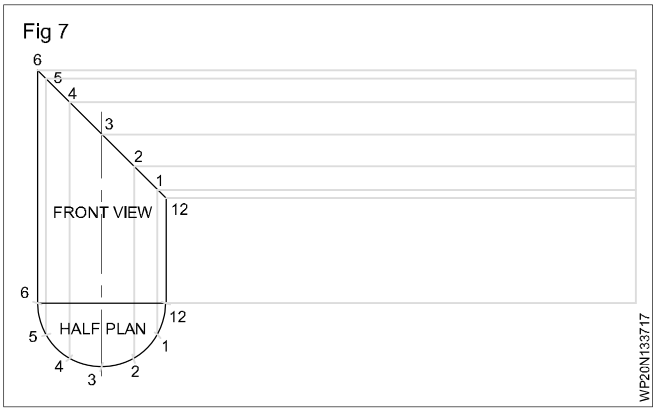
Draw horizontal parallel lines from each point and number them as shown in Fig 6.

Fig 6



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

Fig 7



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

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

Fig 8

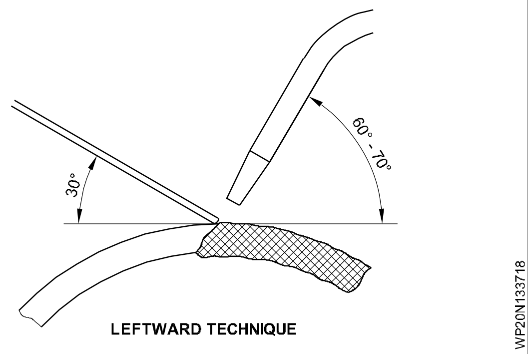
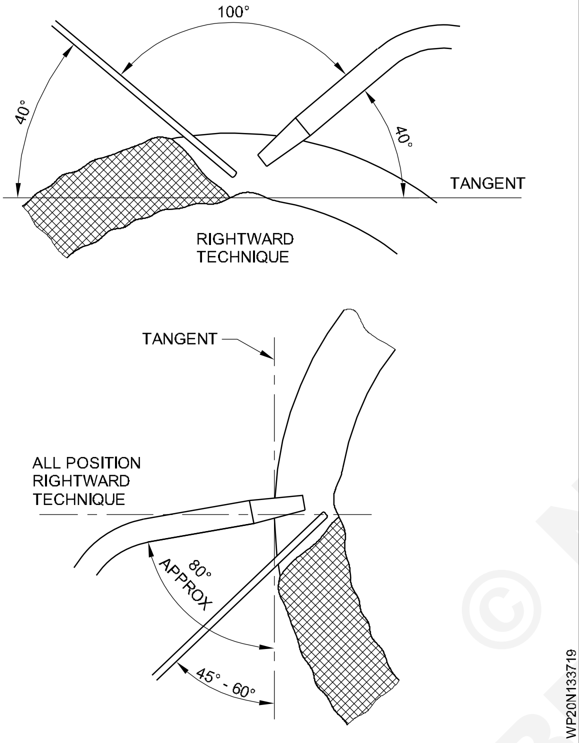


Fig 9



Differences between plate welding and pipe welding

In the plate welding the total welding line can be seen at any time. In pipe welding only a portion of the welding line can be seen at any time.

In plate welding, the line of weld is in only one position. In pipe welding, welding can be done in one position when it can be rotated. (Fig 4) Otherwise all-position welding can be done in the pipe when the pipe is in fixed position. (Fig 6) Sometimes the pipe may be in a fixed position and only one position of welding will be done. E.g. 2G Position. (Fig 5)

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 10

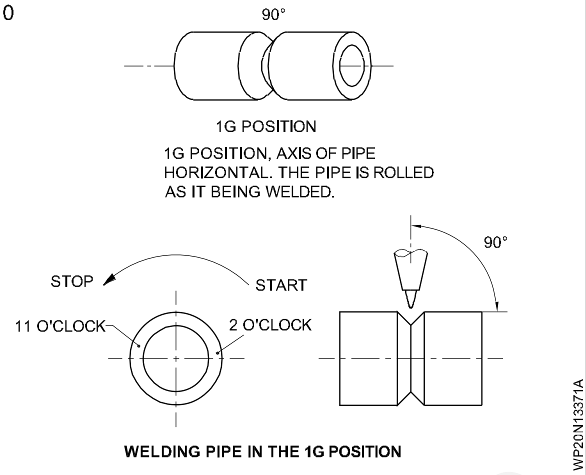
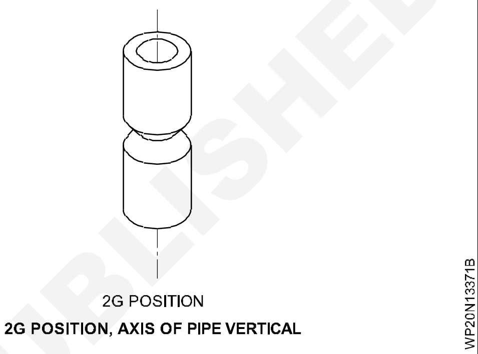


Fig 11



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 12

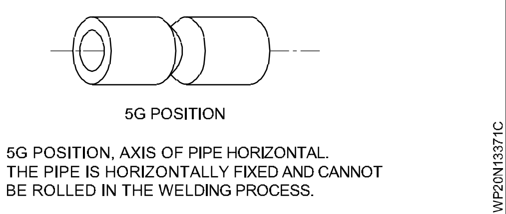
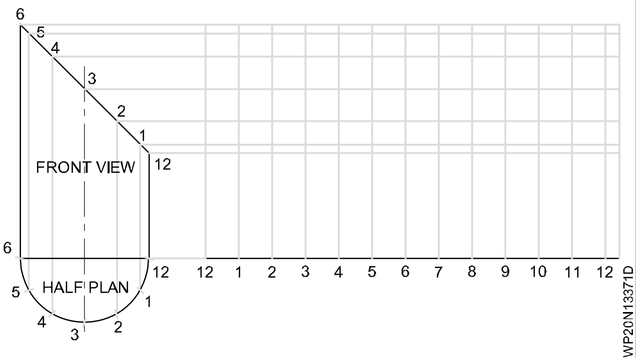


Fig 13



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

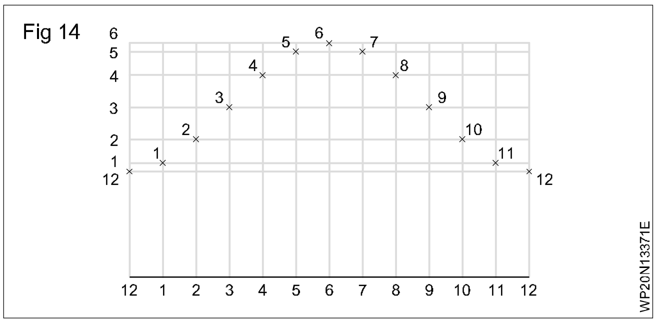


Fig 14

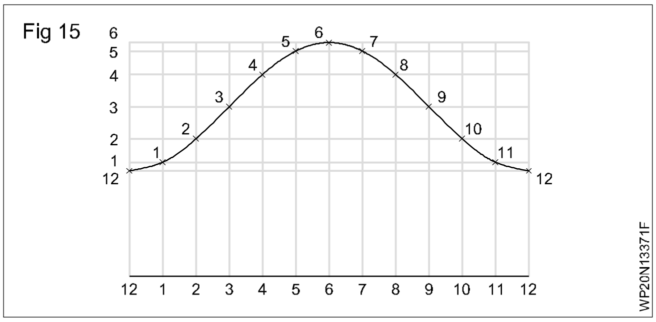


Fig 15

Development of a pipe "T" joint

Objective: At the end of this lesson you shall be able to
- **develop and layout the pattern for 90° "T" pipe of equal diameter by parallel line method.**

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

Draw the front view as shown in Fig 1.

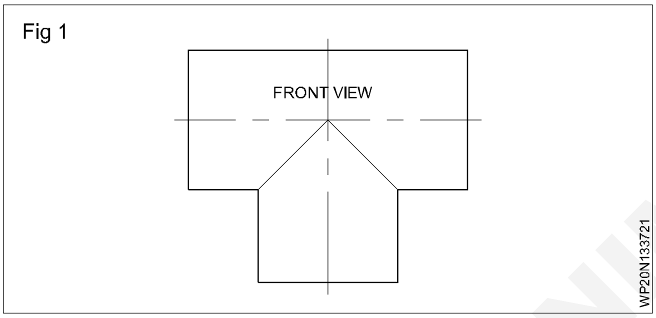


Fig 1

Draw the side view as shown in Fig 2.

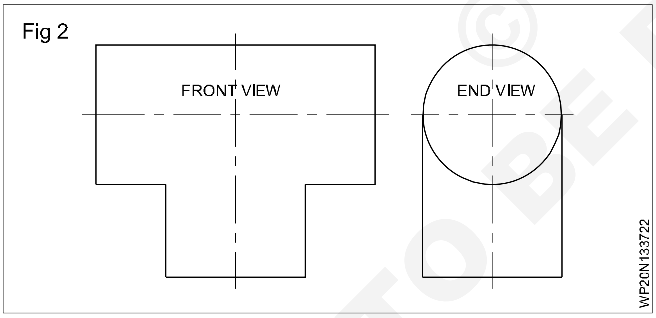


Fig 2

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

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

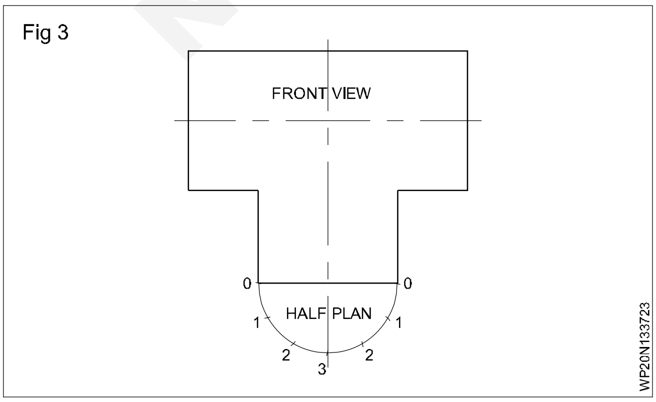


Fig 3

Divide a semi-circle in side view into six equal parts and number as 3, 2, 1, 0, 1, 2, 3 as shown in Fig 4.

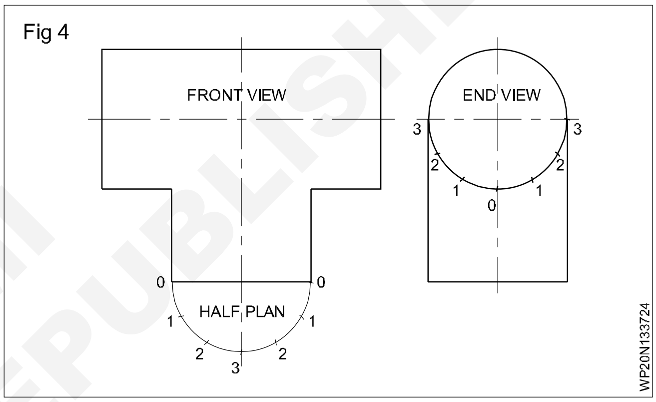


Fig 4

Draw the perpendicular lines from each point of the semi-circle of the view as shown in Fig 5.

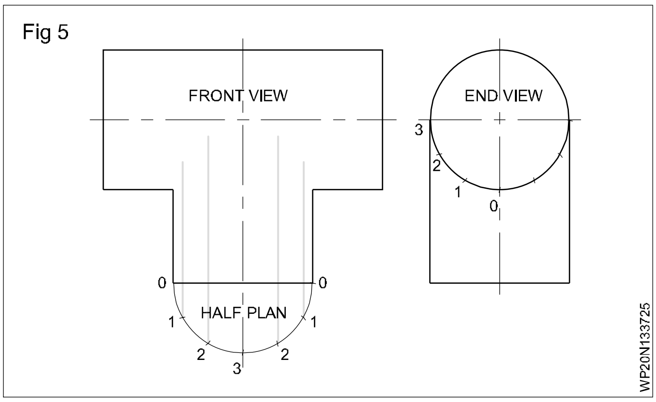


Fig 5

Draw horizontal lines from the side view towards the front view as shown in Fig 6.

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

Join these points to get the line of intersection of "T" pipe as shown in Fig 7.

Extend the base line of the side view and mark the end point as 0. Fig 8

Fig 6

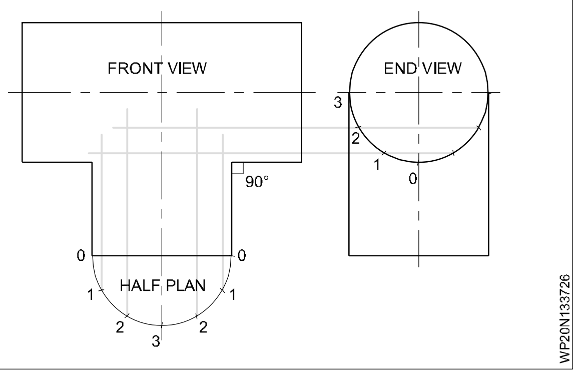


Fig 7

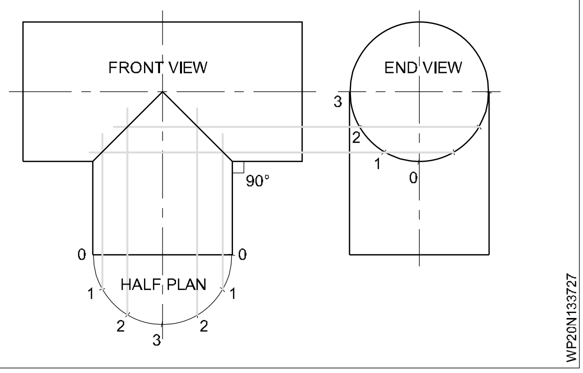
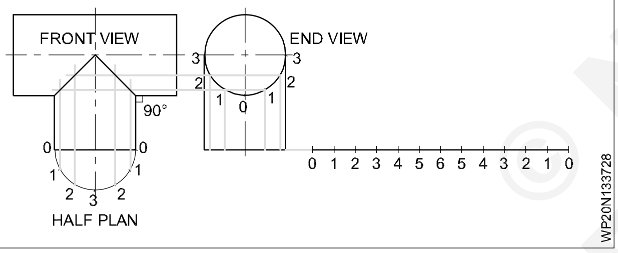
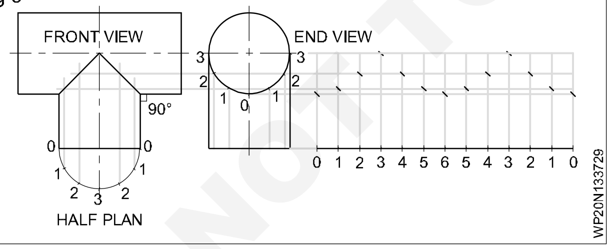


Fig 8



Take one division of the semi-circle in side view and transfer it 12 times on the base line starting from: 0: and number as 0, 1, 2, 3, 2, 1, 0, 1, 2, 3, 2, 1, 0 as shown in Fig 9.

Fig 9



Draw perpendicular lines from these points and draw horizontal lines from the points on the line of intersection of "T". These line meet at their respective points. Fig 9

Join these points by free hand curve. Fig 10

Provide locked grooved joint allowance as shown in Fig 11.

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

Fig 10

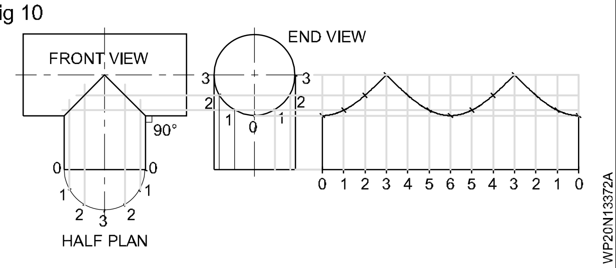
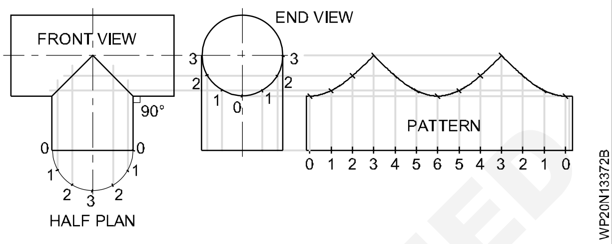


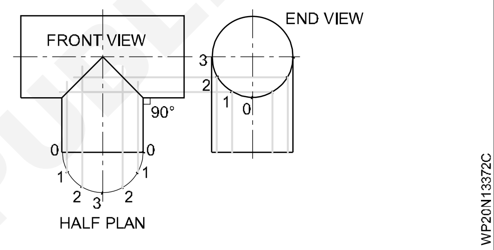
Fig 11



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

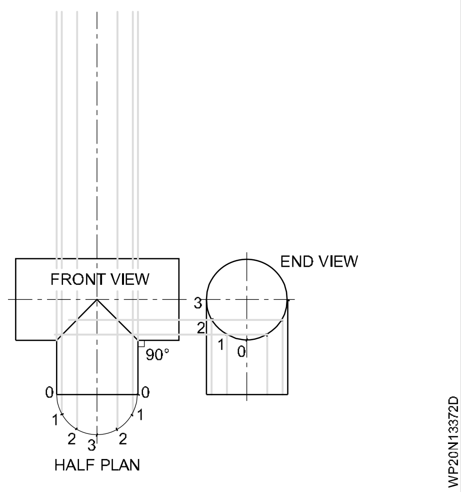
Draw the front view and end view. (Fig 12)

Fig 12



Extend the vertical lines 0, 1, 2, 3, 1, 0 of branch pipe from the front view as shown in Fig 13.

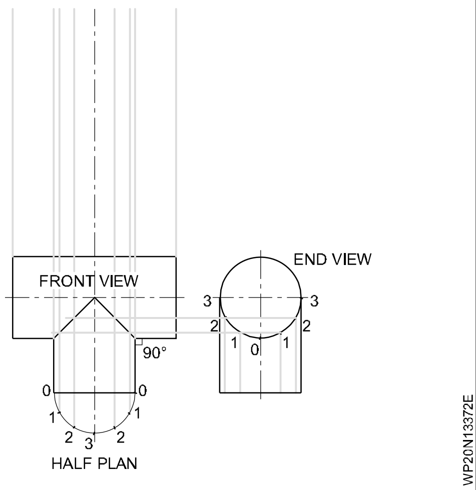
Fig 13



Extend the two extreme end vertical lines of the main pipe from the front view as shown in Fig 14.

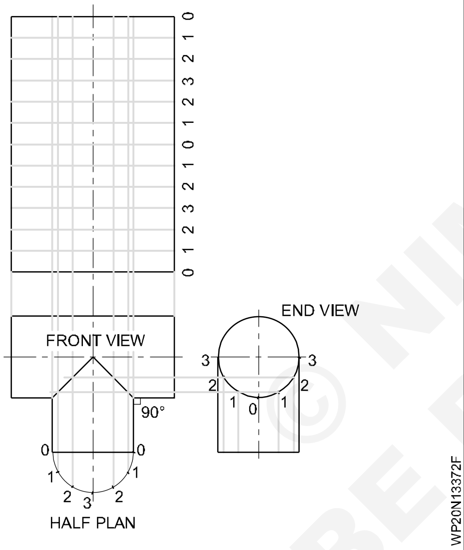
On one of these lines, take point "0" as starting point and mark points 0, 1, 2, 3, 2, 1, 0, 1, 2, 3, 2, 1, 0 at equal distances equal to one division of the semi-circle and draw horizontal lines from these points. (Fig 15)

Fig 14



Now these horizontal lines meet the vertical lines at their respective points as shown in Fig 16.

Fig 15



Join these points by free hand curve and get the pattern for the main pipe. Fig 17

Provide the locked grooved joint allowances as shown in Fig 17.

Fig 16

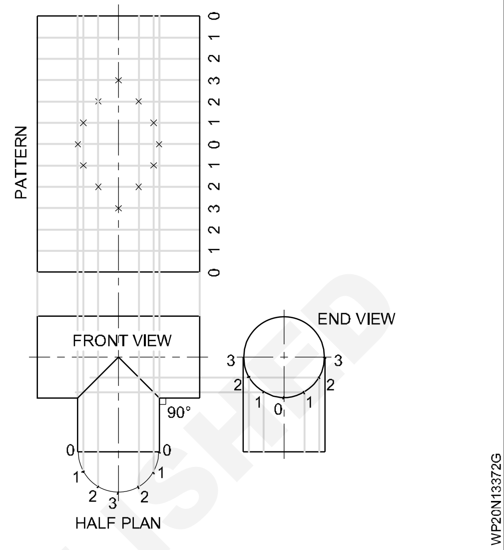
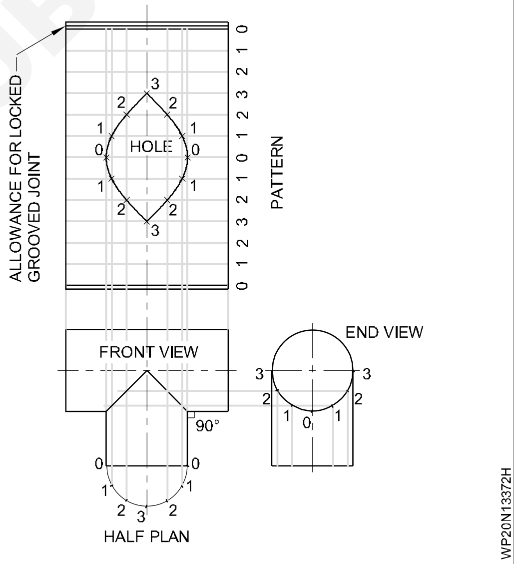


Fig 17



Pipe development for "Y" joint

Objectives: At the end of this lesson you shall be able to
- **develop and able to layout the pattern for "Y" joint pipes intersecting at 120°**
- **develop and layout the pattern for "Y" joint pipes branching at 90°.**

Development of "Y" joint pipes intersecting at 120°: Draw the development of intersecting cylinders of dia. 30 mm at 120°. (Fig 1)

All the cylindrical pipes are of same diameter and intersecting each at equal angles. Hence in this case the development of all the pipes are same and so the development of one pipe will represent other pipes.

- Draw the plan and elevation of the pipe 'A' and mark the division on the plan. (Fig 1b)
- Draw the vertical projectors from the plan to front view to meet the line of intersection.
- Draw horizontal projectors from these points on to the development.
- Mark the intersecting points and join with a smooth curve to complete the required development.

Development of 'Y' joint branching at 90°: Three cylindrical pipes of X, Y, Z form a 'Y' piece. (Fig 2) Draw the lateral surface development of each pipe.

In the three pipes XYZ, Y & Z are similar in size and shape, hence their developments are also similar.

- Draw the development of pipe 'X' as in the previous exercise.
- Draw the elevation and plan of pipe 'Y' as shown.
- Divide the plan circle into 16 equal parts.
- Project the points to the elevation.
- Draw the rectangle ABCD in which AB is equal to   D.
- Draw the development of pipe Y as shown in Fig 2.

Fig 1

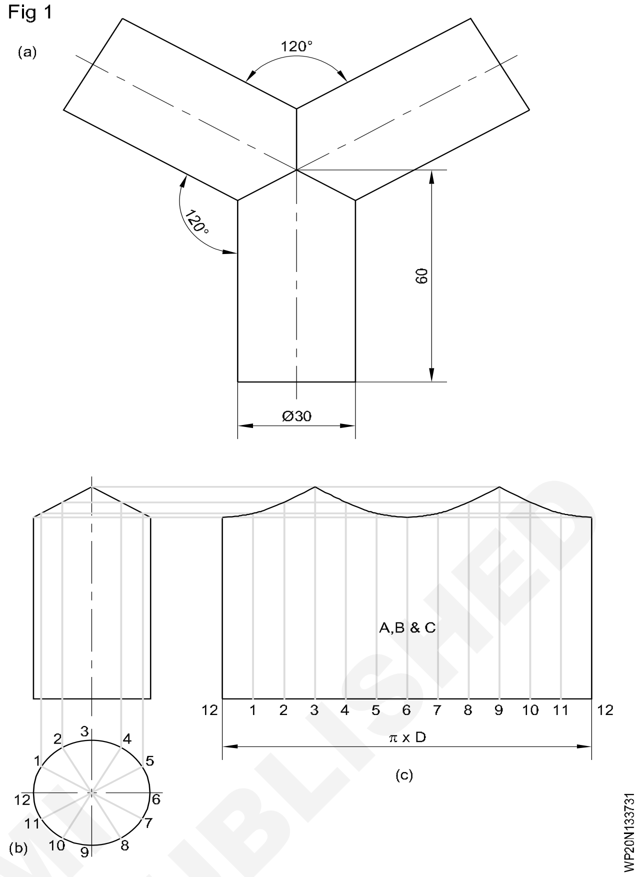
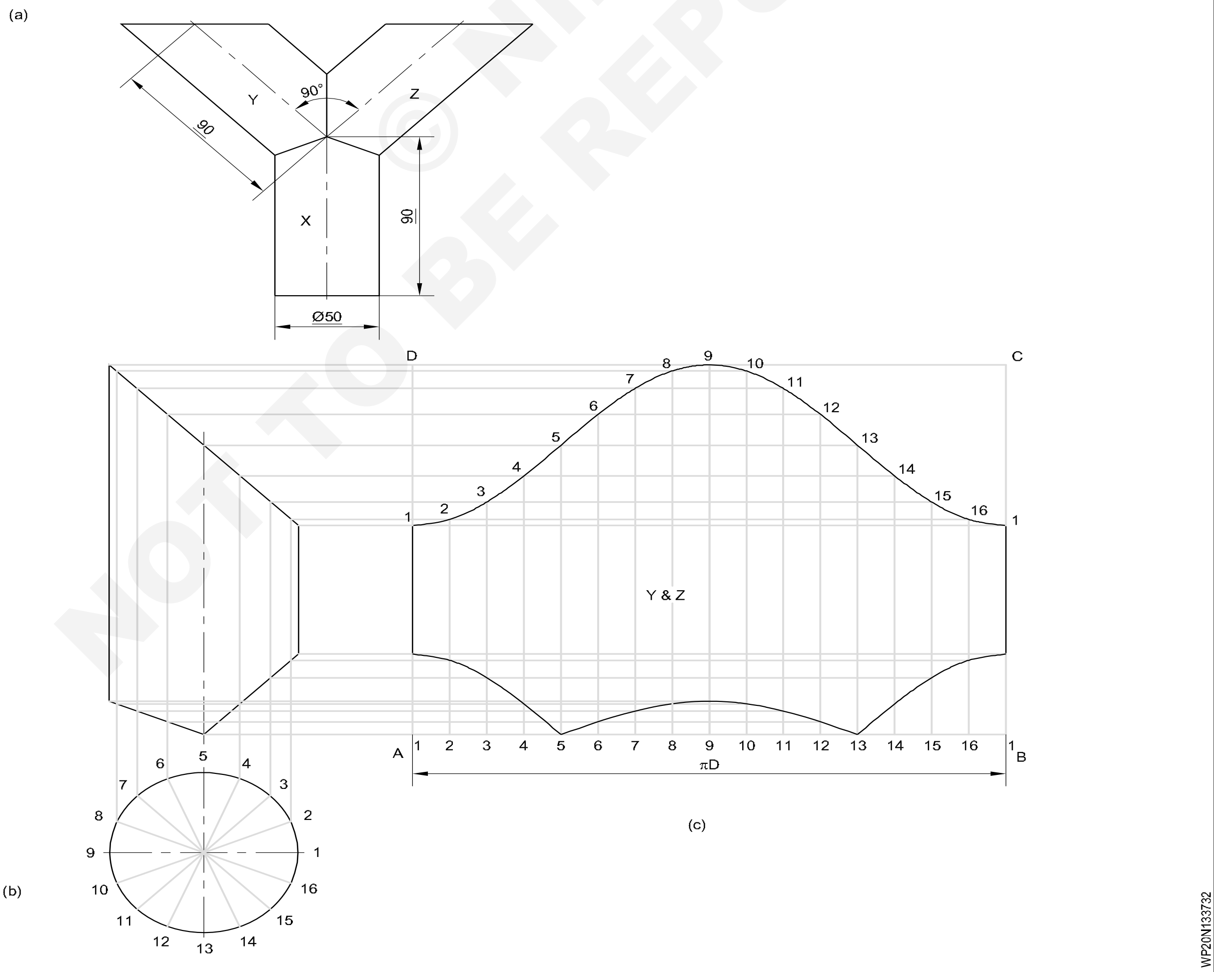


Fig 2



Development of 45° and 90° branch pipe

Objective: At the end of this lesson you shall be able to
- **prepare the development of pipe for 45° and 90° branch pipe.**

Procedure for development of 45° branch pipe: Refer Fig 1. Draw a center line AB.

Mark the points C, D, E and F taking the radius and the length of the given pipe with the center line AB as reference line.

On the line "CD" locate the position of the 45° branch pipe. This will be "G".

Draw a 45° angle at the point "G".

Choose a suitable height and mark the height of the branch pipe (GI) in 45° line from point G.

From I, draw a horizontal line on both sides (XX'). This XX' will be the base line for drawing development.

From I, plot the outside diameter of the branch pipe IJ on the line XX'.

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

Join GK. Draw a perpendicular line to GK at K which meets CD at H. Join KH. Now IHKHJ will be the shape (outline) of the branch pipe.

Draw a semi-circle equal to the branch pipe outside diameter.

Divide the semi-circle into 6 equal parts as 0-1; 1-2; 2-3; 3-4; 4-5 & 5-6.Draw vertical lines from these points 1, 2, 3, 4, 5. Already there will be two vertical lines IG from the points 6 and JH from point 0. These vertical lines will cut the branch pipe lines 'GK' and 'KH' at points 6', 5', 4', 3', 2', 1', & 0'. Note that points 6' and G as points 0' and H are the same points. In the base line XX' plot 12 points equal to the distance of '0-1' as 0, 1, 2, 3, 4, 5, 6, 5, 4, 3, 2, 1, 0.

Draw vertical lines to XX' from these 13 points.

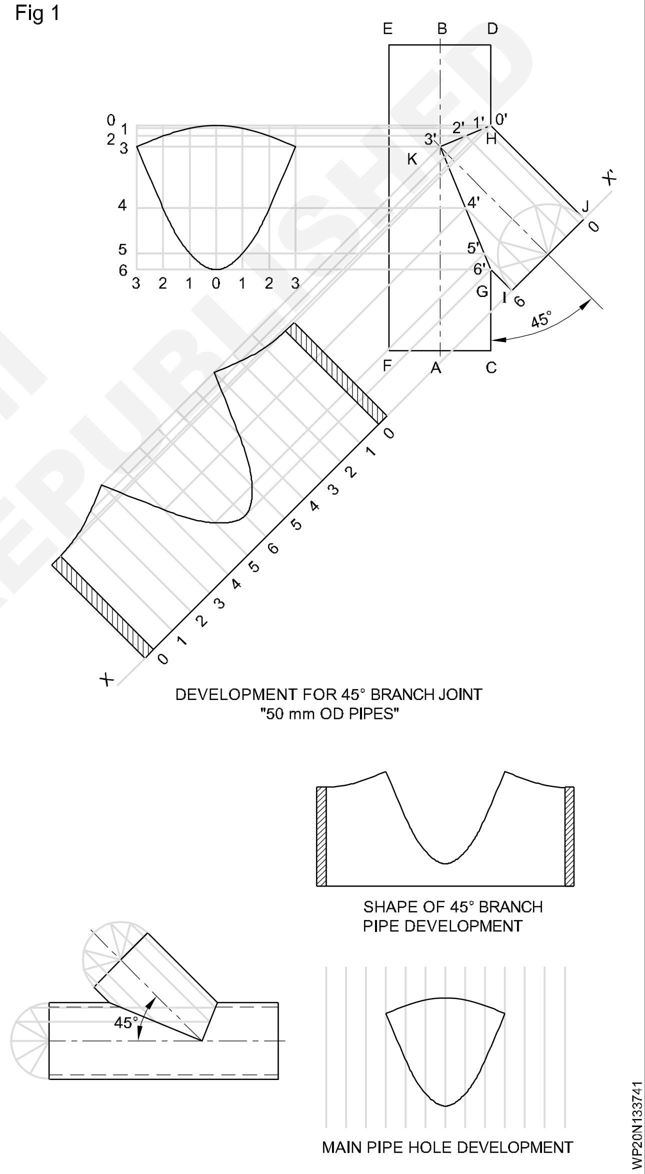
Draw horizontal lines parallel to XX' from points 6', 5', 4', 3', 2', 1', 0'. These 7 horizontal lines will cut the 13 vertical lines from the base line at 13 points.

Join the 13 cutting points with a regular smooth curve. Now the required development for the 45° branch pipe will be ready. Give allowance of 3 to 5 mm at the edges of the development. (Fig 1)

For developing a hole in the base pipe: Above the main pipe, draw 7 lines parallel to AB namely 3, 2, 1, 0, 1, 2, 3 equal to the distance of 0-1 on the semi circle.

Draw vertical lines from 0', 1', 2', 3', 4', 5', 6'. These vertical lines will intercept the 7 horizontal lines. Join the intercepting points with a smooth curve. The required development for hole is now ready.

Fig 1



Uses of Manifold System

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

When large volumes of oxygen and acetylene gas are required on a temporary or permanent basis for many welding and cutting operations in a workshop, a manifold system is most suitable one.

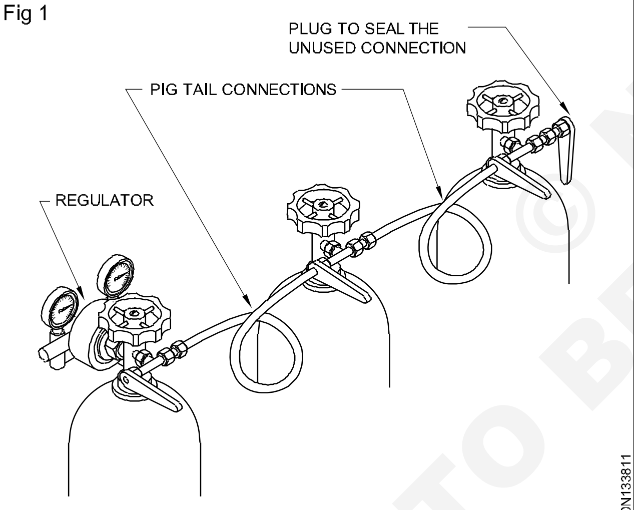
Types

– Portable manifold system

– Stationary manifold system

Portable manifold system means two or three cylinders are coupled with a suitable apparatus - namely 'PIG TAIL' and connected to a main distribution pipe. (Fig 1) Separate arrangements are made for oxygen and acetylene gases.

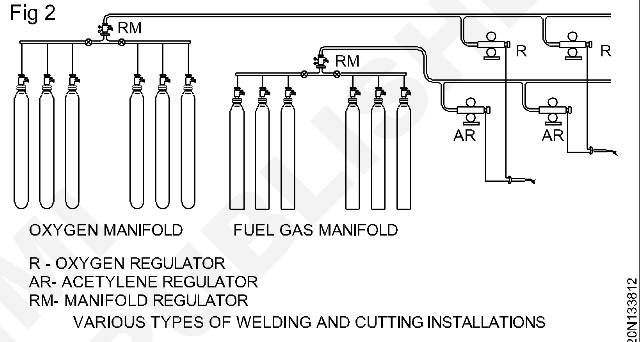
Fig 1



PORTABLE MANIFOLD SYSTEM (EXTENDABLE)

When the demand is even more, many cylinder are coupled together, and this is called stationary 'MANIFOLD' system. (Fig 2) Separate manifold systems are installed for oxygen and acetylene. These manifolds usually have two banks of cylinders. One bank is kept in reserve while the other one is in use.

Fig 2



STATIONARY MANIFOLD SYSTEM

The use of such manifolds reduces substantially the cost of handling the cylinders inside the workshop.

These manifolds are fitted with master regulators which reduce the cylinder pressure to about 15 kg/cm^2 for feeding into the distribution pipe to the various consuming points. The consuming points are fitted with an outlet value, stop-valves and regulators for individual pressure control at the site for gas welding or cutting operations.

Gas Welding Filler rods, Specifications and Sizes

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

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.

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, labour, 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.

Table 1
Filler metals and fluxes for gas welding

Filler metal type	Application	Flux
Mild steel - Type S-FS1	A general purpose rod for welding mild steel where a minimum butt-weld tensile strength of 35.0 kg/mm^2 is required. (Full fusion technique with neutral flame.)	Not required.
Mild steel - Type S-FS2	Intended for application in which minimum butt-weld tensile strength of 44.0 kg/mm^2 is required. (Full fusion technique with neutral flame.)	Not required.
Wear-resisting alloy steel	Building up worn out crossings and other application where the steel surfaces are subject to extreme wear by shock and abrasion. (Surface fusion technique with excess acetylene flame.)	Not required.
3 percent nickel steel Type S-FS4	These rods are intended to be used in repair and reconditioning parts which have to be subsequently hardened and tempered. (Full fusion technique with neutral flame.)	Special flux (if necessary).
Stainless steel decay-resistant (niobium bearing)	These rods are intended for use in the welding of corrosion-resisting steels such as those containing 18 percent chromium and 8 percent nickel. (Full fusion technique with neutral flame.)	Necessary

Filler metal type	Application	Flux
High silicon cast iron- Type S-C11	Intended for use in the welding of cast iron where an easily machinable deposit is required. (Full fusion technique with neutral flame.)	Flux necessary.
Copper filler rod - Type S-C1	For welding of de-oxidized copper. (Full fusion technique with neutral flame.)	Flux necessary.
Brass filler rod - Type S-C6	For use in the braze welding of copper and mild steel and for the fusion welding of material of the same or closely similar composition. (Oxidising flame.)	Flux necessary.
Manganese bronze (high tensile brass) - Type S-C8	For use in braze welding of copper, cast iron and malleable iron and for the fusion welding of materials of the same or closely similar composition. (Oxidising flame.)	Flux necessary.
Medium nickel bronze - Type S-C9	For use in the braze welding of mild steel, cast iron and malleable iron. (Oxidising flame.)	Flux required.
Aluminium (Pure) - Type S-C13	For use in the welding of aluminium grade 1B. (Full fusion technique with neutral flame.)	Flux necessary.
Aluminium alloy-5 percent silicon - Type S-NG21	For welding of aluminium casting alloys, except those containing magnesium, or zinc as the main addition. They may also be used to weld wrought aluminium-magnesium-silicon alloys. (Full fusion technique with neutral flame.)	Flux necessary.
Aluminium alloy-10-13 per-cent silicon - Type 5-NG2	For welding high silicon aluminium alloys. Also recommended for brazing aluminium. (Neutral flame.)	Flux necessary.
Aluminium alloy-5 percent copper	For welding aluminium casting particularly those containing about 5 percent copper. (Full fusion technique with neutral flame.)	Flux necessary.
Stellite: Grade 1	Hard facing of components subjected mainly to abrasion. (Surface fusion technique with excess acetylene flame.)	None is usually required. A castiron flux may be used, if necessary
Stellite: Grade 6	Hard facing of components subjected to shock and abrasion, (Surface fusion technique with excess acetylene flame.)	-do-
Stellite: Grade 12	Hard facing of components subjected to abrasion and moderate shock. (Surface fusion technique with excess acetylene flame.)	-do-
Copper-phosphorus brazing alloy - Type BA-CuP2	Brazing copper, brass and bronze components. Brazing with slightly oxidising flame on copper; neutral flame on copper alloys.	Necessary
Copper-phosphorus brazing alloy - Type BA-CuP5	For making ductile joint in copper without flux. Also widely used on copper based alloys of the brass and bronze type in conjunction with a suitable silver brazing flux. (Flame slightly oxidising on copper; neutral on copper alloys.)	None for copper. A flux is nece-ssary for brazing copper alloys.

Filler metal type	Application	Flux
Silver-copper-zinc (61 percent silver) type brazing alloys - Type BA-CuP3	Similar to type BA-CuP5 but with a slightly lower tensile strength and electrical conductivity (flame slightly oxidising on copper; neutral on copper alloys). NOTE: Phosphorus bearing silver brazing alloys should not be used with ferrous metal or alloys of high nickel content.	None for copper. A flux is necessary for brazing copper alloys.
Silver-copper-zinc (61 percent silver) - Type BA-Cu-AG6	This brazing alloy is particularly suitable for joining electrical components requiring high electrical conductivity. (Flame neutral)	Flux necessary.
Silver-copper-zinc (43 percent silver) - Type BA-Cu-Ag 16	This is a general purpose brazing alloy and is particularly suitable for joining electrical components requiring high electrical conductivity. (Flame neutral)	Flux necessary.
Silver-copper-zinc cadmium (43 percent silver) - Type BA-Cu-Ag 16A	An ideal composition for economy in brazing operation requiring a low temperature, quick and complete penetration. Suitable on steel, copper, brass, bronze, copper-nickel alloys and nickel-silver. (Flame neutral)	Flux necessary.
Silver-copper-zinc-cadmium (50 percent silver) - Type BA-Cu-Ag 11	This alloy is also suitable for steel, copper-nickel alloys and nickel-silvers. (Flame neutral)	Flux necessary.
Silver-copper-zinc-cadmium nickel (50 percent silver) -Type BA-Cu-Ag 12	Specially suitable for brazing tungsten carbide tips to rock drills, milling cutters, cutting and shaping tools; also suitable for brazing steels which are difficult to 'wet' such as stainless steels. (Flame neutral)	Flux necessary.

Gas Welding Fluxes - Types and Functions

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

Flux is a fusible (easily melted) chemical compound to be applied before and during welding to prevent unwanted chemical action during welding and thus making the welding operation easier.

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

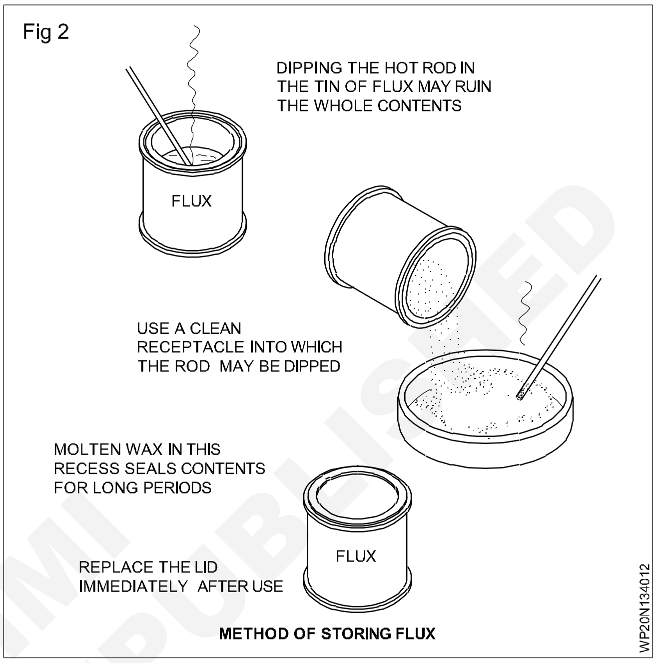
Fluxes help the flow of their metal into very small gap between the metals being joined.

Fluxes act as cleaning agents to dissolve and remove oxides and clean the metal for welding from dirt and other impurities.

Fluxes are available in the form of paste, powder and liquid. The method of application of flux is shown in Fig 1.

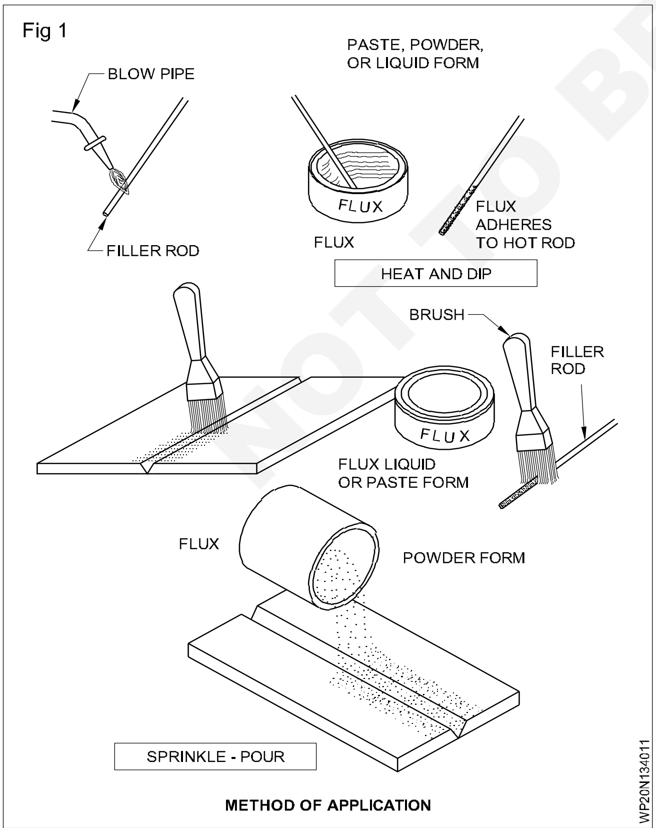
Storing of fluxes: Where the flux is in the form of a coating on the filler rod, protect carefully at all times against damage and dampness. (Fig 2)

Seal flux tin lids when storing especially for long periods. (Fig 2)



METHOD OF STORING FLUX

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.



METHOD OF APPLICATION

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.

When containers, such as fuel tanks, have been welded and parts are inaccessible for the hot water scrubbing method, use a solution of nitric and hydrofluoric acids. To each 5.0 liters of water add 400 ml of nitric acid (specific gravity 1.42) followed by 33 ml of hydrofluoric acid (40 percent strength). The solution used at room temperature will generally completely remove the flux residue in 10 minutes, producing a clean uniformly etched surface, free from stains. Following this treatment the parts should be rinsed with cold water and finished with a hot water rinse. The time of immersion in hot water should not exceed three minutes, otherwise staining may result; after this washing with hot water the parts should be dried. It is essential when using this treatment that rubber gloves be worn by the operator and the acid solution should preferably be contained in an aluminium vessel.

– Magnesium alloys - Wash in water followed quickly by standard chromium. Acid chromate bath is recommended.

– Copper and brass - Wash in boiling water followed by brushing. Where possible, a 2 percent solution of nitric or sulphuric acid is preferred to help in removing the glassy slag, followed by a hot water wash.

– Stainless steel - Treat in boiling 5 percent caustic soda solution, followed by washing in hot water. Alternatively, use a de-scaling solution of equal volume of hydrochloric acid and water to which is added 5 percent of the total volume of nitric acid with 0.2 percent of total volume of a suitable restrainer.

– Cast iron - Residues may be removed easily by a chipping hammer or wire brush.

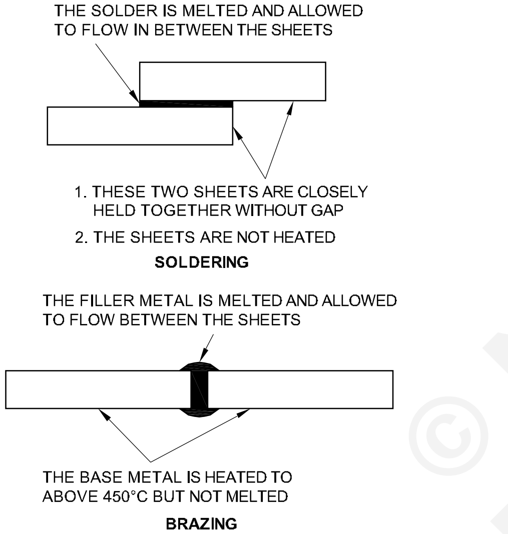
– Silver brazing - The flux residue can be easily removed by soaking brazed components in hot water, followed by wire brushing. In difficult cases the work piece should be immersed in 5 to 10 percent sulphuric acid solution for a period of 2 to 5 minutes, followed by hot water rinsing and wire brushing.

Gas Brazing & Soldering Priciples,types,fluxes & uses.

Objectives: At the end of this lesson you shall be able to
- **explain soft soldering and hard soldering**
- **describe the method of soft soldering, brazing and sliver brazing**
- **describe the difference between brazing and soldering**
- **explain the various methods of brazing**
- **explain the problems in brazing and the remedies.**

Soldering and brazing: The soldering and brazing processes differ from welding in the sense that there is no direct melting of the base metal(s) being welded. In brazing or soldering, the filler alloy flows between two closely adjacent surfaces by capillary action.(Fig 1)

Fig 1



Soft soldering: The filler metals 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.

Types of fluxes

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

Non-corrosive: These are fluxes 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

Steel - zinc chloride

Zinc and galvanized iron - hydrochloric acid

Tin - Zinc chloride

Lead - tallow resin

Brass, copper, brass - Zinc chloride, resin.

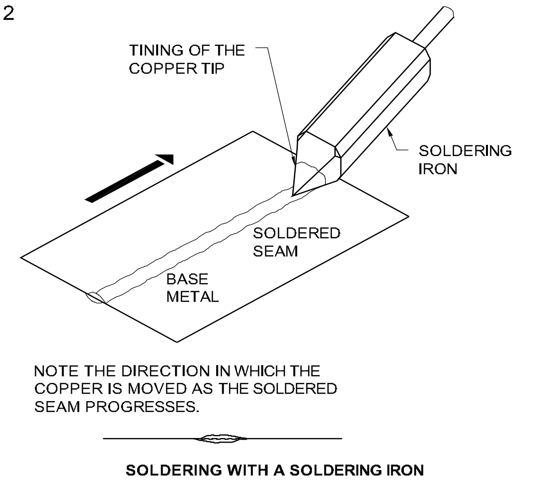
Basic operations in soldering

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

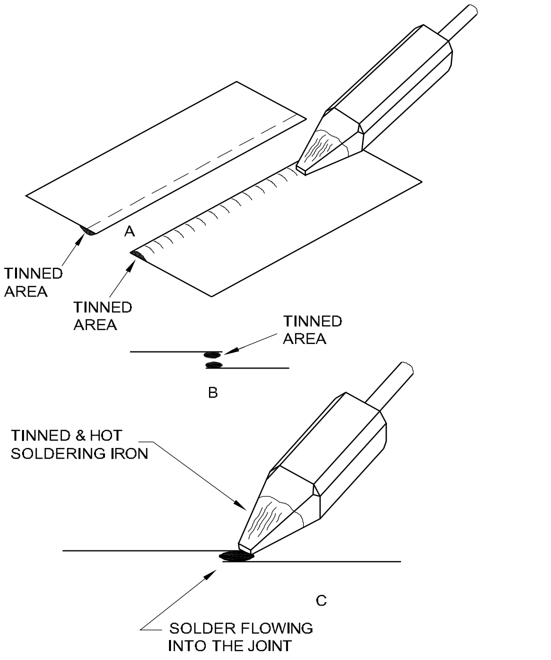
Fig 2



The solder is applied with a copper soldering bit. (Figs 3a, b and c) The joining takes place due to "sweating' of the bit 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.

Fig 3



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

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

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

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

Brazing is employed where a ductile joints is required.

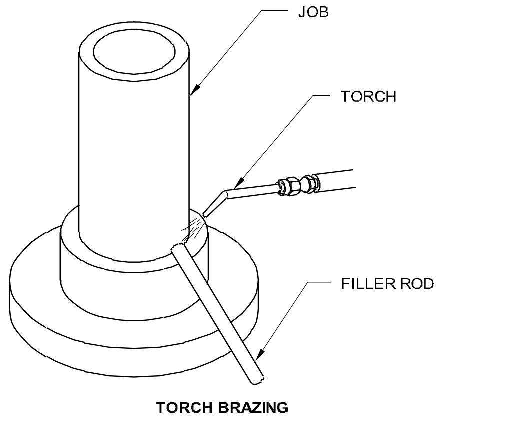
Brazing filler rods/ metals melt at temperature from 860°C to 950°C and are used to braze iron and its alloys.

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

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

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

Fig 4



TORCH BRAZING

Various methods of brazing

Torch brazing: The base metal is heated to the required temperature by the application of the oxy-acetylene flame. (Fig 4)

Conditions to obtain satisfactory brazed or soldered joint

Wet the base metal.

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

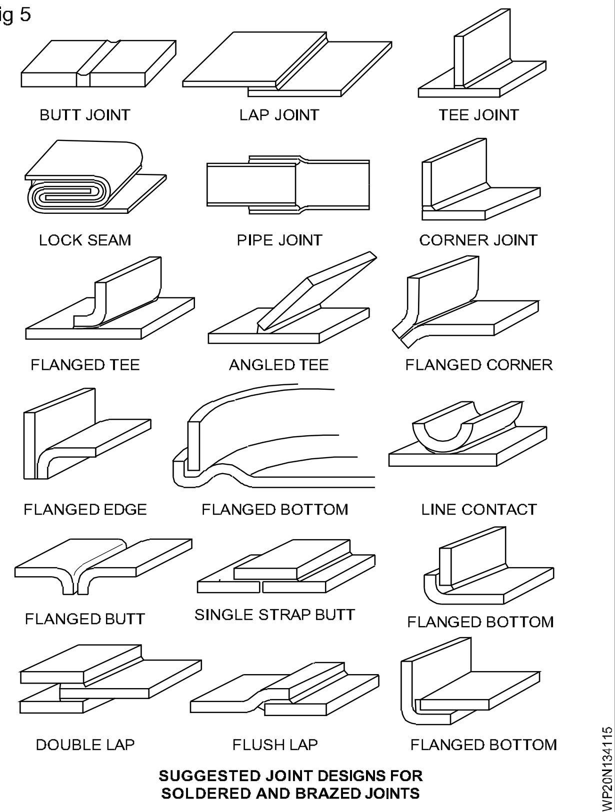
Suggested joint designs for soldering and brazing are shown in Fig 8

Advantages of brazing

The completed joint requires little or no finishing.

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

Fig 5



SUGGESTED JOINT DESIGNS FOR SOLDERED AND BRAZED JOINTS

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.

Gas Welding Defects, causes and Remedies

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

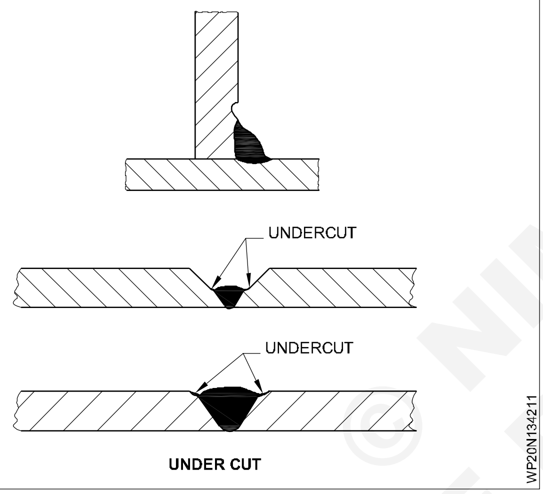
Definition

A fault is an imperfection in the weld which may result in failure of the welded joint while in service.

The following faults occur commonly in gas welding.

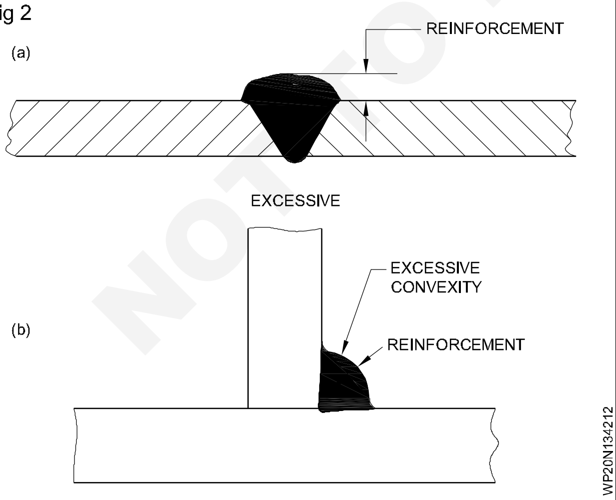
Undercut: A groove or channel formed along the toe of the weld on one side or on both sides. (Fig 1)

Fig 1



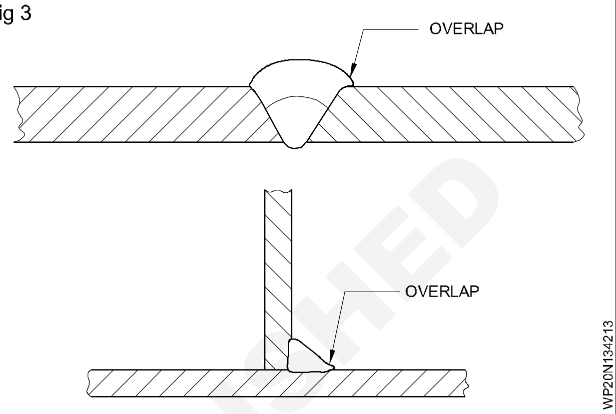
Excessive convexity: Too much weld metal added to the joint so that there is excessive weld reinforcement. (Fig 2)

Fig 2



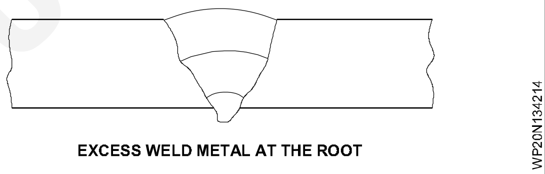
Overlap: Metal flowing into the surface of the base metal without fusing it. (Fig 3)

Fig 3



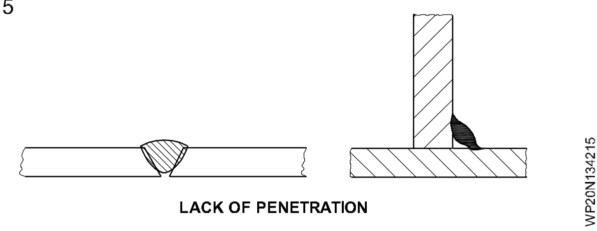
Excessive penetration: Depth of fusion at the root of the grooved joint is more than the required amount. (Fig 4)

Fig 4



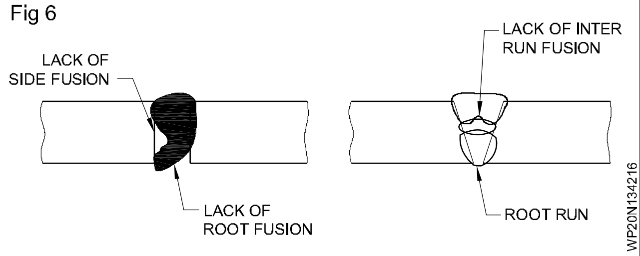
Lack of penetration: Required amount of penetration is not achieved, i.e. fusion does not take place up to the root of the weld. (Fig 5)

Fig 5



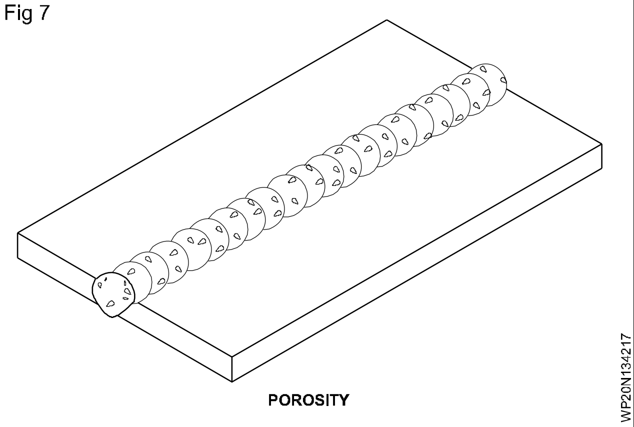
Lack of fusion: If there is no melting of the edges of the base metal at the root face or on the side face or between the weld runs, then it is called lack of fusion. (Fig 6)

Fig 6



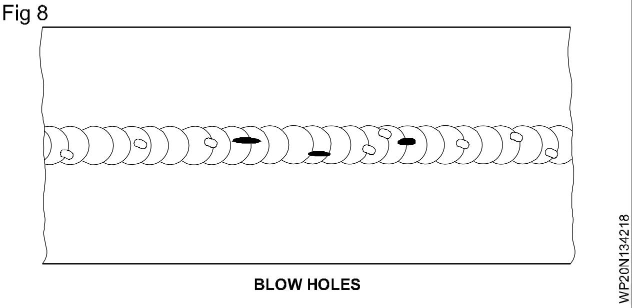
Porosity: Number of pinholes formed on the surface of the deposited metal. (Fig 7)

Fig 7



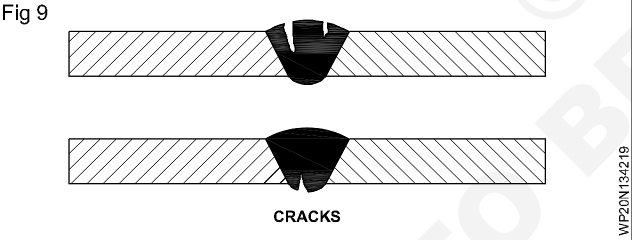
Blow-holes: These are similar to pinholes but have a greater diameter. (Fig 8)

Fig 8



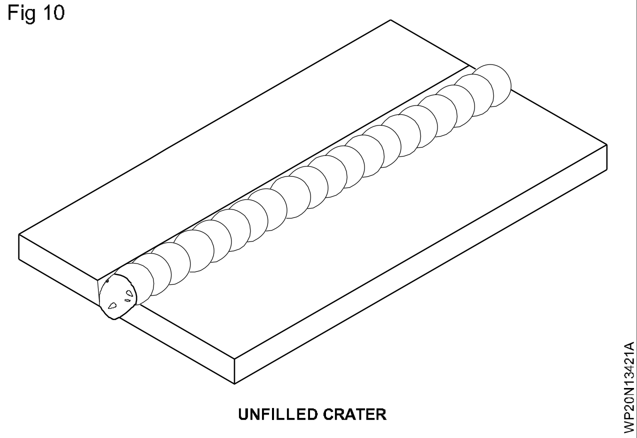
Cracks: A discontinuity in the base metal or weld metal or both. (Fig 9)

Fig 9



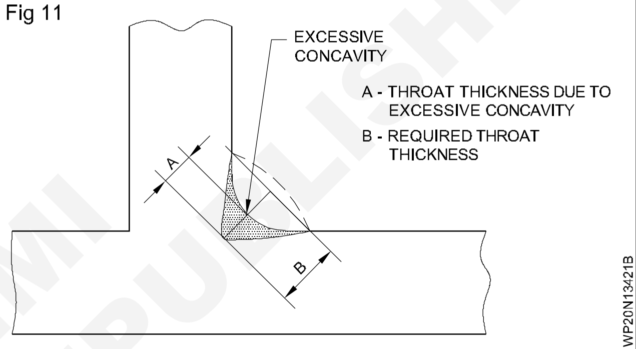
Unfilled crater: A depression formed at the end of the weld. (Fig 10)

Fig 10



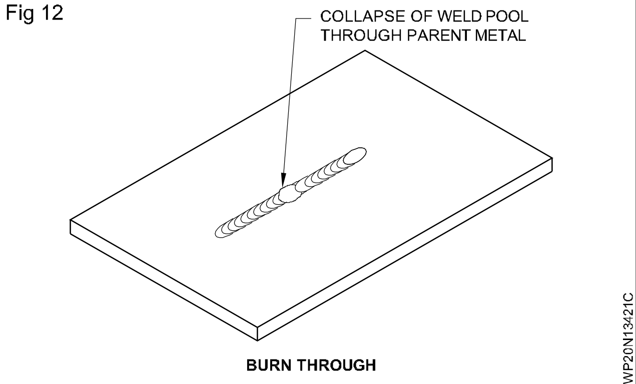
Excessive concavity/insufficient throat thickness: Enough weld metal is not added to the joint so that there is insufficient throat thickness. (Fig 11)

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



Gas welding defects, causes and Remedies

Objectives: At the end of this lesson you shall be able to
- **explain the causes of weld defects**
- **state the remedies to prevent the defects.**

Welding defects: Possible causes and remedies

	Defect	Possible causes	Appropriate remedies
1	Fillet weld with insufficient throat thickness.	Incorrect angle of filler rod and blowpipe.	Maintain filler rod and blowpipe at the appropriate angles.
2	Excessive concavity in butt weld profile.	Excess heat build-up with too fast a speed of travel or filler rod too small.	Use the appropriate size nozzle and filler rod with the correct speed of travel.
3	Excessive penetration. Excess fusion of root edges.	Angle of slope of nozzle too large. Insufficient forward heat. Flame size and/or velocity too high. Filler rod too large or too small. Speed of travel too slow.	Maintain the nozzle at the correct speed of travel. Select correct nozzle size. Regulate flame velocity correctly. Use correct size of filler rod.
4	Burn through.	Excessive penetration has produced local collapse of weld pool resulting in a hole in the root run.	Maintain blowpipe at the correct angles. Check nozzle size, filler rod size. Travel at the correct speed.
5	Undercut along vertical member of filler welded Tee joint.	Incorrect angle of tilt used in blowpipe manipulation.	Maintain blowpipe at the Correct angle.
6	Undercut in both sides of weld face in butt joint.	Wrong blowpipe manipulation; incorrect distance from plate surface, excessive lateral movement. Use of too large a nozzle.	Use correct nozzle size, speed of travel and lateral blowpipe manipulation.
7	Incomplete root penetration in butt joint (single 'V' or double 'V').	Incorrect set up and joint preparation. Use of unsuitable procedure and/or welding technique.	Ensure joint preparation and set up are correct. Appropriate procedure and/or welding technique must be used.
8	Incomplete root penetration in close square Tee joint.	Incorrect set up and joint preparation. Use of unsuitable procedure and/or welding technique.	Ensure joint preparation and set up are correct. Appropriate procedure and/or welding technique must be used.
9	Lack of root penetration.	Incorrect joint preparation and set up. Gap too small. Vee preparation too narrow. Root edges touching.	Prepare and set up the joint correctly.
10	Lack of fusion on root and side faces of double Vee butt joint.	Incorrect set up and joint preparation. Use of unsuitable welding technique.	Ensure the use of correct joint preparation, set up and welding technique.
11	Lack of inter-run fusion.	Angles of nozzle and blowpipe manipulation incorrect.	Correct the angles of slope and tilt. Use blowpipe manipulation to control uniform heat build-up.

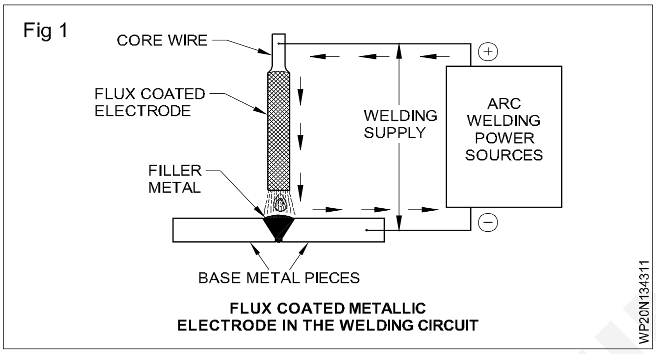
	Defect	Possible causes	Appropriate remedies
	Overlap		
12	Weld face cracks in butt and fillet welds.	Use of incorrect welding procedure. Unbalanced expansion and contraction stresses. Presence of impurities. Undesirable chilling effects. Use of incorrect filler rod.	Use correct procedure and filler rod. Ensure uniform heating and cooling. Check suitability and surface preparation of material before welding. Avoid draughts and use appropriate heat treatment.
13	Surface porosity and gaseous intrusions.	Use of incorrect filler rod and technique. Failure to clean surfaces before welding. Absorption of gases due to incorrectly stored fluxes, unclean filler rod. Atmospheric contamination.	Clean plate surfaces. Use correct filler rod and technique. Make sure the flame setting is correct to avoid gas contamination.
14	Crater at end of weld run. Small cracks may be present.	Neglect to change the angle of blowpipe, speed of travel or increase the rate of weld metal deposition as welding is completed at the end of the seam.	Reduce the angle of the blowpipe progressively with speed of travel to lower the heat input and deposit, and deposit sufficient metal to maintain the toe of the weld pool at the correct level until it has completely solidified.

Electrodes types, Functions of flux, Coating Factor, Sizes of Electrode.

Objectives: At the end of this lesson you shall be able to
- **explain arc welding electrode**
- **state the types of electrodes**
- **explain the coating factor**
- **describe the characteristics of flux coating on electrode**
- **explain the functions of flux coating during welding.**

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

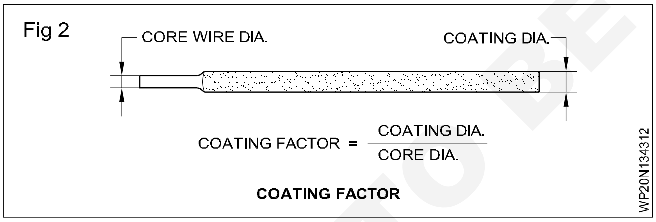


FLUX COATED METALLIC ELECTRODE IN THE WELDING CIRCUIT

Coating factor (Fig 2): The ratio of the coating diameter to the core wire diameter is called the coating factor.

$$= \frac{\text{Coating diameter}}{\text{Coating wire diameter}}$$

Fig 2



COATING FACTOR

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.

Functions of Flux

Composition/characteristics flux: The coating of the welding electrodes consists of a mixture of the following substances.

These are: sodium and potassium silicates.

Purpose or function of flux coating: During welding, with the heat of the arc, the electrode coating melts and performs the following functions.

- It stabilizes the arc.
- It forms a gaseous shield around the arc which protects the molten weld pool from atmospheric contamination.
- It compensates the losses of certain elements which are burnt out during welding.
- It retards the rate of cooling of the deposited metal by covering with slags and improves its mechanical properties.
- It helps to give good appearance to the weld and controls penetration.
- It makes the welding in all positions easy.
- Both AC and DC can be used for the welding.
- Removes oxide, scale etc. and cleans the surfaces to be welded.
- It increases metal deposition rate by melting the additional iron powder available in the flux coating.

Types of electrodes for ferrous and alloy metals

Mild steel electrode: Mild steel is characterized by carbon content not exceeding 0.3%. Mild steel electrode core wire contains various alloying elements.

Carbon 0.1 to 0.3%

(Strengthening agent)

Keep carbon as low as possible.

Silicon above 0.5%

(Deoxidizes, prevents weld metal porosity.)

Manganese 1.65%

(Increases strength and hardness.)

Nickel

(Increases strength and notch toughness.)

Chromium

(Increases tensile strength and hardness. Lowers the ductility.)

Molybdenum 0.5%

(Increases hardness and strength.)

Indian Standard System laid down in IS:814-1991 a classification and coding of covered electrodes for metal arc welding of mild steel, and low alloy high tensile steel. Mild steel and low alloy high tensile steel electrodes are classified into seven recognised groups, depending upon the chemical composition of the flux coating.

Stainless steel electrodes: Selecting proper electrodes depends primarily on the composition of the base metal to be welded.

These electrodes are available with either lime or titanium coatings. The lime coated electrode is used only with DC reverse polarity. Titanium coated electrodes can be used in AC and DC reverse polarity, and will produce smoother and stable arc.

The coding system for stainless steel electrodes differs somewhat from that for the M.S. electrode. The I.S. 5206-1969 specification for corrosion-resisting chromium and chromium-nickel steel covered electrodes will give full details.

During welding, the electrode will tend to get red hot quickly. To avoid this, a 20 to 30% lower current than what is used for ordinary M.S. electrode is recommended.

Sizes of Mild Steel Electrodes

Objectives: At the end of this lesson you shall be able to
- **state the size, length and current setting of M.S. electrodes**
- **explain the functions of electrode**
- **state the BIS coding for M.S. electrode.**

The electrode size refers to the diameter of its core wire.

Each electrode has a certain current range. The welding current increases with the electrode size (diameter).

Electrode sizes

Metric

1.6mm

2.0mm

2.5mm

3.15mm

4.0mm

5.0mm

6.0mm

6.3mm

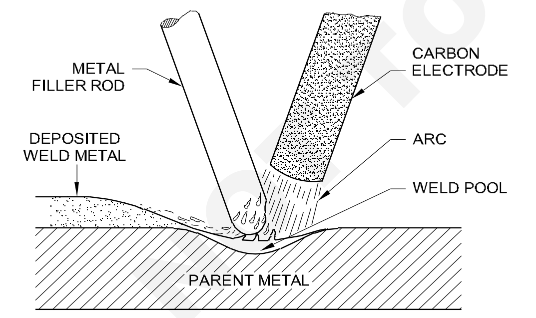
8.0mm

10.0mm

Standard length of electrodes: The electrodes are manufactured in two different lengths, 350 or 450mm.

Types of electrodes: Electric arc welding electrodes are

Fig 1



CARBON ARC PROCESS

of three general types. They are:

Carbon electrodes

Bare electrodes

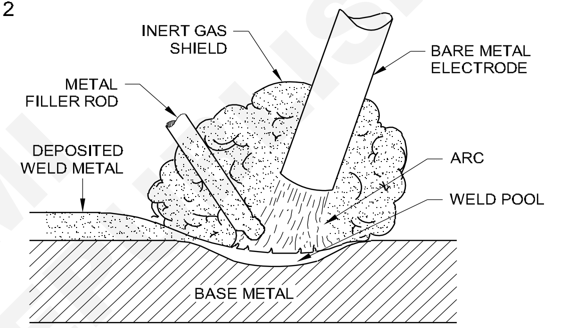
Flux coated electrodes

Carbon electrodes are used in the carbon arc welding process (Fig 2). The arc is created between the carbon electrode and the job. The arc melts a small pool in the job and filler metal is added by using a separate rod.

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

Bare electrodes are also used in some arc welding processes (Fig 3). An inert gas is used to shield the molten

Fig 2



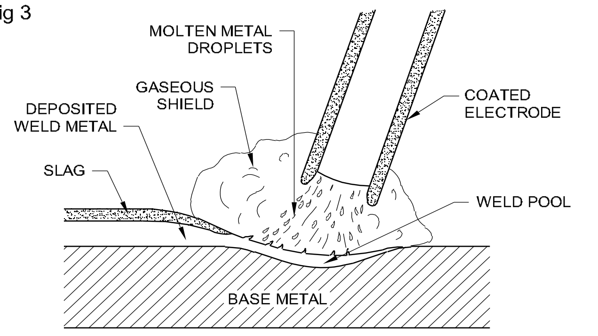
PROCESS USING BARE ELECTRODE & GASEOUS SHIELD

weld metal and prevent it from absorbing oxygen and nitrogen. Filler metal is separately added through a filler rod. Usually tungsten is used as one of the bare wire electrode. In Co_2 welding and submerged arc welding processes the mild steel bare wire electrode is also used as a filler wire.

Flux coated electrodes are used in the manual metal arc welding process for welding ferrous and non-ferrous metals. (Fig 4)

The composition of the coating provides the flux, the protective shield around the arc and a protective slag which forms over the deposited weld metal during cooling.

Fig 3



PROCESS USING FLUX COATED ELECTRODE

Chart

Types of Arc welding and cutting/gouging electrodes

- Consumable electrode
  - Coated electrode
    - <u>Factors</u>
      - Methods of flux coating
        - Dipping process
        - Extrusion process
      - Coating flux
        - Light coated
        - Medium coated
        - Heavy coated
        - Super heavy coated
      - Type of flux coating
        - Cellulosic coated
        - Rutile coated
        - Iron powder coated
        - Basic coated
      - Purpose of flux coating
        - Shallow penetration
        - Deep penetration
        - All positive welding
        - Flat/down hand position only
        - Hard facing
        - Gouging
      - Core wire material
        - Ferrous
          - Mild steel
          - Alloy steel
          - Stainless steel
          - Cast iron
        - Non ferrous
          - Phosphor bronze
          - Nickel alloy
          - Aluminium
        - Hard facing
  - Bare wire electrode
    - Copper coated mild steel
      - Solid
      - Flux cored
- Non consumable electrode
  - Carbon electrode
    - Welding
    - Cutting
  - Bare wire metal electrode
    - Tungsten
      - Pure tungsten
      - Thoriated tungsten
      - Zirconium based tungsten

Effects of Moisture pick up Storage and Baking of Electrodes

Objectives: At the end of this lesson you shall be able to
- **explain about special purpose electrodes and their application**
- **state the necessity of baking a coated electrode**
- **store and handle the electrode properly for better weld quality.**

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

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 Sthe 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.

Storage and Baking of Electrodes

Objectives: At the end of this lesson you shall be able to
- **explain about special purpose electrodes and their application**
- **state the necessity of baking a coated electrode**
- **store and handle the electrode properly for better weld quality.**

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

- Keep electrodes in unopened packets in a dry store.
- Place packages on a duckboard or pallet, not directly on the floor.
- Store so that air can circulate around and through the stack.
- Do not allow packages to be in contact with walls or other wet surfaces.
- The temperature of the store should be about 5°C higher than the outside shade temperature to prevent condensation of moisture.
- Free air circulation in the store is as important as heating. Avoid wide fluctuations in the store temperature.
- Where electrodes cannot be stored in ideal conditions place a moisture-absorbent material (e.g. silica-gel) inside each storage container.

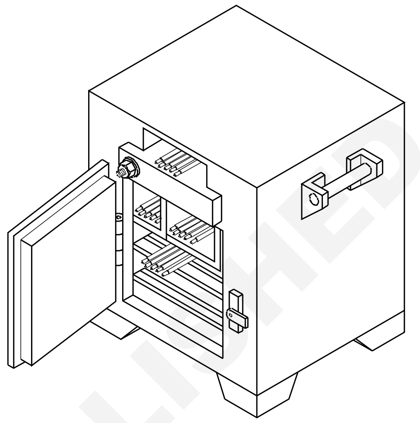
Store and keep the electrodes (air tight) in a dry place.

Bake the moisture affected/prone electrodes in an electrode drying oven at 110-150°C for one hour before using. (Fig 1).

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:

Fig 1



ELECTRODE DRYING OVAN

- 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.

Weldability of metals, Importance of Preheating, Post Heating and maintenance of inter pass tempearture.

Objectives: At the end of this lesson you shall be able to
- **At the end of this lesson you shall be able to**
- **Explain the effects of weldable quality on ferreres and non-ferrous metals.**
- **State the purpose of preheating**
- **Explain the method of preheating**
- **Describe the types of preheating**
- **Explain the purpose of post-heating a bigger Job**
- **Describe the maintenance of inter-pass temperature**

Weldability:

- The ferrite and Martin site structure on carbon steels are not suitable for welding. But, the crystal fine structure enables brazing.
- Austenitic steels are suitable for welding. In present days all types of steels are welded using inert gas shielded arc process.

Weldability of cast Iron:

Cast Iron is welded after performing preheating to a temperature of 200°C-210°C. On completion of first layer of welding, the same preheating is repeated to maintain the reinforcement of weld. Next, the whole job is evenly heated. This is called post-heating.

The job is cooled slowly, by covering under a heap of lime or ash or dry sand.

Weldability of copper:

99.9% pure copper with 0.01 to 0.08% oxygen in the form of cuprous oxide is known as electrolyte copper and this is not weldable.

A small quantity of phosphorous added to electrolyte copper to de-oxidise, so as to make it weldable.

The surface of the base metal is preheated to a fairly high temperature resulting in peacock neck blue colour; before the actual welding started.

Once the metal is cooled after welding, to reduce the grain size and locked up stresses, the pressuring is done.

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

Small casting jobs may be preheated by the application of a blowpipe flame. But larger jobs should be preheated in a 'gas-furnace' or by means of a temporary charcoal furnace.

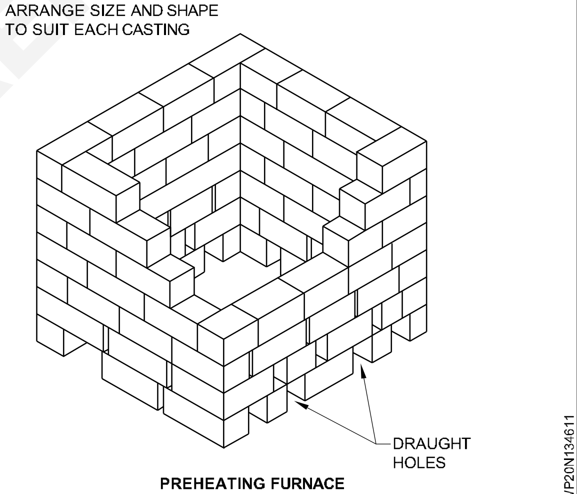
Methods of preheating

Preheating methods depend upon the size of the job and the technique used for welding. Preheating can be done in a temporarily built gas or charcoal furnace (Fig 1) blacksmith's forge and even by the oxy-acetylene flame. Heavy jobs can be preheated from the furnace and small jobs by a flame from a blowpipe or from the forge.

Types of preheating

The type of preheating depends on the size and nature of the job. There are three types of preheating.

Fig 1



PREHEATING FURNACE

- 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

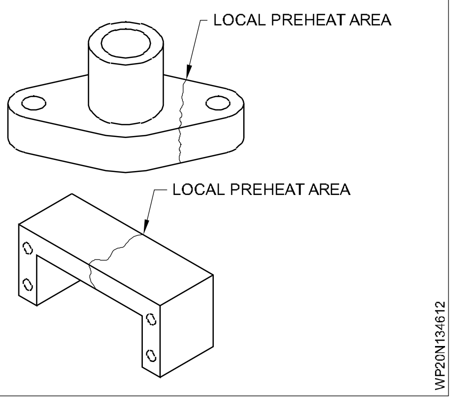
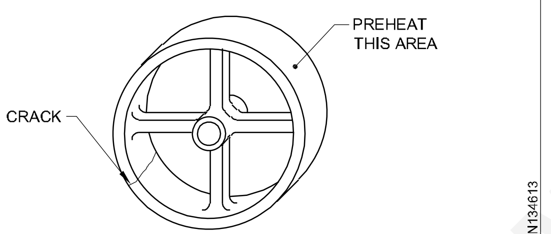


Fig 3

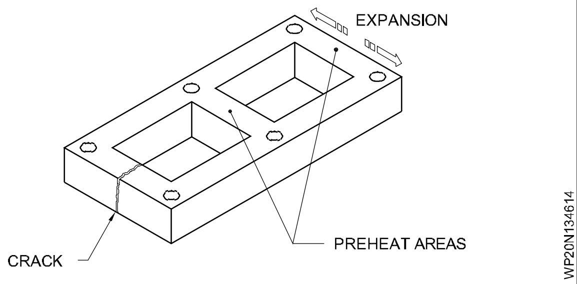


TECHNIQUE OF LOCAL PRE-HEATING

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

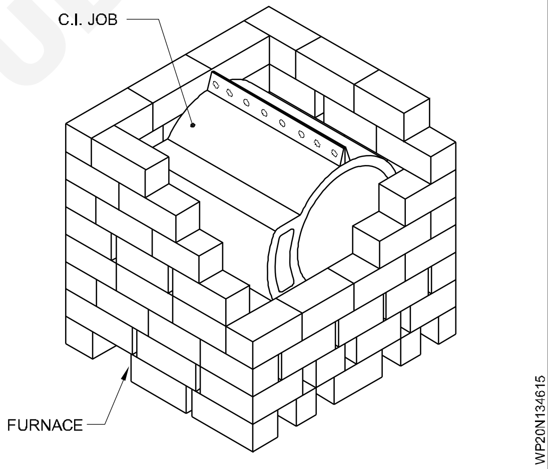


The slag and oxide on the surface of the finished weld can be removed by scraping and brushing with a wire-brush after cooling. The weld should not be hammered as cast iron is brittle.

Maintenance of inter-pass temperature: The temperature of the preheated job can be checked by wax crayons. Marks are made on the cold job pieces by these crayons before preheating and after the job pieces reach the preheating temperature the marks will disappear.

This indicates that the job has been heated to the required preheating temperature. Different wax crayons are available for checking different temperatures. The temperature which is checked by the crayon will be marked on it.

Fig 5



Welding of low Carbon, Medium and High Carbon Steel and Alloy Steels

Objectives: At the end of this lesson you shall be able to
- **state the composition of carbon percentage in low carbon steel and medium carbon steel**
- **state the type of flame needed for welding low carbon steel**
- **describe the method of welding low carbon steel**
- **explain the procedure for the welding of medium carbon steel.**

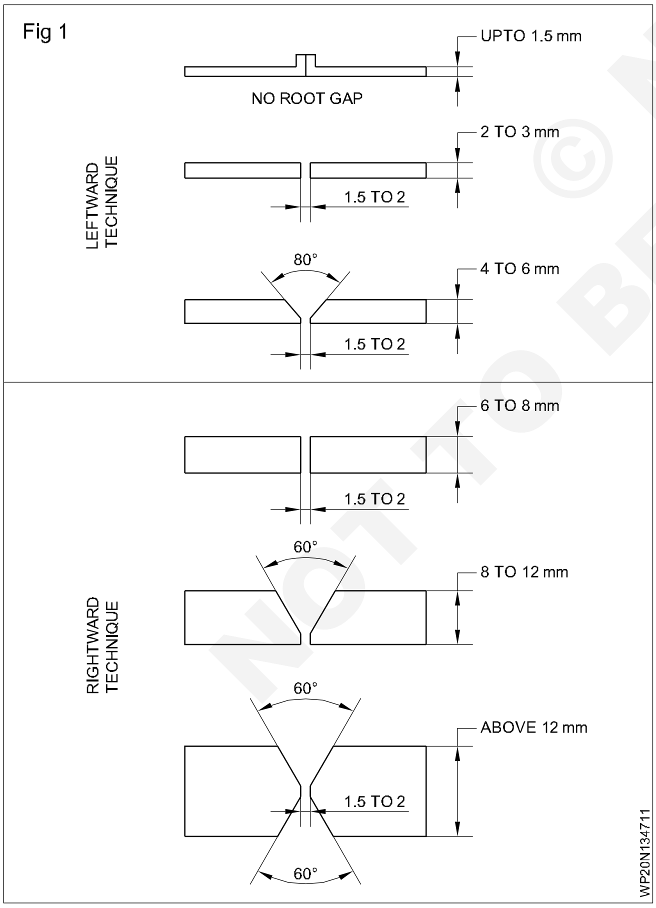
A plain carbon steel is one in which carbon is the only alloying element. The amount of carbon in the steel controls its hardness, strength and ductility. The higher the carbon the lesser the ductility of the steel.

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

Low carbon steels: Steels with a range of 0.05 to 0.30 per cent are called low carbon steel or mild steel. Steels in this class are tough, ductile and easily machinable and quite easy to weld.

Welding technique: Up to 6 mm, leftward technique is a suitable one. Above 6 mm rightward technique is preferable.

Preparation: (Refer Fig 1 given below)



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.

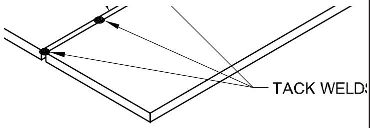
High carbon steel: High carbon steels contain 0.6% to 1.2% carbon. This type of steel is not weldable by gas welding process because it is difficult to avoid cracking of base metal and the weld.

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.

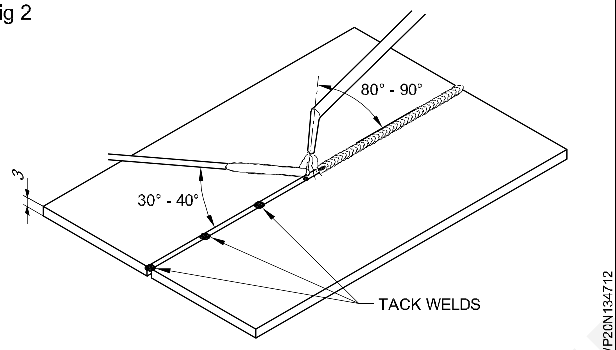
Start welding from the right hand edge of the joint and proceed in the leftward direction.

Table 1

Thickness	Preparation	Assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1 mm	Square edge	No gap	20	1	1.2 mm
1.2 mm	Square edge	No gap	20	2	1.2 mm
1.5 mm	Square edge	No gap	25	2	1.6 mm
3 mm		No gap	45	5	3 mm

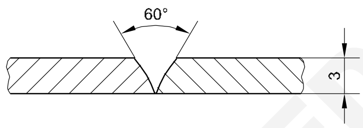
Keep the tip of the inner cone of the flame within 1 to 1.5 mm of the molten puddle, and hold the blowpipe at an angle of 80-90° to the work. (Fig 2)

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



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.

Welder - Weldability of steels (OAW, SMAW)

Alloying elements and their functions on steel

Objectives: At the end of this lesson you shall be able to
- **state the necessity of alloying elements**
- **identify the common alloying elements**
- **describe the effects of each such element.**

Necessity of alloying elements: Certain elements are added to increase the mechanical properties of metals.

Common alloying elements: The following are some common alloying elements.

Carbon

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
- **explain the classification of stainless steel**
- **state the physical properties of stainless steel**
- **explain the welding procedure**
- **describe the weldability test of stainless steel**
- **state the effect of weld decay.**

Types of stainless steel: Stainless steel is an alloy of iron, chromium, and nickel. There are many different classification of stainless steel according to the percentage of its alloying elements. Accordingly there are three main classifications for stainless steel.

One group is FERRITIC, which is non-hardenable and magnetic. The other group is MARTENSITE, which is 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 martensite are non-weldable. Usually the austenitic type of stainless steel is called 18/8 stainless steel which contain 18 percent chromium 8% nickel apart from the iron percentage. To eliminate corrosive action in this type of stainless steel stabilizing elements such as columbium, titanium, molybdenum, zirconium etc. are added in a small percentage. So, this weldable type of stainless steel is called a 'stabilized type' stainless steel. These elements also can be added to filler rods.

Physical properties of stainless steel: The coefficient of expansion of stainless steel of ferrite and martensite are approximately the same as carbon steel whereas the austenitic type of stainless steel has about 50 to 60% greater coefficient of expansion than carbon steel. So, while welding this type of stainless steel, distortion will be more. The heat conductivity is approximately 40 to 50% less than that of carbon steel for austenitic type.

All these types have a brighter colour without having any stain in appearance.

Types of stainless steel filler rods: Specially treated stainless steel filler rods, which contain stabilizing elements such as molybdenum, columbium, zirconium, titanium etc., are available.

The chromium percentage is also sometimes 1 to 1 1/2 percent more than in the base metal, so as to compensate the losses that may occur during the welding operation from the base metal. The melting point of the filler rod also will be 10° to 20°C less than the base metal. Filler rods of different sizes are available in the market.

Flux: A special type powdered flux which contains zinc chloride and potassium dichromate is available. During welding powered flux is to be made into a paste form by adding water and applied on the underside of the joint.

Method of controlling distortion: Since stainless steel has a much higher coefficient of expansion with lower thermal conductivity than mild steel, there are greater possibilities of distortion and warping.

Whenever possible clamps and jigs should be used to keep the pieces in line until they have cooled. And also a thick metal plate of copper should be used as a backing bar during welding so as to reduce distortion in the parent metal. Tacks at frequent intervals (i.e. pitch of tack is 20 - 25 mm) will also reduce distortion.

Welding procedure

The type of edge preparation, nozzle size, filler rod size, pitch of tack for different thickness of sheets to be welded are given in Table 1.

Start welding from the right edge of the joint and proceed in the leftward direction.

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

Fig 1

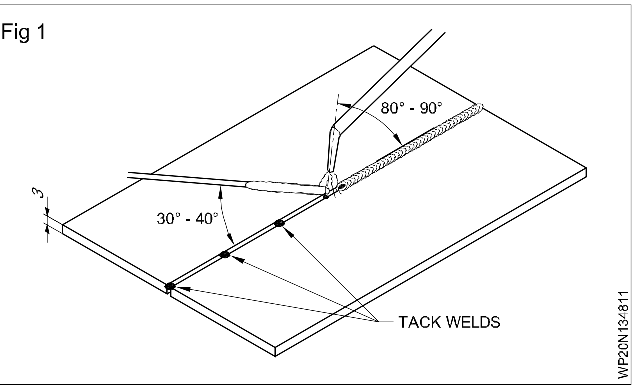
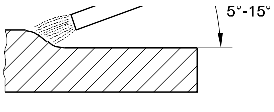
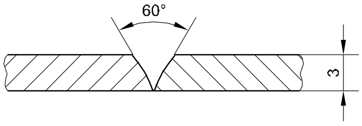


Table 1

Thickness	Preparation	Assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1 mm	Square edge	No gap	20	1	1.2 mm
1.2 mm	Square edge	No gap	20	2	1.2 mm
1.5 mm	Square edge	No gap	25	2	1.6 mm
3 mm		No gap	40	5	3 mm

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 brazable. Austentic type stainless steel is a good weldable one. Nowadays the inert gas shielded arc is used very widely for welding all types of stainless steel.

Brass-Types Properties and Welding Methods

Objectives: At the end of this lesson you shall be able to
- **state the composition of brass**
- **state the selection of nozzle, flame and flux**
- **explain the necessity of oxidising flame and welding technique.**

Composition of brass: Brass is an alloy of copper and zinc in various proportion, possibly with the addition of other elements in very less percentage.

The percentage of zinc various from 1 to 50% which makes available 15 individual commercial brasses. These brasses containing 20 to 40% zinc have a variety of uses.

Melting temperature of brass: The melting point of copper is 1083°C and that of zinc is 419°C. Brass melts at intermediate temperatures. The greater the amount of copper the higher the melting point. The melting point of brass is generally around 950°C.

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.

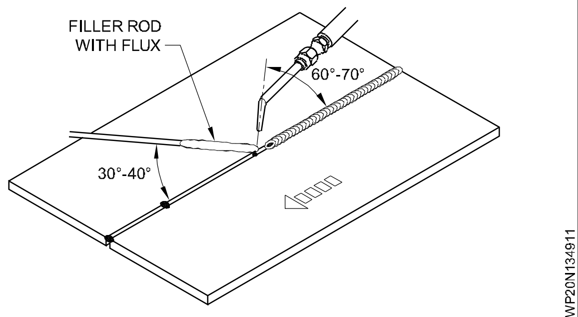
Flux is very important in welding brass. A fresh mixture of borax paste makes a good flux for brass welding.

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.

Table 1

Thickness	Preparation	Assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1 mm	Square edge	No gap	25	2	1.6 mm
1.2 mm	Square edge	0.8 mm gap	38	3	2 mm
1.5 mm	Square edge	0.8 mm gap	38	3	2 mm
3 mm	Single V	1.5 mm gap	75	5 to 7	3 mm

Copper-types-Properties and Welding Methods

Objectives: At the end of this lesson you shall be able to
- **describe the various types of copper**
- **state the physical properties of copper**
- **explain the welding procedure.**

Copper types 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.

Properties 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.

Proper 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.

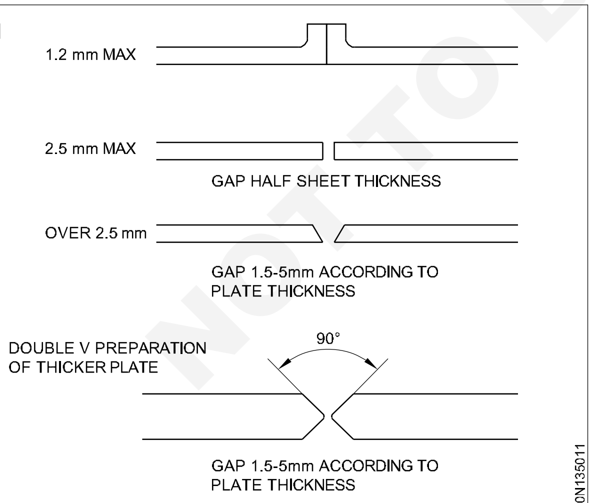
Melting point: 1083°C.

Density: 8.98 g/cm^3

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

Welding Methods (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.

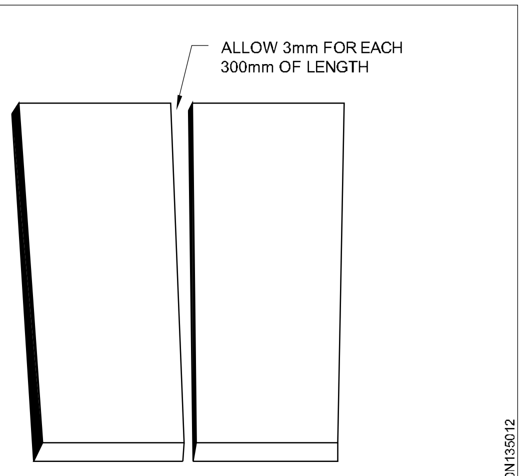
Effects of setting 'carburizing' or 'oxidising' flame

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.

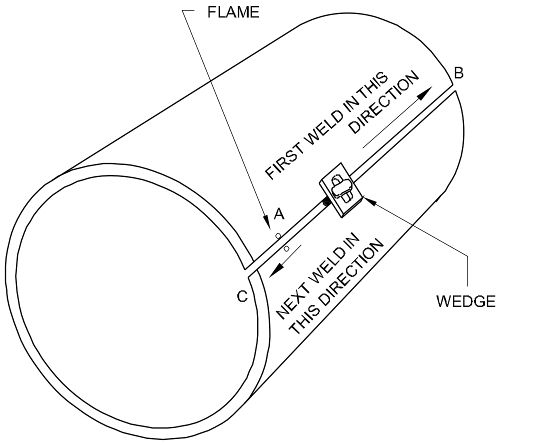
Setting: 1.6 mm root gap between the sheets with a divergence allowance at the rate of 3-4 mm per 300 mm run. (Fig 2) Use wedge for welding long seam in copper. (Fig 3) No tacking is done.

Fig 2



DIVERGENCE ALLOWANCE

Fig 3

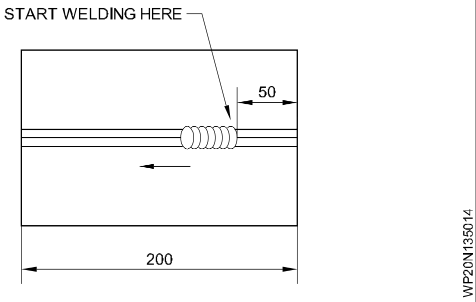


WELDING LONG SEAM IN COPPER

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

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

Fig 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.

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.

Introduction to Induction Welding its Parameters

Objectives: At the end of this lesson you shall be able to
- **define induction welding**
- **state the use of induction welding.**

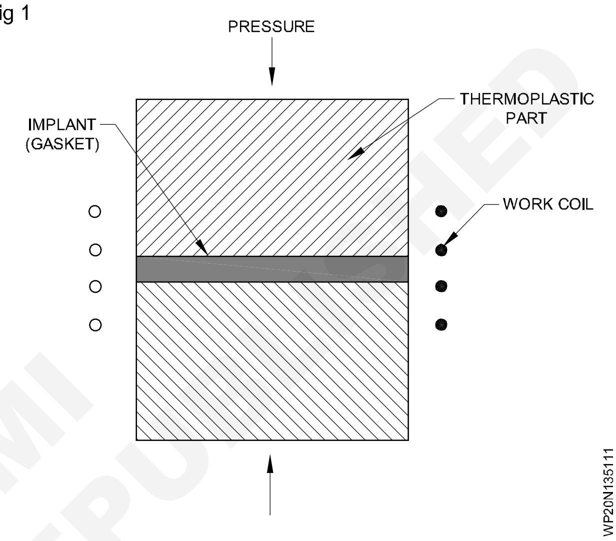
What Does Induction Welding Mean?

Induction weldimg 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 cells.
Induction welding process

Induction welding uses induction heating from radio frequency alternating current to magnetically excite an implant placed at the joint interface of the two parts being welded. This implant, or gasket, is normally a composite of the polymer to be welded with either metal fibers or ferromagnetic particles.

Induction welding is used in the tube and pipe industry for the longitudinal welding of stainless steel (magnetic and non-magnetic), aluminium, low-carbon and high-strength low-alloy (HSLA) steels and many other conductive materials.

Fig 1



Aluminium Properties and Weldability, Welding Methods

Objectives: At the end of this lesson you shall be able to
- **explain the properties of aluminium and its alloys**
- **state the difficulties in welding of aluminium by oxy-acetylene process**
- **describe the joint design, importance of flux and welding procedure**
- **state the various process of welding aluminium**
- **explain the advantages and disadvantages of welding of aluminium by oxy-acetylene process.**

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.

Weldability

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.

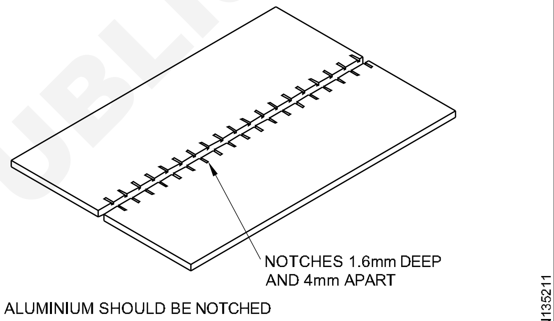
Molten aluminium oxidizes very rapidly form a heavy coating of aluminium oxide on the surface of the seam which has a higher melting point - 1930°C. This oxide must be thoroughly removed by using a good quality flux.

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)

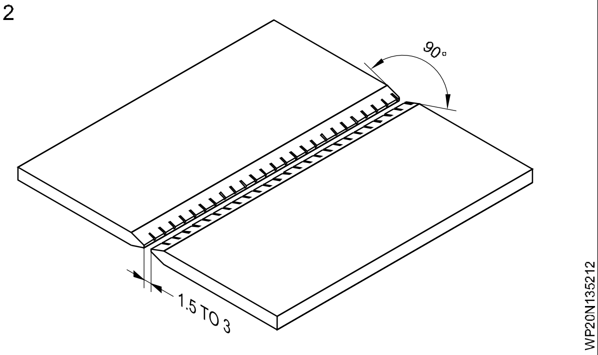
Fig 1



UNBEVELLED BUTT JOINTS ON 1.6mm TO 4mm

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 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

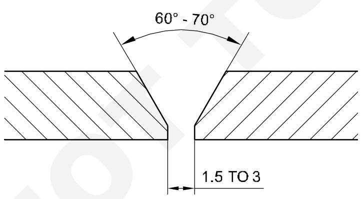
The flux residue, if not properly removed, may result in corrosion.

Distortion is greater than in arc welding.

Heat-affected zone is wider than in arc welding.

Welding speed is lower.

Table 1

Metal thickness	Preparation	Joint assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1	Square	No gap	25	1	2.5 mm
1.2	Square	No gap	40	2	2.5 mm
1.5	Square	No gap	40	2	2.5 mm
3		1.5 - 3 mm gap	75	5	3.15 mm

Arc Cutting and Gouging

Objectives: At the end of this lesson you shall be able to
- **state the different arc cutting and gouging processes**
- **state the equipment and accessories**
- **explain the different electrodes and their properties**
- **describe the current setting for different size electrodes**
- **describe the arc cutting and gouging procedures**
- **explain the advantages and applications.**

Different arc cutting and gouging processes

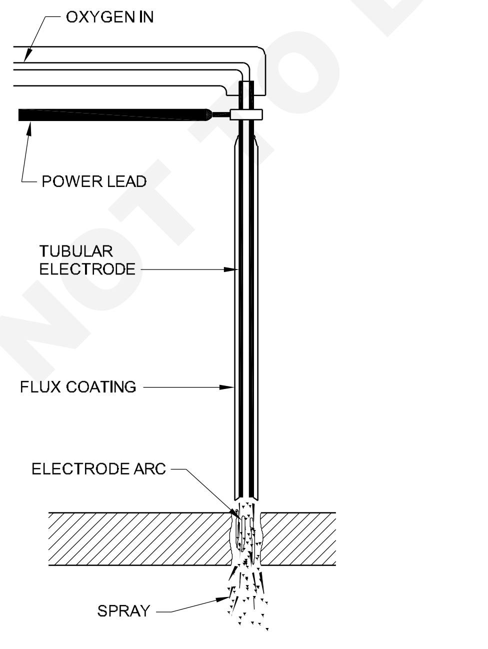
- Metallic arc cutting gouging process
- Carbon arc cutting process
- Air arc cutting process
- Plasma arc cutting process
- Oxy-arc cutting process
- Carbon arc gouging process

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.

Fig 1



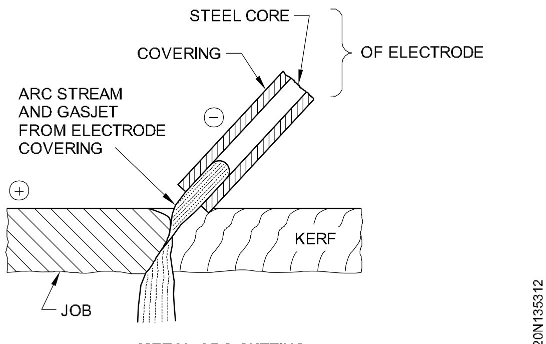
SCHEMATIC OF OXYGEN ARC CUTTING ELECTRODE IN OPERATION

Electrodes and their properties

Oxy-arc cutting electrode: This electrode is similar to the manual arc welding electrode and is coated with a flux, whose function is to provide an insulated sleeve to stabilise the arc and to make the products of combustion more fluid. The core wire, however, is in the form of a hollow tube through which a stream of oxygen is passed and designed holder, capable of conveying electric current to the electrode as well as oxygen to the arc, is used. (Fig 1)

Metallic arc cutting and gouging electrodes: These electrodes are normally the same as welding electrodes or are sometime specially designed as cutting electrodes (Fig 2) at a current setting which is 20 to 50% higher than that normally used for a given size for welding. Although AC can be used, DC with electrode negative is preferred. Sometimes it helps to make the electrode slightly wet. Water in the coating reduces overheating of the electrode to some extent and disassociates in the arc to render it more penetrating.

Fig 2



METAL ARC CUTTING

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

CURRENT SETTING FOR DIFFERENT SIZE ELECTRODES

Metal thickness		Electrode diameter		AC Range amps	DC (DCEN) amps
in.	mm	in.	mm		
1/8	3.2	3/32	2.4	40-150	75 - 115
1/8 - 1	3.2 - 25.4	1/8	3.2	125-300	150 - 175
3/4 - 2	19.1 - 50.8	5/32	4.00	250-375	170 - 500
1 - 3	25.8 - 76.2	3/16	4.8	300-450	—
3 and over	76.2 and over	1/4	6.4	400-650	—

Arc cutting and gouging procedure

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

Choose the welding machine and set the polarity DCEN, if DC is used.

Select the electrode size according to the thickness of the material.

Set the current as per the requirements for the selected electrodes.

Strike the arc and move the electrodes up and down on the edge of the plate. As the metal melts brush it downwards with the arc. Feed the electrodes into the slot and make the molten metal to run away underneath. Use only half the electrode and keep it away to cool for use again.

Check the cut surface for its smoothness and uniformity.

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

Choose the machine and set the polarity DCEN if DC is used.

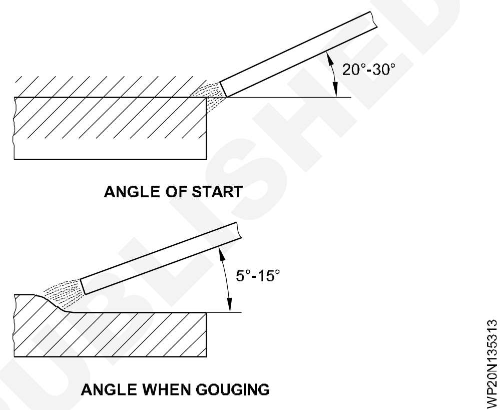
Select suitable sizes of electrodes and set the required current.

Strike the arc and as a molten pools is established, lower the electrode holder and reduce the angle between 5°-15° from 20°-30°. (Fig 3)

Move the electrode along the line of marking from the right to the left side of the plates and push the molten pool and slag away from the gouged groove.

Because of the rapid fusion due to the arc heat, move the electrode fast and control the gouging operation. Ensure that the angle of slope is not too steep, and avoid grooving too deeply. Maintain the angle of the electrode constant and the rate of travel uniform to obtain a groove of uniform width and depth.

Fig 3



Clean the surfaces.

Check the smoothness, depth and uniformity.

Advantages: Arc gouging procedure can be used when other cutting and gouging processes are not available.

In emergency it is more useful.

It can be used on metals which are difficult to cut by the oxy-acetylene cutting process.

(Cast iron, stainless steel, wrought iron, manganese steel and non-ferrous metals etc.)

Applications: Metallic arc cutting and gouging are used:

– to remove weld defects
– to make the groove on the root penetration for depositing sealing run
– to cut the scarp
– to remove rivets
– to pierce holes
– to remove casting defects and make grooves.

Cast Iron its - Properties-types

Objectives: At the end of this lesson you shall be able to
- **explain the methods of edge preparation.**
- **describe the cast iron welding technique.**
- **select of iller rods for the Jobs to be welded.**

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.

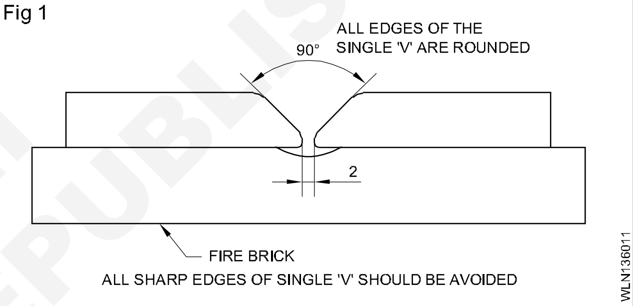
Nodular cast iron: It is also known as spheroidal graphite iron (SG iron). It is obtained by adding magnesium to the molten grey cast iron. The tensile strength and elongation of nodular iron is similar to that of steels which makes this iron a ductile material.

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 to free graphite formit gives a grey colour to the fractured structure.

Welding methods of cast iron.

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).

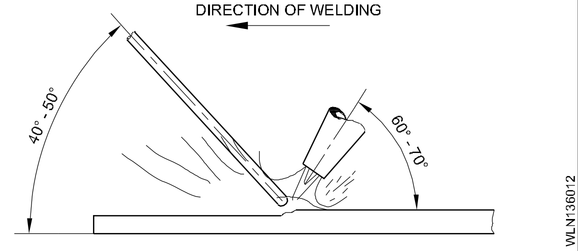
Flux: The flux should be of good quality to dissolve the oxides and prevent oxidation.

Cast iron flux is composed of borax, sodium carbonate, potassium carbonate, sodium nitrate and sodium bicarbonate. This is in a powder form.

Welding the technique of cast iron welding: The welding operations should be performed on the preheated, dull red hot, cast iron piece. The preheating temperature for C.I welding varies from 200°C to 310°C.

The blowpipe angle should be 60° to 70° and the filler rod angle 40° to 50° to the line of weld. (Fig 2)

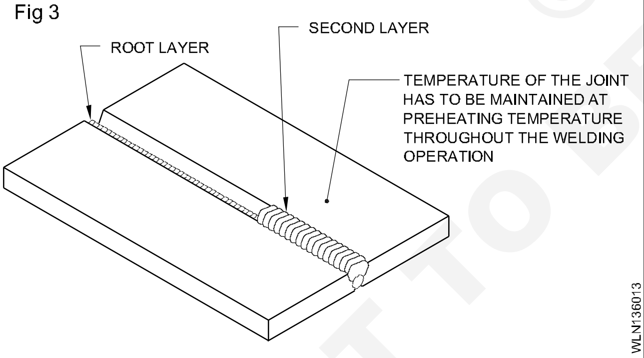
Fig 2



Using the leftward or forehead technique, the first layer should be complete by giving a slight weaving motion to the blowpipe but not to the filler rod. The hot rod end should be dipped into the powdered flux at intervals.

After the completion of the first layer, play the flame on the job so as to heat evenly and then deposit the second layer with a slight reinforcement of weld metal from the surface of the job. (Fig 3)

Fig 3



The technique of welding the second layer is the same as that for the first layer.

After completion of the second layer, play the flame again on the whole job for getting an even heat. This is called 'post heating'.

Then allow the job to cool slowly by covering with a heap of lime or ash or dry sand.

Selection of filler rod

Filler rod should be selected according to the:

– kind or type of metal to be welded, i.e. ferrous, non-ferrous, hard facing (Table 1).

thickness of metal to be welded (including joint edge preparation) (Table 2)

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

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

Table 1

Metals	Filler rods
Mild steel and wrought iron	Copper coated mild steel (C.C.M.S)
High carbon and alloy steel	High Carbon steel Silicon-manganese steel Wear-resisting alloy steel 3.5% Nickel steel
Stainless steel	Columbium stainless steel
Cast iron	Super silicon cast iron Ferro silicon cast iron Nicotectic cast iron
Copper and its alloys (brass, bronze)	Copper-silver alloy Silicon-brass, silicon-bronze Nickel bronze Manganese bronze
Aluminium and its alloys	Pure aluminium 5% Silicon aluminium alloy 10-13% Silicon aluminium alloy

Table 2

Thick-ness mm	Edge preparation mm	Root gap	Dia. of filler rod mm
0.8	Square	-	1.6
1.6	Square	2.4	1.6
2.4	Square	3.2	1.6
3.2	80° Vee	3.2	2.4
4.0	80° Vee	3.2	3.2
5.0	80° Vee	3.2	4.0

More the thickness of the metal welded, more the diameter of the filler rod used. Less the number of weld runs deposited, less the distortion and faster the welding.

Outline of the Subjects to be Covered

Objectives: At the end of this lesson you shall be able to
- **brief the outline of the subjects pertaining to this trade.**

During the One-year duration of "Welder (Pipe)" trade, a candidate is trained on Professional Skill, Professional Knowledge, Engineering Drawing, Workshop Calculation & Science and Employability Skill related to job role. In addition to this, a candidate is entrusted to undertake project work, extracurricular activities and on-the-job training to build up confidence. The duration, trainee learns about elementary first aid, firefighting, environment regulation and housekeeping etc. The practical part starts with basic pipe work viz. cutting of pipes, threading, joining, etc. Cutting Pipes in different angles, joining of pipes of different diameter and angles by gas welding, thread cutting on different types of pipes & fittings accessories. On completion of each job the trainees will also evaluate their jobs by visual inspection, and identify the defects for further correction/improvement. They learn to adapt precautionary measures such as preheating; maintaining inter-pass temperature and post weld heat treatment for Welding Alloy steel, Cast Iron etc. The Work Shop calculation taught will help them to plan and cut the required jobs economically without wasting the material and also used in estimating the Electrodes, filler metals etc. The Workshop Science taught will help them to understand the materials and properties, effect of alloying elements etc. Engineering Drawing taught will be applied while reading the job drawings and will be useful in understanding the location, type and size of weld to be carried out.

Professional Knowledge subject is simultaneously taught in the same fashion to apply cognitive knowledge while executing task. In addition, components like Physical properties of engineering materials, different types of iron, properties and uses, introduction to GTAW & GMAW, Heat & Temperature are also covered under theory part. In addition to above components the core skills components viz., Workshop calculation & science, engineering drawing, employability skills are also covered. These core skills are essential skills which are necessary to perform the job in any given situation.

Importance of Pressure Vessels and Pipe Welding

Objectives: At the end of this lesson you shall be able to
- **importance of Pressure vessels**
- **importance of Pipe Welding.**

Pressure Vessels

Introduction

A pressure vessel is considered as any closed vessel that is capable of storing a pressurized fluid, either internal or external pressure, regardless of their shape and dimension.

Importance

Welding on pressure vessels must be extremely high quality to withstand working conditions.

Pressure vessels are used to store and transfer liquids and gases under high pressure. Welding on pressure vessels must be extremely high quality to withstand working conditions.

Application

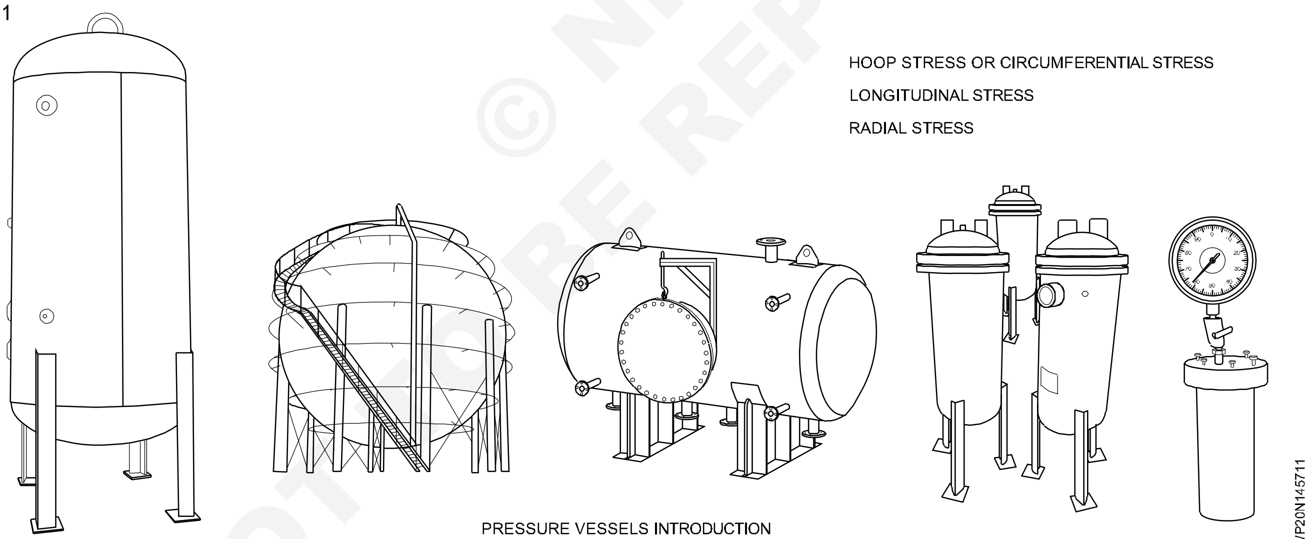
Vessels are used in various industries such as chemical, military and defense, petrochemical, as well as energy, oil, and gas for storage of toxic and non-toxic gases, chemicals, and liquids, among others.

Pipe Welding

Pipe welding is a method for joining two pipes together. Welding techniques used for pipes include are welding processes including MIG welding and TIG welding. Some make a distinction between pipe welding and pipeline welding, with pipe welding relating to metal pipes at plants and refineries and pipeline welding referring to choose used to transport gas, water, oil and other liquids over many miles.

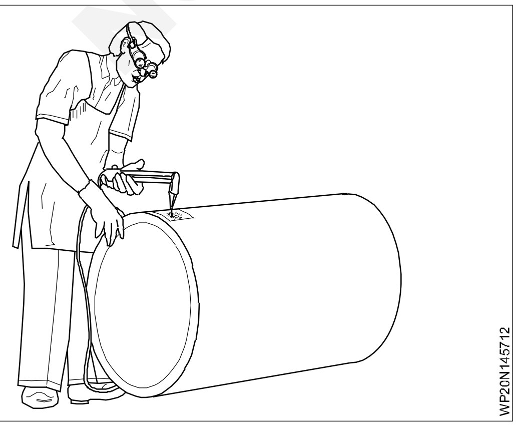
Pipe and pipeline welders undertake welding jobs in the construction industry, at oil and gas fields, in the water industries, fabrication shops and nuclear power stations, among others.

Fig 1



PRESSURE VESSELS INTRODUCTION

Fig 2



Gas cutting & Plasma Cutting

Objectives: At the end of this lesson you shall be able to
- **explain different types of gas cutting machines**
- **explain profile cutting using templates**
- **state gas cutting defects, their causes and remedies.**

There are two types of cutting machines.

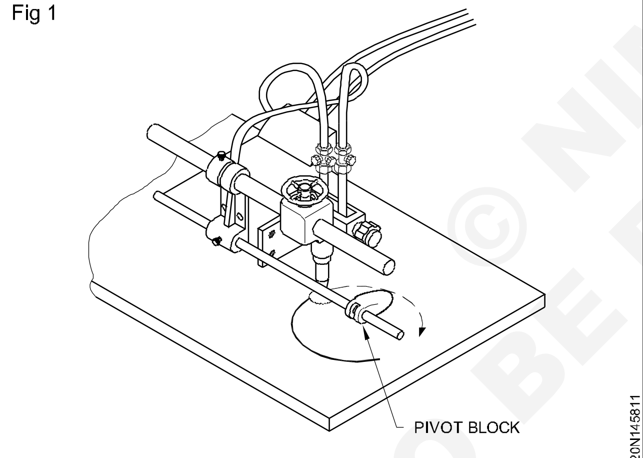
- Manually driven cutting machines
- Electrically driven cutting machines

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 1)

Fig 1



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

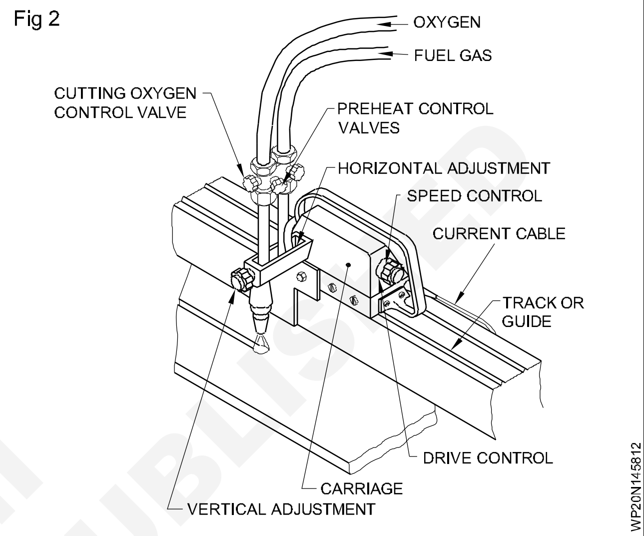
PORTABLE MACHINES

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 2)

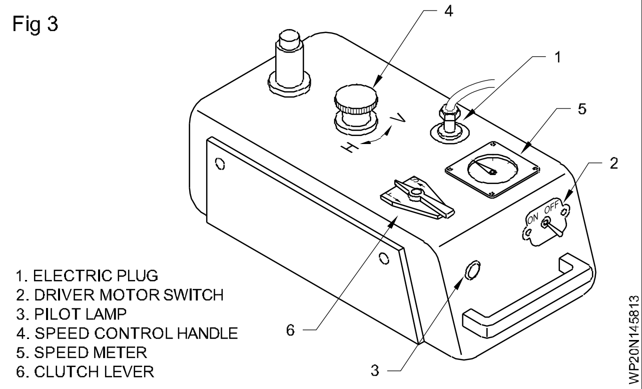
Fig 2



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

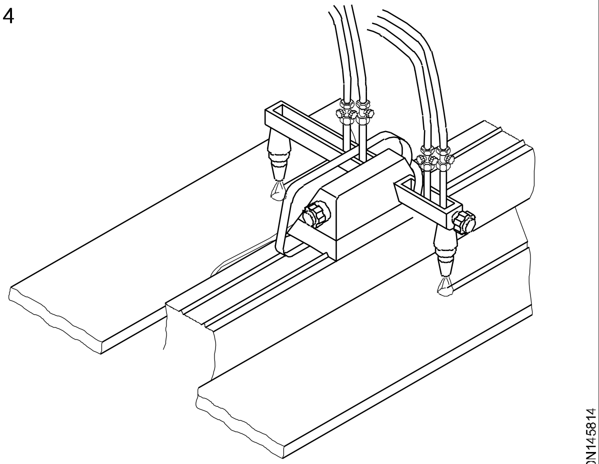
The electrical control unit fitted to the carriage is shown in Fig 3.

Fig 3



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 4)

Fig 4



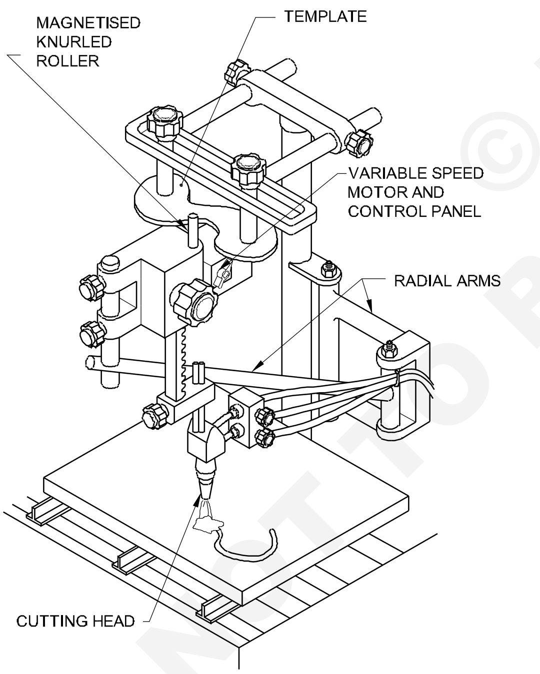
PORTABLE MACHINE WITH MULTIPLE CUTTING HEADS

STATIC MACHINES

These machines are generally used to produce more accurate work than what is possible with manually operated or portable cutters.

These machines can be used with radial arm and cross carriage arrangements. In general the work is required to be brought to the machine. With this machine straight line cutting, circle and profile cutting can be done. (Fig 5)

Fig 5

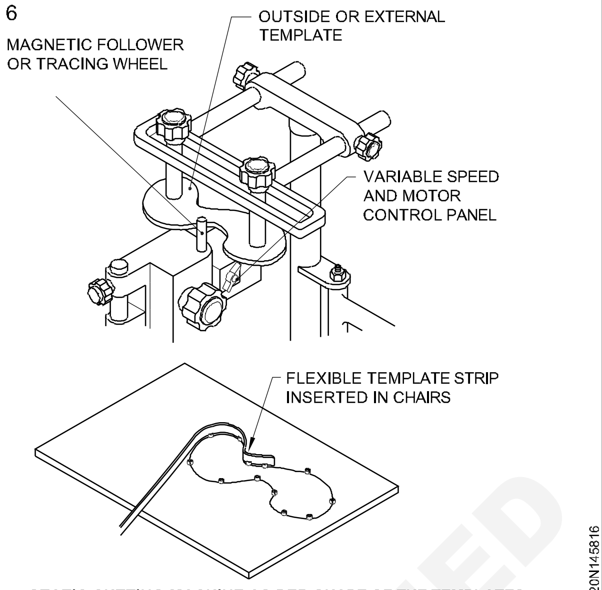


STATIC MACHINE WITH RADIAL ARM CUTTING MACHANISM

Profile cutting by using templates

Profile cutting can be done by static cutting machines as per the shape of the templates. (Fig 6) The templates are mainly used for reproducing the same shapes into a no. of pieces. The templates are made from wood, hardboard, aluminium or steel.

Fig 6



STATIC CUTTING MACHINE AS PER SHAPE OF THE TEMPLATES

Two types of templates are in use depending on their size.

- Outside template
- Inside template

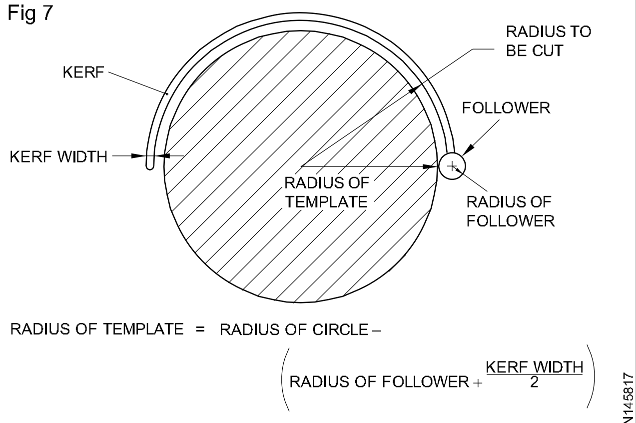
Outside template

The outline of the template will be the shape to be cut, reduced in size by the radius of the follower wheel or roller which is (Knurled) attached with the motor af the machine.

The size of the template is excluding the radius of the tracing wheel (knurled wheel) - half of the kerf width. (Fig 7)

Example

Fig 7



EXTERNAL TEMPLATE

To cut a circle using an extermal template

Radius of circle		100 mm
Radius tracing wheel	6.5 mm (a)	
Half the kerf width		0.8 mm (b)
Difference [(a) - (b)]		5.7 mm
So pre-radius of external template		100-5.7 mm
	=	94.3 mm

Gas cutting - Plasma arc cutting

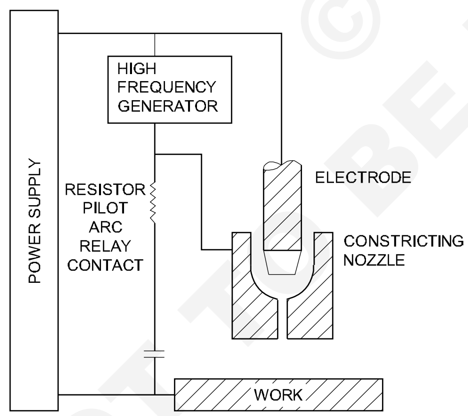
Cutting processes - plasma arc cutting

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 1).

Fig 8



BASIC PLASMA ARC CUTTING CIRCUITRY

Plasma cutting system (Fig 2,3,4)

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 is shown in Fig 1. It employs direct current straight polarity (DCEN). The nozzle surrounding the electrode is connected to the workpiece (positive) through a current limiting reisitor and a pilot arc relay contact.

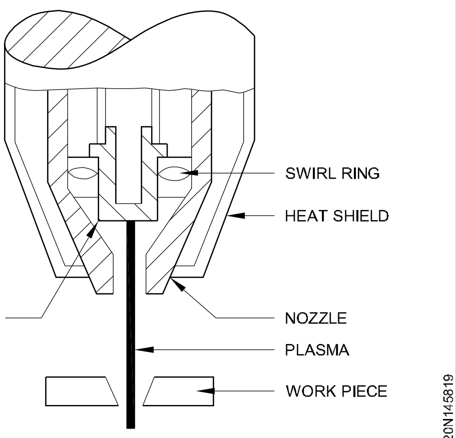
The pilot arc between the electrode and nozzle is initiated by a high frequency generator connected between the electrode and nozzle. The orifice gas ionized by the pilot arc is blown through the constricting nozzle orifice and forms a low resistance path to ignite the main transferred arc between the 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.

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.

If the high-frequency circuit is weak:

1 **Check tightness of all leads in the external welding circuit.**
2 **Increase high-frequency rheostat to maximum.**
3 **Maximum recommended welding cable length is exceeded. Have the machine as close to work as possible.**

Fig 9



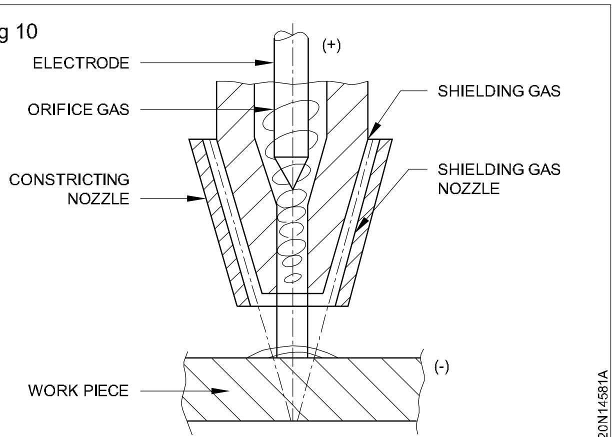
COMPONENTS OF AN AIR-PAC TORCH

4 **Welding cables should lie in a straight line from the machine to the work for maximum high frequency. Avoid having work and electrode cables touch each other and avoid having them in contact with metallic objects or lying on metal.**
5 **Check spark gaps adjust if required.**
6 **Make certain that the shielding gas is flowing.**
7 **If the checks above are of no help, run checks listed under "If the high-frequency current does not start".**

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.

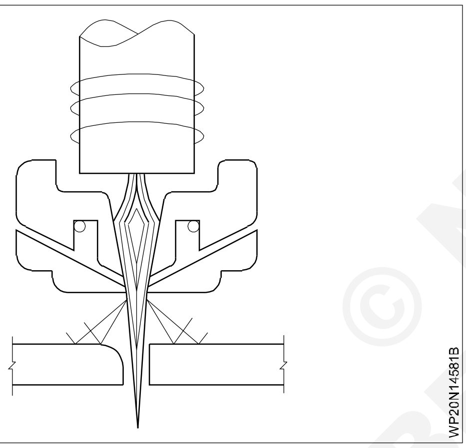
Process variables (Fig 5 & 6)

Fig 10



DUAL FLOW PLASMA ARC CUTTING

Fig 11



i Torch design - constricting nozzle shape and size.

ii Process variation - dual gas flow, water injection, air plasma.

iii Cutting gas type and its flow rate.

iv Distance between nozzle and job.

v Cutting speed.

vi Plasma cutting current.

vii Power used during cutting.

viii Manual/machine cutting.

ix Material to be cut and its thickness.

x Quality of cut required - rough or smooth.

xi The bevel angle and round off corner etc.

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).

Application of plasma cutting

i Straight and sharp cutting of all metals and non-metals.

ii Cutting of risers and gates for forging and casting.

iii Stack cutting of several sheets of 1.5 to 6 mm thickness.

iv For making holes in thick sheets (by piercing operation).

v For gouging, rough machining etc.

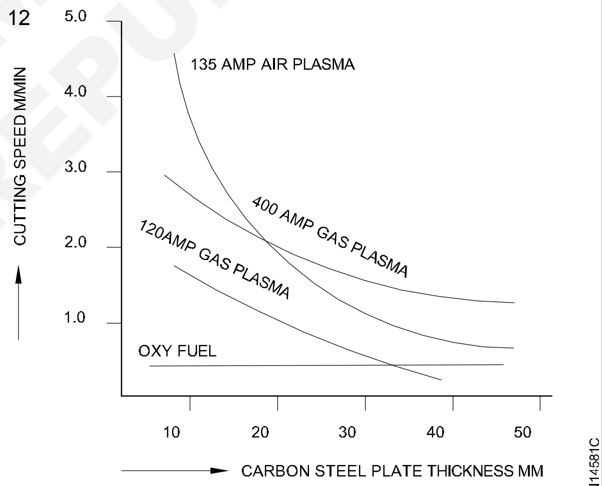
vi For sizing the scarp.

Safety precautions in plasma cutting

The operator and persons in the vicinity of plasma cutting operation must be protected from:

i arc radiation and spatter - protect body and eyes

Fig 12



COMPARISON OF OXY FUEL AND PLASMA CUTTING PROCESSES

ii metal fumes and gases - use breathing mask, proper ventilation

iii noise - up to 115 dB - use ear plugs

iv electrical shocks - high operating voltage (180-400V) and both anode and cathode in torch; input supply is to be switched off before attending to the torch etc.

Gases for Plasma cutting

- no need to promote oxidation & no preheat
- works by melting and blowing and/or vaporisation
- "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

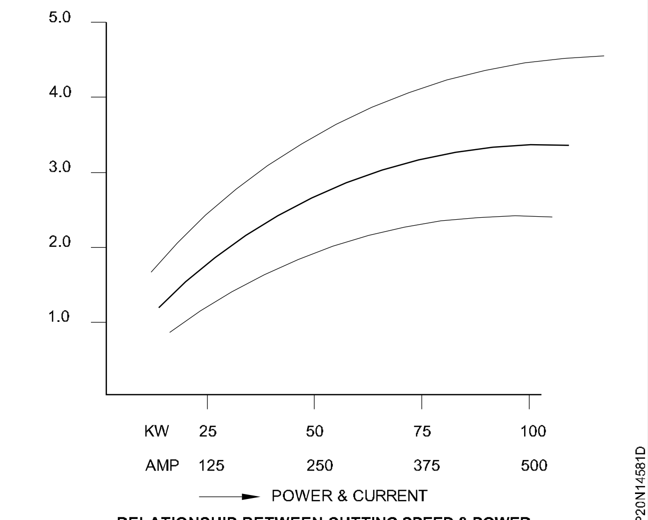


Fig 13 RELATIONSHIP BETWEEN CUTTING SPEED & POWER

- shielding gas - optional
- applications : stainless steels, aluminium and thin sheet carbon steel. (Fig 7)

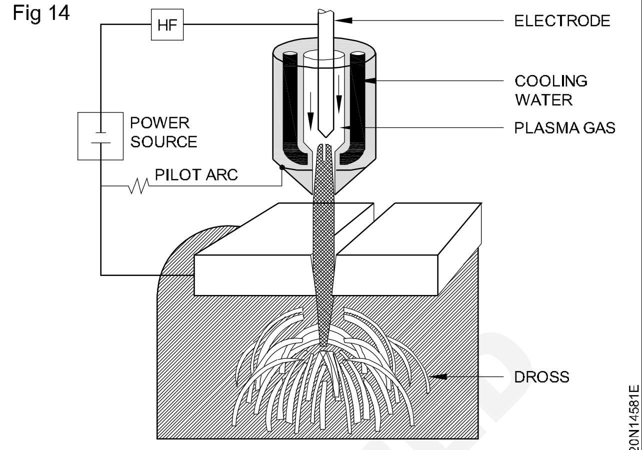


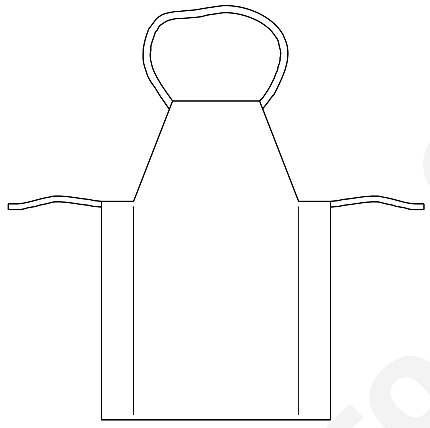
Fig 14 GASES FOR PLASMA CUTTING

Safety in Shielded Metal Arc Welding

Objectives: At the end of this lesson you shall be able to
- **identify the safety apparels and accessories used in arc welding**
- **select the safety apparels and accessories to protect from burns and injuries**
- **learn how to protect yourself and others from the effect of harmful arc rays and toxic fumes**
- **select the shielding glass for eye and face protection.**

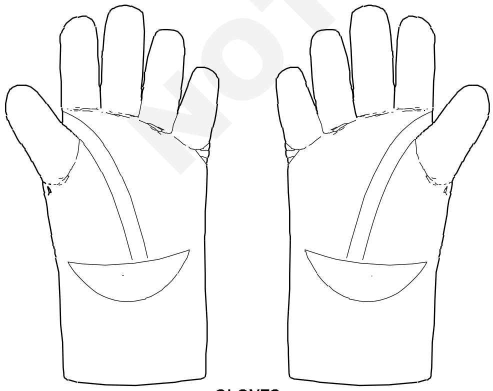
1 Safety apparels
   a Leather apron
   b Leather gloves
   c Leather cape with sleeves
   d Industrial safety shoes
2 a Hand screen
   b Adjustable helmet
   c Portable fire proof canvas screens
3 Chipping/grinding goggles
4 Respirator and exhaust ducting

Fig 1



APRON

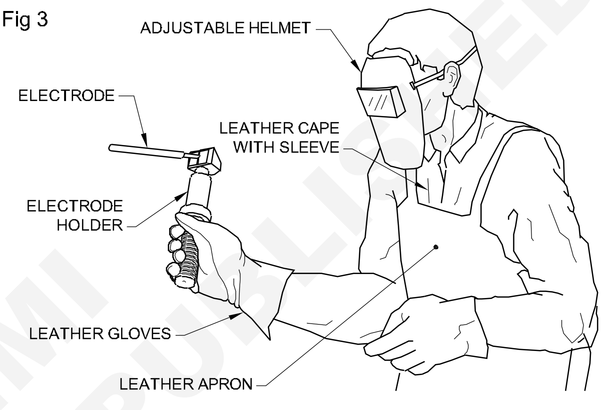
Fig 2



GLOVES

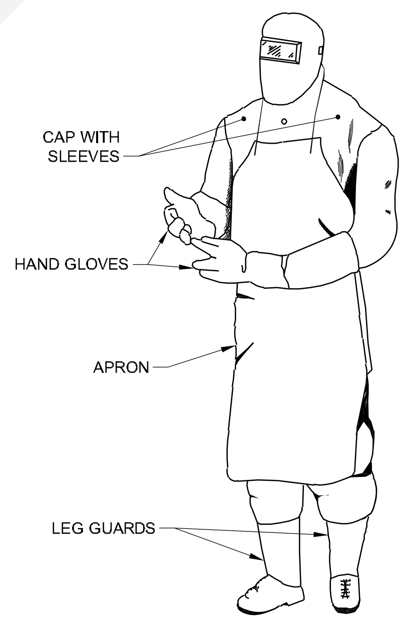
The leather apron, gloves, cape with sleeves and leg guard Fig 3,4,5 and 6 are used to protect the body, hands, arms, neck and chest of the welder from the heat radiation and hot spatters, from the arc and also from the hot slag particles flying from the weld joint during chipping off the solidified slag.

Fig 3



CAPE WITH SLEEVES

Fig 4



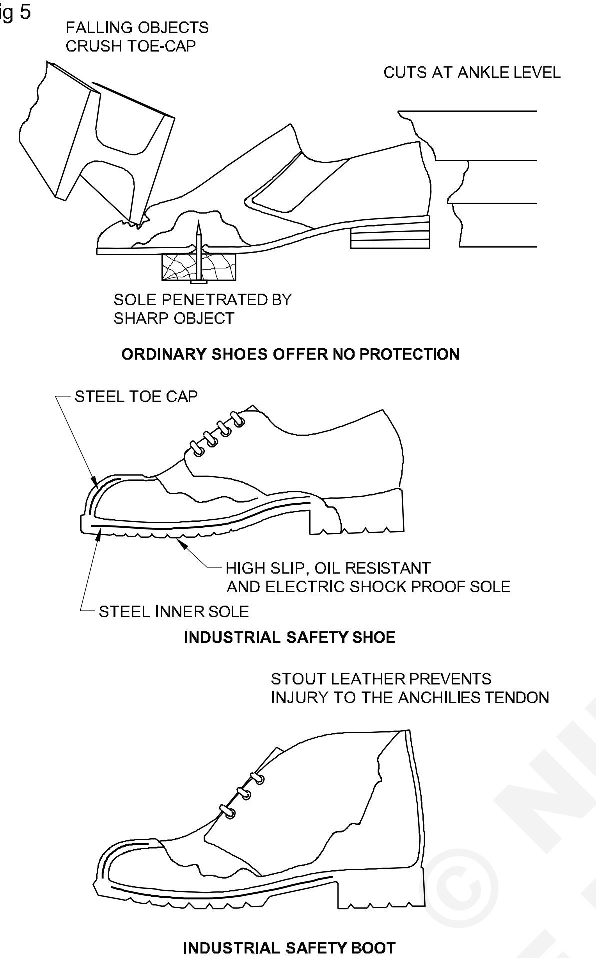
LEG GUARDS

All the above safety apparels should not be loose while wearing them and suitable size has to be selected by the welder.

The industrial safety boot (Fig 5) is used to avoid slipping injury to the toes and ankle to the foot. It also protects the welder from the electric shock as the sole of the shoe is specially made of shock resistant material.

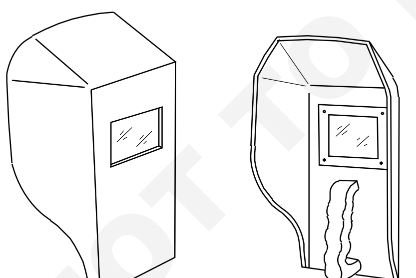
Welding hand screens and helmet: These are used to protect the eyes and face of a welder from arc radiation and sparks during arc welding.

Fig 5



A hand screen is designed to hold in hand. (Fig 6)

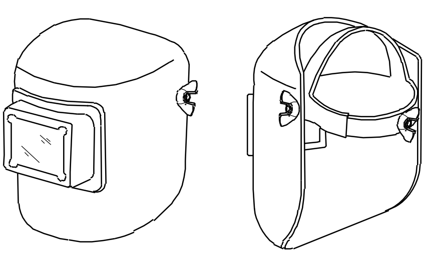
Fig 6



HAND SCREEN

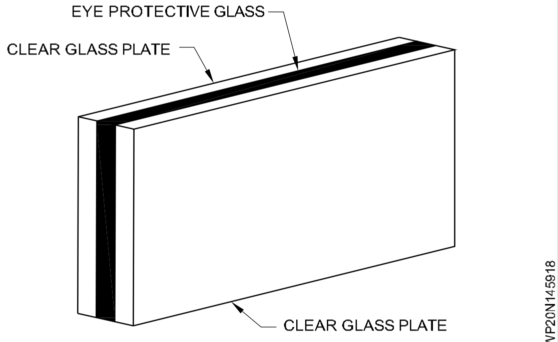
A helmet screen is designed to wear on the head. (Fig 7)

Fig 7



WELDING HELMET

Fig 8



Clear glasses are fitted on each side of the coloured glass to protect it from weld spatters. (Fig 8)

The helmet screen provides better protection and allows the welder to use his both hands freely.

Coloured (filter) glasses are made in various shades depending on the welding current ranges. (Table1)

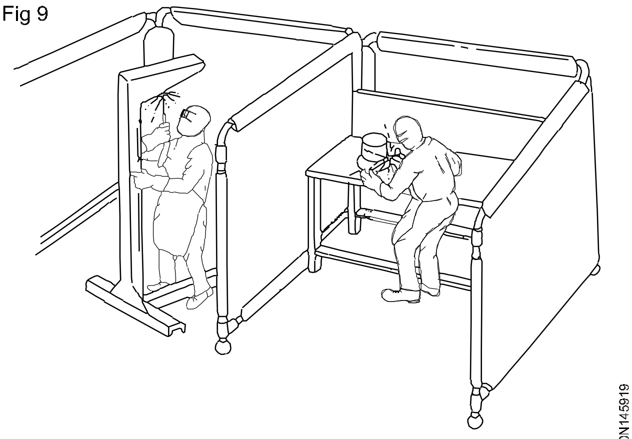
Table 1

Recommendations of filter glasses for manual metal arc welding

Shade No. of coloured glass	Range of welding current in amperes
8-9	Up to 100
10-11	100 to 300
12-14	Above 300

Portable fire proof canvas screens Fig. 9 are used to protect the persons who work near the welding area from arc flashes.

Fig 9



PORTABLE FIREPROOF CANVAS SCREENING

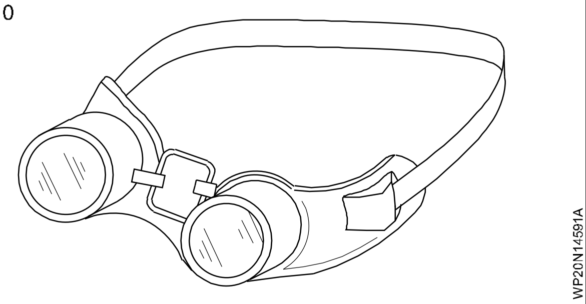
Plain goggles are used to protect the eyes while chipping the slag or grinding the job. Fig, 10

It is made of bakelite frame fitted with clear glasses and an elastic band to hold it securely on the operator's head.

It is designed for comfortable fit, proper ventilation and full protection from all sides.

Sometimes toxic fumes and heavy smoke may be liberated (given out) from the weld while welding non-ferrous alloys like brass etc. Use a respirator and use exhaust ducts

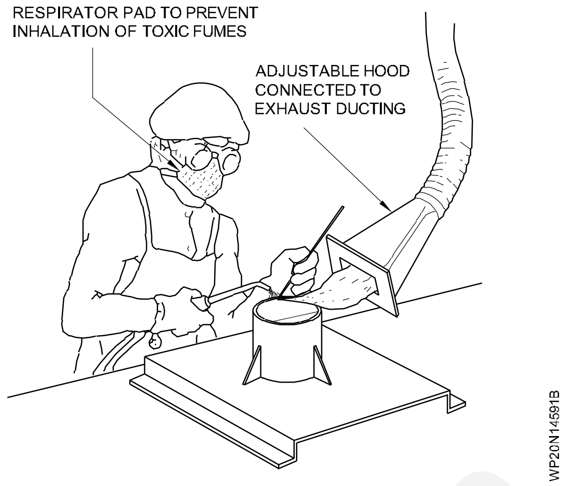
Fig 10



and fans near the weld area to avoid inhaling the toxic fumes and smoke Fig 11.

Inhaling toxic fumes will make the welder become unconscious and fall on the hot welded job/on the floor. This causes burns or injury.

Fig 11



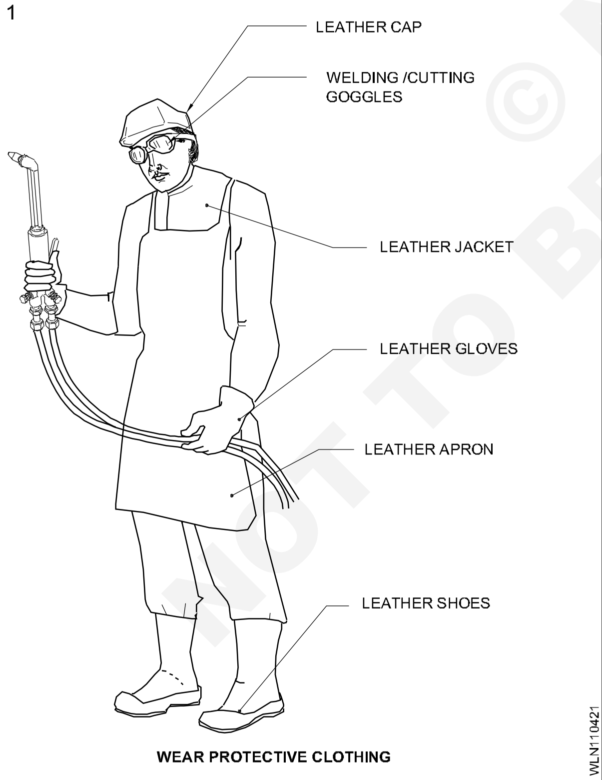
Safety in Gas cutting process

Objectives: At the end of this lesson you shall be able to
- **describe the safety precautions to be followed by handling gas cutting equipment**
- **explain the safety precautions to be followed by the operator**
- **state the safety required during gas cutting operation.**

Equipment safety: Safety precautions for gas cutting equipment are the same as those adopted in the case of gas welding equipment.

safety for the operator (Fig 1)

Fig 1



WEAR PROTECTIVE CLOTHING

Always use safety apparel

Goggles, gloves and other protective clothing must be warn.

Safety during operation: Keep the work area free from flammable materials.

Ensure that the combustible material is at least 3 meters away from the cutting operation area.

In case the flammable material is difficult to remove, suitable fire resisting guards/partitions must be provided.

- protection of your eyes
- protection from burns
- protection of clothing
- protection of inhaling burnt gases.

protect yourself and others from the flying sparks.

Ensure that the metal being cut is properly supported and balanced so that it will not fall on the feet of the operator or on the hoses.

Keep the space clear underneath the cutting job so as to allow the slag to run freely, and the cutting parts to fall safely.

Be careful about flying hot metal and sparks while starting a cut. Containers which hold combustible substance should not be taken directly for cutting or welding. (Fig 2) Wash the containers with carbon tetrachloride and caustic soda before welding or cutting and fill them with water before repairing. (Fig 3)

CG & M **Related Theory for Exercise 1.5.60**
Welder (Pipe) - SMAW

Principle of Shielded Metal are Welding (SMAW).

Objectives: At the end of this lesson you shall be able to
- **explain the types of fixture.**
- **explain the purpose of f ixture 2 clamps.**

Refer Lesson 1.2.14

CG & M **Related Theory for Exercise 1.5.61**
Welder (Pipe) - SMAW

Types of Power Source.

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

Refer Lesson 1.2.18

CG & M **Related Theory for Exercise 1.5.62**
Welder (Pipe) - SMAW

Polarity Type and Arc Length

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

Refer Lesson 1.2.23

CG & M **Related Theory for Exercise 1.5.63**
Welder (Pipe) - SMAW

Welding Position and Importance

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

Refer Lesson 1.2.20

Edge Preparation andTack Weld Procedure

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

Refer Lesson 1.2.10

CG & M Related Theory for Exercise 1.5.65
Welder (Pipe) - SMAW

Welding Fixtures and Clamps

Objectives: At the end of this lesson you shall be able to
- **explain the types of fixture.**
- **explain the purpose of fixture 2 clamps.**

Welding Fixtures

Welding fixtures are carefully designed to hold and support the various components welded in proper locations and prevent distortions in welded structures. For this, the locating element needs to be careful clamping has to be light but firm, and the placement of clamping elements has to be clear of the welding area. The fixture must be pretty stable and rigid to withstand the welding stresses.

Welding engineering demands quality that is consistently high coupled with maximum productivity and so the design of high tech welding fixtures has improved dramatically over the past 25 years. Of course, the type of welding fixtures used will depend on what is being manufactured. So, for instance, if tanks are being constructed, the fixtures will need to have the ability to rotate components during the welding process.

Gas Welding Fixtures

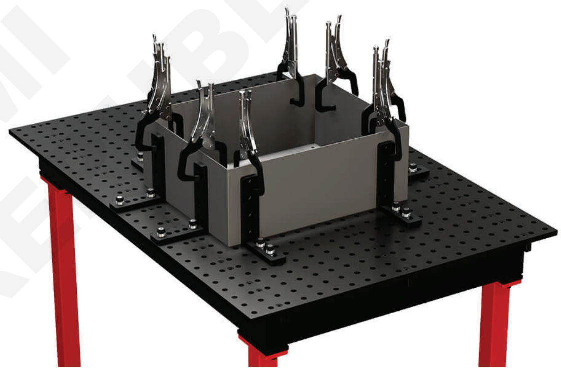
Welding is done by burning fuel in the presence of oxygen which produces extremely high temperatures that melt the parts and join them during welding. In the case of gas welding, the heat loss should be minimum to avoid weld cracks. Hence fixtures should be designed in such a way that large fixture masses are located away from the weld line while providing enough support to the workpieces.

Special care is required while welding copper and aluminium due to excessive heat loss from the materials. To address this difficulty, tack welding has to be done on the points away from the fixture contact points and the rest of the welding is done out of fixtures. C-clamps and hold down plates are additionally used to support the workpiece and prevent weld distortions.(Fig 1)

Arc Welding Fixtures

The workpiece can react chemically with oxygen and nitrogen gases from the air at higher temperatures produced

Fig 1



by the arc while welding. To prevent the part from reacting with air, a protective shielding gas is used around the welding area to minimise the exposure of the workpiece to the surroundings.The temperatures produced in arc welding are much higher than those in gas welding. Therefore the fixture, in this case, should provide good support, proper alignment to the workpiece and also allow heat dissipation from the weld area. They should provide enough force to align the workpiece firmly. This force is applied at suitable points by clamps supported by backing bars. These backing bars not only provide robust support to the molten metal but also shield them distortion.Resistance Welding Fixtures The fixtures must be free of debris and flash for safe operation. There are various reasons for heating up of the fixture like inductance, insulation, weld flash and location. Even magnetic tooling causes similar issues. The tool absorbs energy and heats up during welding which forces the welder to work harder for spot welding. To avoid this, fixtures, base plates and other components are made from non- magnetic materials.Insulate fixture to prevent current flowing through it and heating up due to resistance heating. From bolts to mating surfaces, insulate all the components of““the fixture.

Laser Welding Fixtures

Laser welding is known for its versatility and quickness in producing narrow, deep welds with a minimum distortion and heat input. It has gained much popularity among the parts that require little to no-post weld processing. Also, laser welding with a proper fixture eases the tool work, results in a precise product in less time a fixture is the one that makes work easier for tools, reduces lead time, improves productivity and quality of the welded parts without any distortion. A different fixture is designed for different welding operations.

Welding clamps are metal sheet or leg holders that temporarily hold two pieces of materials together tightly. This makes it easier for welders to run the arc and weld the pieces together without worrying about movements in the sheets. The clamps enable you to weld pieces together in a tight alignment.

- construction
- 4 inch opening
- 3.25 inch throat depth.

Strong Hand PR115 Locking C-Clamps

- Round Tip
- Nickel and chrome heat treated steel construction
- 4 inch opening
- 3.25 inch throat depth

Locking Pliers

C-Clamps, Cantilever Clamps

Sliding Arm Clamps

Fig 2

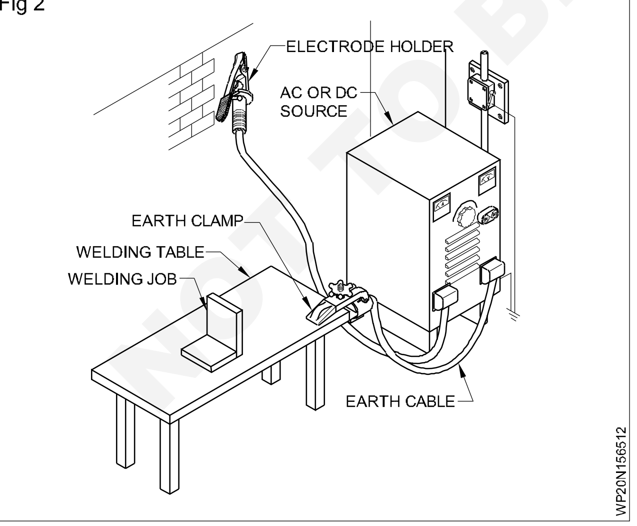


Fig 3

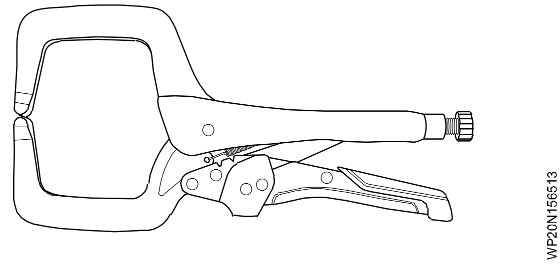
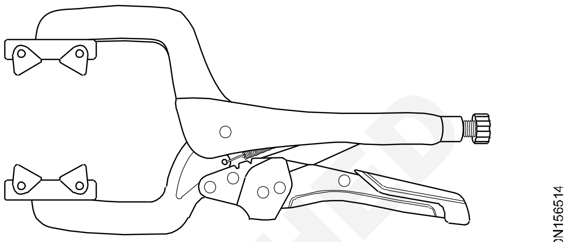
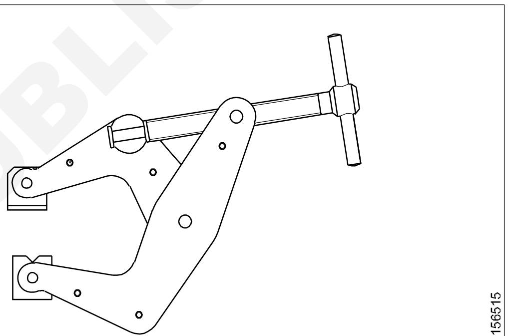


Fig 4



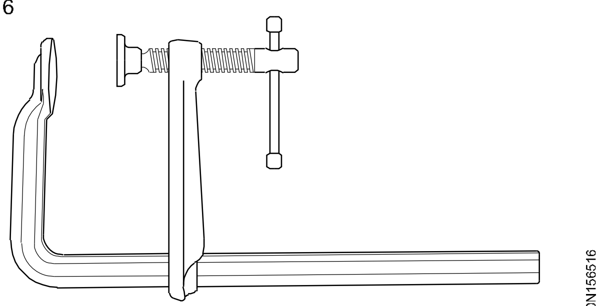
LOCKING PLIER

Fig 5



CANTILEVER CLAMP

Fig 6



SLIDING ARM CLAMP

CG & M | Related Theory for Exercise 1.5.66
Welder (Pipe) - SMAW

Electrodes - Types - Description

Objectives: At the end of this lesson you shall be able to
- **explain arc welding electrode**
- **state the types of electrodes**
- **explain the coating factor**
- **describe the characteristics of flux coating on electrode**
- **explain the functions of flux coating during welding.**

Refer Lesson 1.3.43

CG & M | Related Theory for Exercise 1.5.67
Welder (Pipe) - SMAW

Functions of Flux and Characteristic of Flux

Objectives: At the end of this lesson you shall be able to
- **explain arc welding electrode**
- **state the types of electrodes**
- **explain the coating factor**
- **describe the characteristics of flux coating on electrode**
- **explain the functions of flux coating during welding.**

Refer Lesson 1.3.43

CG & M | Related Theory for Exercise 1.5.68
Welder (Pipe) - SMAW

Selection of Electrode

Objectives: At the end of this lesson you shall be able to
- **explain arc welding electrode**
- **state the types of electrodes**
- **explain the coating factor**
- **describe the characteristics of flux coating on electrode**
- **explain the functions of flux coating during welding.**

Refer Lesson 1.3.43

CG & M | Related Theory for Exercise 1.5.69
Welder (Pipe) - SMAW

Electrode Storage and Backing Temperature

Objectives: At the end of this lesson you shall be able to
- **explain about special purpose electrodes and their application**
- **state the necessity of baking a coated electrode**
- **store and handle the electrode properly for better weld quality.**

Refer Lesson 1.3.44 & 45

Types of Metals and their Characteristics

Objectives: At the end of this lesson you shall be able to
- **state the different kinds of metals**
- **explain the characteristics of the metals.**

Name of Metal	Characteristics	Positives	Negatives	Common Uses
STEEL	Most common metal used, made mostly form iron, very strong, does not bend easily, does not bend easily, dark gray color	Mass-produced because it can be made cheaply, very strong	Oxidized with exposure to water (Rusts if left unprotected)	Skyscrapers, bulldozers, hammers, trains, railroads, stadiums
STAINLESS STEEL	Same as steel, but chromium is added to make it corrosion resistant (wont' rust), silver color	Will not rust, very strong, clean surface does not hold germs	Expensive to make	Post & pans, forks & knives, surgical instruments, dental instruments (plus the St. Louis Arch!)
ALUMINUM	Soft, bendable, lightweight, strong, non-corroding, lignt silver color	Cheap to make, will not rust, lightweight, easily recyclable	Solt, melts at low temperature	Aluminum foil, baseball bats, airplanes, street light poles, gutters
COPPER	Very soft, bendable, very high electrical and heat conductivity, reddish-brown color, oxidzes with exposure to air (making it green!)	Best material to conduct heat or electricity	Soft, very expensive, oxidizes in air	Electrical wires, plumbing lines (plus the outside of the Statue of Liberty!)
STONZE	Mixture of copper and aluminum (and tin), slightly bendable, gold/yellow color	Very low metal-to metal friction	Expensive to make, slightly soft	Sculptures, bells, Olympic medals, cymbals
TITANIUM	Very strong, hard, non magnetic, doesn't corrode, dark silver in color, poor conductor of heat and electricity	Will not rust, the highest strength-to weight ratio of any metal	Very expensive to make, unstable	Jet engines, missiles, implants, prostheses, aircraft carriers, submarines
ALLOYS (many types)	Combination of the above metals that take the best characteristics of each metal to make an even stronger metal	Super strong or strong and won't rust or strong and conducts heat	Make for a particular use, which might make it expensive	Space shuttle, rockets, tanks
PLASTIC (not metal)	Blended polymers, ranges from soft to hard, generally doesn't conduct heat; includes nylon, rubber, plastic, Teflon, etc.	Easily moldable into various shapes, cheap to make, easily recyclable, won't rust, lasts forever	Not as strong as metal	Toys, bottles, food packagind tires, gutters

Introduction to Pipe Welding

Objectives: At the end of this lesson you shall be able to
- **preparation of pipe welding proven**
- **position of pipe welding**
- **Advantages of pipe welding**

Pipe welding is a method for joining two pipes together. Welding techniques used for pipes include arc welding processes including MIG welding and TIG welding. Some make a distinction between pipe welding and pipeline welding, with pipe welding relating to metal pipes at plants and refineries and pipeline welding referring to those used to transport gas, water, oil and other liquids over many miles.

Pipe Welding Steps

As with all welding work, there are a number of steps that should be followed, starting with process selection, which involves the consideration of factors such as

- Pipe material
- Pipe diameter and wall thickness
- Welding location
- Weldment properties
- Welding direction (Uphill or downhill)
- Required welding quality
- Economic considerations
- Health and safety

With the process and equipment selection complete, it is time to begin the actual welding, typically with the following steps

1 Joint Preparation

Joint preparation should follow the appropriate guidelines as set out by the relevant standard

2 Pipe End Cleaning

Remove an undesirable moisture or coatings including, oil, paint, rust or varnish. This will prevent defects and costly repair or re- welding.

3 Welding

Having selected the correct materials (including electrodes) and parameters (preheat requirements, etc), according to the required specifications, the welding can begin with the root passes. Hot passes follow this before the welding fill and final cap passes.

4 Repairs

Ideally, you will be able to skip this step, but it is worth checking the weld and making any defect repairs.

Pipe Welding Passes

Pipe welds require several different weld passes

- **Root Passes**

  These first passes should fill the gap between the two sections of piping.

- **Hot Passes**

  These join the root weld to both groove faces.

- **Fill Passes**

  These passes fill out most of the groove before the final cap passes are made.

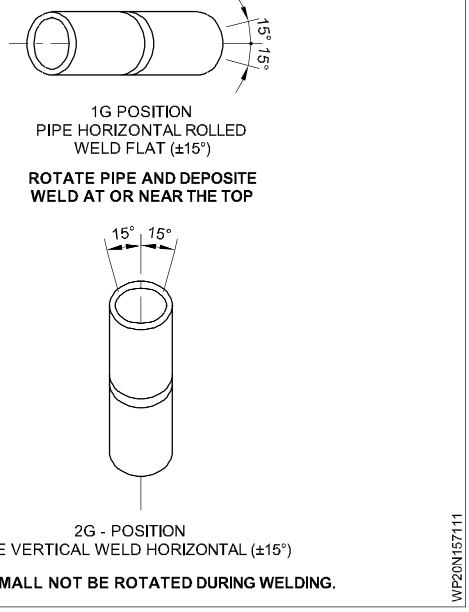
- **Cap Passes**

  These final passes should complete the weld with as little build up beyond the surface of the pipe as possible. You can grind this layer back if required to improve the weld beading and remove contamination before a final, finishing cap pass.

Pipe Welding Positions

There are four types of pipe welding position 1G, 2G, 5G and 6G. Each position details whether the pipe is stationary or rotating and whether the pipe is placed horizontally, vertically, or inclined at an angle.

Fig 1



- **1G Welding**

  This position places the pipe horizontally. The pipe can be rotated along the horizontal (X) axis, with the welder remaining stationary. The weld is completed on the top of the pipe and is the most basic of the pipe welding positions.

- **2G Welding**

  This position places the pipe upright in a vertical position. The pipe can be rotated along the vertical (Y) axis, with the welder remaining stationary. The welding is performed horizontally on the side of the pipe.

- **5G Welding**

  The 5G position places the pipe horizontally but, unlike with the 1G position, the pipe cannot be rotated. Instead, the welder must move around the stationary pipe in a vertical direction to create the weld.

- **6G Welding**

  This position inclines the pipe at a 45° angle to create a sloping surface. The pipe is fixed, as with 5G, and the welder must move around the pipe. This is the most advanced of the four positions and requires a greater level of expertise from the pipe welder.

Welders will learn each type of position in turn, with 1G being the easiest to master and 6G the most difficult. A welder will need to gain certification in each position in turn, so someone qualified in 1G positions cannot weld 2G, 5G or 6G, but if you are qualified in 6G you can weld in any of the other positions. These standards preserve the safety of the work environment when performing pipe welds.

Advantages

Welding pipes has a number of advantages over other joining techniques, such as screwed fittings. These advantages include

1 **Fewer Fittings**

Welding eliminates the need for fittings to join straight sections of pipe. A screwed pipe requires a fitting between every joint while welding can quickly join pipes following end preparation of the parts to be joined.

2 **Lower Costs**

Welded pipe can use thinner wall pipe than with screwed connections, leading to significant cost savings for long runs and larger jobs. Screwing pipes together can also require higher labour costs along with the higher costs of the threaded fittings themselves.

3 **Improved Flow**

Screwed fittings create turbulence and fluid resistance in the flow through the pipe. Welded solutions can create smooth and streamlined surfaces to allow for improved flow.

4 **Ease of Repair**

Welded systems are generally easier to repair than screwed systems. Where a welded pipe can often be repaired in place, a screwed system requires disassembly and reassembly for repair. This obviously increases labour costs and downtimes for the pipe system.

5 **Fewer Leaks**

A welded pipe is generally able to handle vibration better than a screwed system,““making it less prone to leaks.

6 **Easier Insulation**

It is easier to insulate welded pipes, as there are no threaded connections to create difficult bumps that need covering.

7 **Location**

Welded pipes can be placed close together but threaded pipes need extra space so that wrenches and other tools can be used.

8 **Labour**

While the labour required to weld or screw smaller pipes is about the same, as the pipe size is increased, so the labour costs and time required to install the welded pipe decreases as the screwed pipe increases. A screwed pipe also requires different tooling for different pipe sizes, while a skilled welder can use the same welding machine for a range of pipe sizes.

Types of Pipes and Pipe Schedule

Objectives: At the end of this lesson you shall be able to
- **explain ferrous to non ferrous pipes**
- **state the pipe schedule**

Pipes are defined as circular tubular products used for conveying fluids (liquids, gases, and fluidized solids). Pipes are designed for a particular design pressure corresponding to design temperature. Various parameters related to pipes are Pipe Size, Pipe Schedule or thickness, Pipe Material, Pressure withstanding capability, Temperature withstanding capability, etc. Different types of pipes are used in the industrial sector for different purposes.

Pipe Types based on Material

Pipes are normally classified based on the which is used to produce the pipe during manufacturing. In general, there are two types of pipes:

1 Metallic Pipes and

2 Non-metallic Pipes

Metallic Pipes

The pipes made of metal are known as metallic pipes. They can be grouped into two categories

- Pipes made from ferrous materials, and
- Pipes made from non-ferrous materials

Type of Pipes made from ferrous materials

These types of pipes are stronger and heavier. These pipes have iron as their main constituent element. Common examples of pipes made from ferrous materials are.

- Carbon steel pipes
- Stainless steel pipes
- Alloy steel pipes
- Cast Iron pipes

This category of pipes is suitable for higher temperature and pressure applications. Most of the pipes used in the oil and gas, refinery, chemical, petrochemical, power plants, etc are made of ferrous materials.

Type of Pipes made from Non-ferrous materials

In this group of pipes, iron is not the main constituent element. They are usually made of copper, aluminum, brass, etc. Common pipes made from non-ferrous materials are.

- Aluminum and Aluminum alloy pipes.
- Copper and copper alloy pipes.
- Nickel and Nickel alloy pipes.
- Titanium and titanium alloy pipes.
- Zirconium and Zirconium alloy pipes.

What is the NPS of a pipe?

'NPS' is an abbreviation of Nominal Pipe Size, which is a term used as a guideline number defining the diameter of the pipe.

What is a Pipe Schedule?

Pipe schedule (SCH) is how the wall thickness of a pipe is described. It is not an actual measurement, but a guide number based on a wall thickness formula. Two pipes the same diameter may have different schedules, which means they have a different wall thickness. So somebody specifying a pipe for a high pressure application will select a bigger number which represents a bigger schedule (wall thickness).

Additionally, in the case of stainless steel, piping schedules are specified with a letter 's' as a suffix after the number. An example to illustrate is an NPS 14 pipe with a schedule of 40s shown in the table below.

The reason stainless steel is schedules are treated in this way is due to their extra strength. Less wall thickness is required to withstand the same pressure as compared with other steels.

NPS Nominal Pipe Size	-	14
40 Schedule	-	0.438 wall thickness
40s Schedule	-	0.375 wall thickness

The list of pipe schedules used today are as follows; 5, 5S, 10, 105, 20, 30, 40, 40S,60, 80, 80S, 100, 120, 140, 160, STD, XS AND XXS

Just when you thought you were beginning to understand pipe sizing unfortunately there's an added complexity to be aware of:““Different sizes of pipes are manufactured in different ways and this has affected““how pipe sizing works.

Preparation Work Before Welding

Objectives: At the end of this lesson you shall be able to
- **understand the preparation of Pines**
- **preparation pipe for welding**

Preparation of Pipes for Welding

Pre-preparation of the pipes before welding improves the quality of the weld seam, ensures its physical appearance and economical work. In the preparation stage for welding, preparation is made by paying attention to the thickness of the part, the appropriate welding mouth, and the smoothness of the equipment.

Preparation of Small Diameter Pipes for Welding

The following procedure is followed for the preparation of welding to pipes.

- Marking
- Cutting
- Cleaning
- Practice
- Opening welding bent

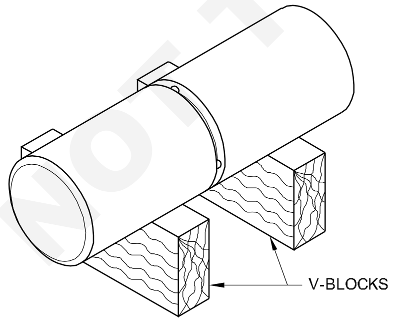
Pipe Beveling Methods

For pipes with a wall thickness of more than 4 mm, the weld mouth is opened in order to increase penetration. Small diameter pipes can be welded with files, pipe cutters, grinders, and oxy gas.

V Bearings in Pipe Welds

During the spotting of the pipes, a "V" bed is used to ensure that the axes are opposite each other and remain stable during welding. In special cases, angle iron is also used.(Fig 1)

Fig 1



Cleaning Weld Joints

The mouths of the pipes of the same diameter, which are cut and to be joined at welding, are cleaned. There should be no axial misalignment in the pipes to be joined by welding. Otherwise, welding to pipes might not be performed correctly.(Fig 2)

Fig 1

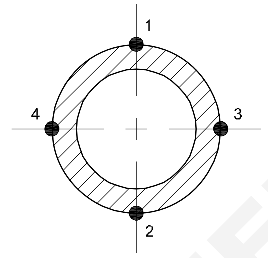


Fig 3

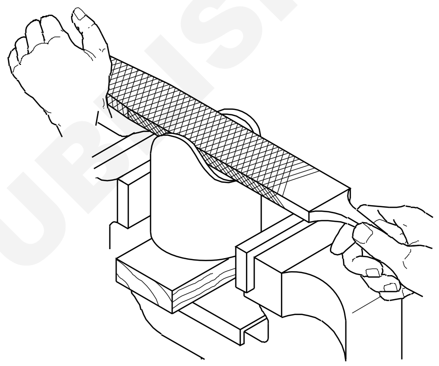


Fig 4

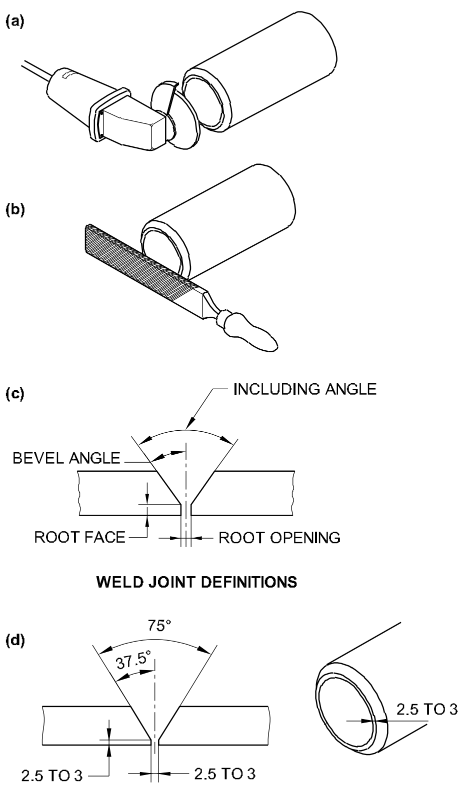
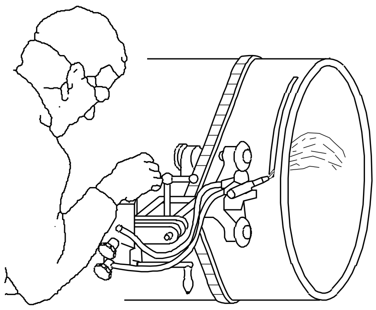


Fig 5



ROTATED PIPE CUTTING HEAD

Preparation of Large Diameter Pipes for Welding

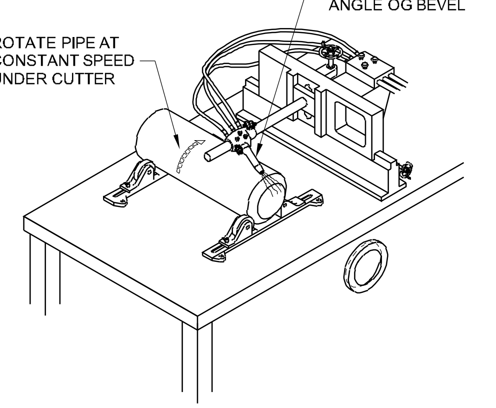
Cutting

The pipes must be cut in the dimensions and position of the place to be installed. Commonly used cutting methods with oxy gas, cutting electrodes, plasma, cutter of a hand grinder, band and hydraulic saws, cutting tools, etc. done by methods.

Cleaning

As a result of cutting operations, burrs can form inside the pipes. For the burrs not to cause blockages in future operations like performing welding to pipes, burrs and foreign (oil, rust, paint) residues must be cleaned. To clean them, it is necessary to use chisels, files, hand, and stationary grinders, wire brushes, and sandpapers, and chemicals. For the strength of the weld, no foreign matter residue should be left.

Fig 6



CUTTING BEVEL ON PIPE

Lapping

The cut and cleaned pipes must be lapped together before being welded. Otherwise, welding errors may be encountered. To do the lapping process, we can use the machines usually utilized for weld beveling and cleaning.

Intersection and Beveling

Welding to pipes is not always done end-to-end (linearly). Pipes are laid in ways such as angled turns in different directions, the intersection of pipes coming from different directions, and the joining of pipes of different diameters. In such cases, it is necessary to remove the intersection. Pipes with a wall thickness of more than 5 mm must also be welded. In such cases, we use special beveling methods. The value of the bevel angle is between 50-90"."

Basic pipe Welding procedure uphill Welding,downhill Welding and Horizontal Welding

Objectives: At the end of this lesson you shall be able to
- **understand the term uphill & down hill pipe welding**
- **explain procedime for uphill downhill pipe welding**
- **State the advantage of welding.**

Downhill vs Uphill Pipe Welding

Uphill and downhill welding methods are frequently used by skilled pipe welders. When it comes to comparing one to the other, new welders often want to know which one is the "best" method for vertical welding.But, the truth is, there isn't really one technique that is better than the other.The uphill welding method is often used to weld pipes at petroleum refineries.Whereas, the downhill pipe welding method is used to connect the longer pipeline sections that ultimately deliver crude oil to the refineries.The way to determine whether a pipe weld should be completed uphill or downhill is determined by the thickness of the pipe being welded and the quality of weld that's required to complete the job. A skilled pipe welder needs to be able to understand when to use each method based on the circumstances, the weld required, and the type of materials they are working with.

Uphill Welding When to Use This Method

The pipes used in refineries are often much thicker than the pipes used along the rest of the pipeline. This increased thickness requires a greater level of penetration to properly join sections of the pipes together.

In this instance, uphill vertical welding is the best choice as it will allow for the right level of penetration. Because the welder needs to fight the pull of gravity on the molten weld pool, they need to move more slowly and this allows them to achieve deeper penetration than they would when welding downhill.

Advantages of Uphill Welding

- **Deeper Penetration**

  As mentioned above, the pipes used in refineries are thicker than the ones used along a pipeline. By welding refinery pipes with the uphill method, the welder can ensure a deeper penetration and therefore a stronger weld. In order to counter the effects of gravity, the weld is completed more slowly in an attempt to maintain the weld pool which results in deeper penetration of the pipes being welded together.

- **Better Sidewall Fusion**

  A skilled pipe welder doesn't just work slower when uphill welding, they also use special techniques and different welding patterns to control and maintain their weld pool. The welder will often use special patterns for each pass and have longer pauses at different points in their weld pattern. As a result, these special patterns help produce better sidewall fusion around the pipes being welded.

- **Stronger Welds**

  Ultimately, uphill welding will produce stronger welds thanks to the deeper penetration and better sidewall fusion. Refineries are a dangerous place to work and the strongest possible welds are absolutely necessary to ensure the safety of those working in the facility and to ensure that there aren't any issues that could cause pipes to burst and impact production or the lands and water surrounding the refineries.

Drawbacks to Uphill Welding

- **Heat Input**

  As you've learned by now, pipe welding uphill requires the welder to work slower in order to combat gravity's pull and achieve deeper penetration. While this is an advantage to uphill welding, it also comes at a cost. Because the welder needs to move more slowly, and use different patterns and techniques to complete the weld, they also run the risk of applying too much heat to the workpiece. If this happens, it can lead to distortions in the pipe which could end up causing the pipe to weaken and fail when in use.

- **Burn Through**

  Burn through is another risk the welder needs to account for when using the uphill method. With such intense heat being used to complete the weld, you create the potential to burn through the base material if the arc outruns the filler material. You need to be careful that you don't move too quickly and move past the molten weld puddle you're trying to control. If that happens, a large hole can form which can create a whole host of other problems that are difficult to fill and repair.

- **Melt Out and Holes**

  It's not just the heat applied to the pipes being welded that you need to be concerned about, but also the molten metal itself. When the intense heat input becomes too great the weight of the molten metal can increase. If this happens and it overcomes its tensile strength, there's a chance that the molten metal can partially or completely fall out of the weld. If this happens, it can cause a hole in the pipe or a bulge of extruded materials. In either case, it results in a repair that must be completed before continuing or completing the weld.

Downhill Welding

When to Use This Method Some welders will argue that downhill welding is easier than uphill. The biggest difference between the two is the speed at which you work. In downhill welding, you are more or less racing against gravity rather than trying to combat it. This welding method is often applied to pieces of pipe used to deliver crude oil into a refinery. As welders try to build miles upon miles of pipeline, speed makes a real difference.The faster a pipeline can be assembled, the quicker it can start feeding oil into the refinery. When welders are working in the field, they'll use this technique to increase their production time. Pipe welding is all about working hard and fast. Although it's an effective technique when given the right materials, it also has limitations and drawbacks that every skilled pipe welder needs to be aware of.

Advantages of Downhill Pipe Welding

- **Faster Welds**

  Arguably the biggest benefit of downhill pipe welding is speed. With this method, it is essentially a race against gravity and a fight to stay ahead of the molten weldi pool as you work. The welder is able to work quickly without creating any major weld defects that could impact the performance of the pipe when in use. Downhill welding produces a visually acceptable weld and increases production time allowing pipelines to be assembled quicker, reducing building and labor costs.

- **Work with Thinner Materials**

  Because this method of pipe welding is a race against gravity, you can work with thinner materials. The materials being welded need to be thin enough to allow for the required speed of movement without causing weld formation defects. Uphill welding requires much thicker materials to be used and the welder to work slowly. With the downhill method, you can weld pipes with thickness up to 0.49 inches (12.5 millimeters).

- **Less Chance of Burn Through**

  The downhill method requires you to move quickly which, in turn, reduces the chances of creating too much heat input and causing pipe defects and burn through holes. Because you're working with thinner materials, they don't absorb and dissipate heat the same way thicker welding materials do with the uphill method. The faster speed of movement allows the material to have the proper penetration and completes the fusion while limiting the chances of too much heat input causing defects.

Drawbacks to Downhill Welding

- **Less Fusion**

  While speed is a benefit to downhill pipe welding, it's also a major drawback. Because you need to work quickly to stay ahead of gravity and weld pool, it ultimately leads to less fusion and penetration. This tends to be okay when downhill welding as you are generally working with thinner materials. As a welder, however, you need to be aware of the reduced fusion so you can ensure that the pipe weld is otherwise strong enough to perform properly when in use.

- **Contamination and Defects**

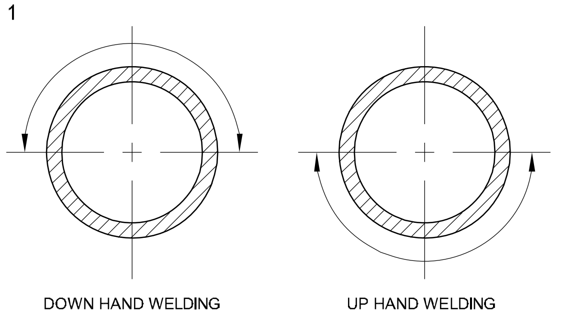
  If you don't move quickly enough when downhill pipe welding, you could end up contaminating the weld. As you race to stay ahead of the molten puddle, you run the risk of the puddle moving too quickly and getting ahead of the electrode. If this happens, you'll end up contaminating the weld and be forced to repair it. Other defects are possible as well.If the puddle outpaces the protective shielding gas you are using, it can lead to porosity in the weld itself, making it weaker, or, it can cause slag to form in the weld which will also make it weaker. In either instance, if you do not practice caution and you do not move quickly enough, you might end up completing a poor-quality weld that is more likely to fail and/or need a repair.

- **Limited Use**

  While there are advantages and use cases for downhill pipe welding, it does have limitations. First, you need to make sure the pipes you are working with aren't too thick. You'll also need to use special consumables like high cellulose rods to prevent contamination.

  This method of pipe welding should only be used for low-pressure (and low- stress) piping. If speed is more important to you than the quality of the welditself, then the downhill method is the way to go. However, if a weld defect is likely to lead to a critical failure (which is the last thing you want to happen at a petroleum refinery, for example), the downhill welding method should be avoided at all costs.

Fig 1



Pipe Welding position 1G 2G 5G & 6G

Objectives: At the end of this lesson you shall be able to
- **explain the different pipe welding position.**

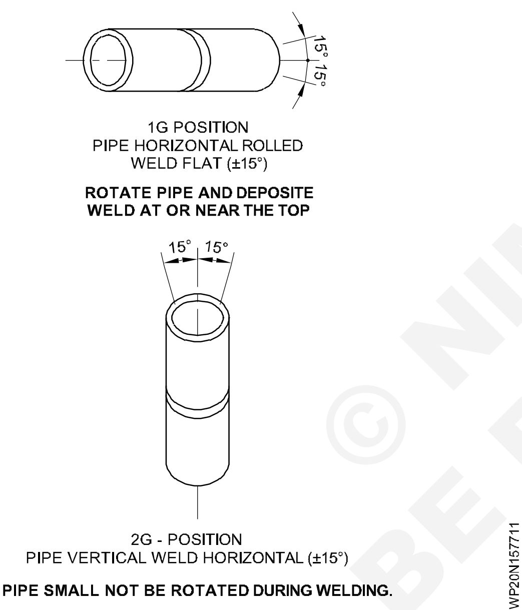
Welded pipe joints

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.

1G - Pipe weld in flat (roll) position i.e. pipe axis is parallel to the ground.

2G - Pipe weld in horizontal position i.e. pipe axis is perpendicular to the ground. (Fig 1)

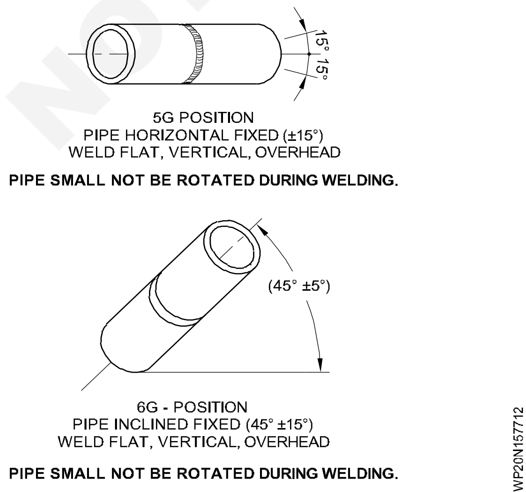
Fig 1



5G - Pipe weld in flat (fixed) position i.e. pipe axis is parallel to the ground.

6G - Pipe weld in including (fixed) position i.e. pipe axis is including to both horizontal and vertical planes. (Fig 2)

Fig 2



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.

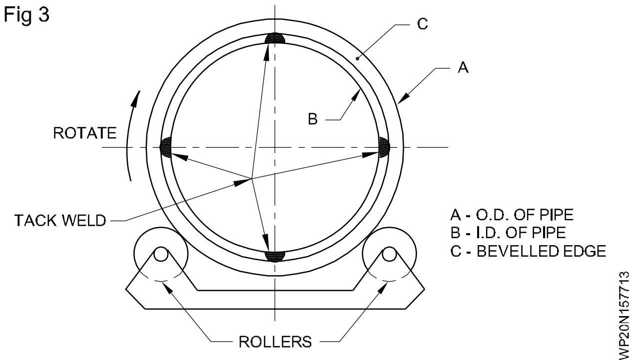
Setting the pipes for welding: Tack weld together with 4 small equally spaced tacks. The gap should be equal to the root face dimension plus 0.75 mm. Support the tacked assembly on V blocks or rollers so that the assembly can be rolled or rotated with the free hand.

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.

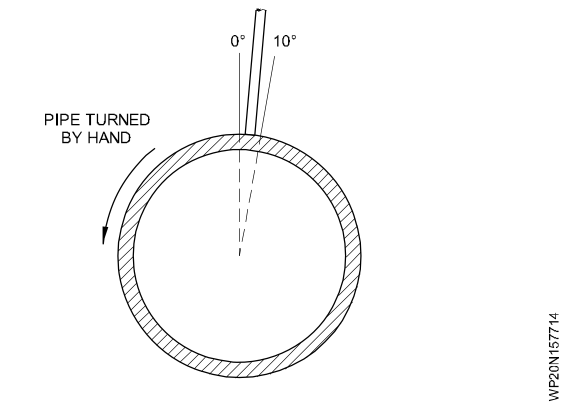
Rotate the assembly as welding proceeds. (Fig 3) keeping the welding arc within an area between vertical and 10° from the vertical in the direction of welding Fig 4. (Use a helmet type screen).

Fig 3



- 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 centre and hold the arc length as short as possible. Continue to weld as the pipe is rotated manually at steady speed.

Fig 4

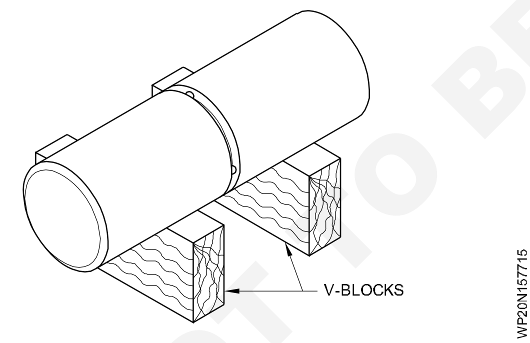


- Deposit first run by weaving the electrode very slightly from root face to root face.
- Adjust the speed of rotation to obtain full fusion of the root faces without excessive penetration.
- Chip out tack weld as they are approached. Do not weld over tacks otherwise loss of penetration at the tacking 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.

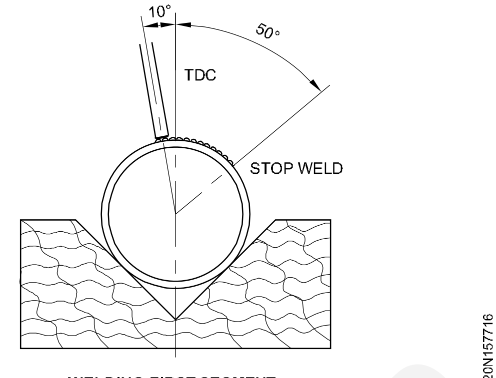
- The edges of the pipe are bevelled to 35 to 40° angle with a root gap of 2.5 mm.
- Tack the pipe as before and support the assembly on two vee blocks. (Fig 5)

Fig 5



- 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 6)
- When a segment equivalent to 60° has been welded, terminate/stop the weld run. Avoid the formation of a crater.

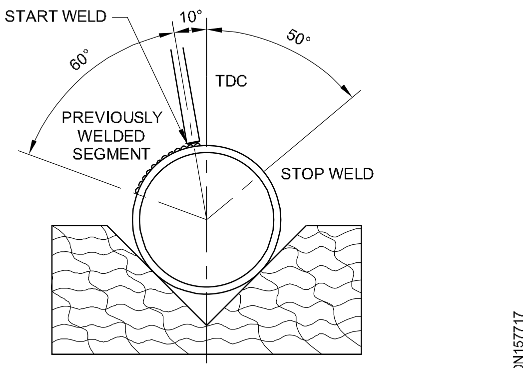
Fig 6



WELDING FIRST SEGMENT

- Move the pipe until the end of the segment is at 10° before TDC.
- Strike the arc on the end of the previous weld run and establish a weld pool.
- Weld a further 60° segment. (Fig 7)
- Continue welding in segments until the root run has been completed.
- Move the pipe until the mid point of the segments is at TDC.
- Strike the arc and deposit the second (filling) run, use a side-to-side weaving position to fill the preparation and to achieve fusion of the pipe edges.
- Complete the filling run in 60° segments.

Fig 7



WELDING SECOND SEGMENT

Selection of Electrode (SMAW) for root pass and Cover Pass Welding

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of coding electrodes**
- **describe the electrode coding as per AWS.**

Introduction

The primary element of the shielded metal arc welding (SMAW) process is the electrode itself. It is made of a solid metal core wire covered with a layer of granular flux held in place by a bonding agent. Since the electrode is an important feature of the process, it is necessary to understand how various types are classified and identified.

AWS specifications

American Welding Society (AWS) specifications A5.1 to A 5-34 describe the requirements for various electrodes, filler wires, flux, gas. They describe the various classifications and characteristics of these electrodes.

Most of the industrial countries issue filler metal specifications. In the United States, the AWS provides filler metal specifications. They are approved by ANSI (American National Standards Institute) and have become an American national standard.

The American Society of Mechanical Engineers (ASME) in its "Boiler and pressure vessel code" issues filler metal specifications that are identical to AWS specifications. ASME adds the prefix letters SF to the specification number.

ASW A 5.1/ASME SFA 5.1

Many countries use specifications of the industrialized countries (American, European, Canada) All welding consumables (filler metals and fluxes) shall conform to one of the following specifications:

AWS

A 5.1, A 5.20, A 5.2, A 5.23, A 5.5, A 5.28, A 5.17, A 5.29, A 5.18

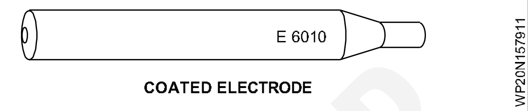
Consumable that do not conform to the specification above may be used provided the welding procedure specifications involving their use are qualified and approved.

AWS Codification (Classification)

The American Welding Society has a classification system to identify SMAW electrodes for mild steel, low alloy steel, stainless steel and cast iron. AWS classifications for filler metals provide valuable information to welders about their usability. It includes what the materials are best suited for and how to use them maximizes performance. They also offer insight into the mechanical properties that a given filler metal will provide.

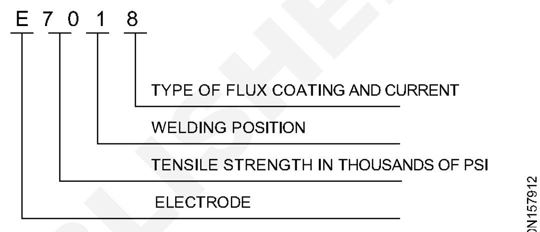
A simple numbering system is used for electrode classification. The welding electrodes are classified according to: type of current, type of covering, and welding position, mechanical properties of the weld metal in the welded condition. (Figs 1,2 & 3)

Fig 1



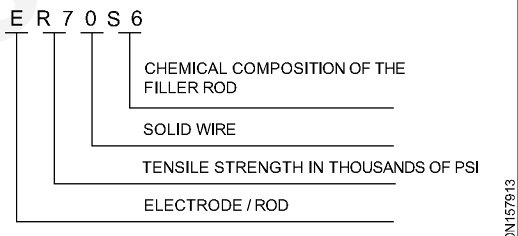
COATED ELECTRODE

Fig 2



SWAM ELECTRODE CODIFICATION SYSYEM

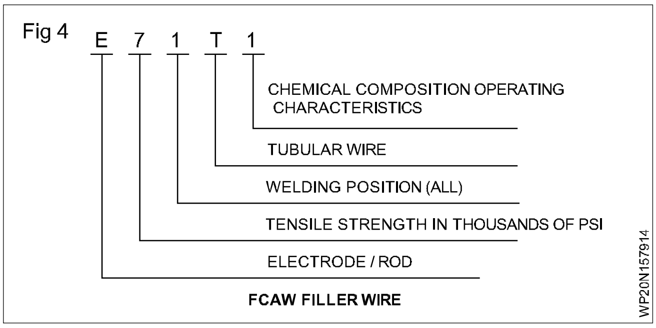
Fig 3

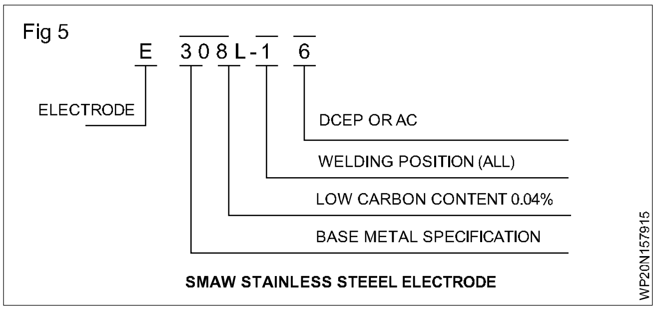


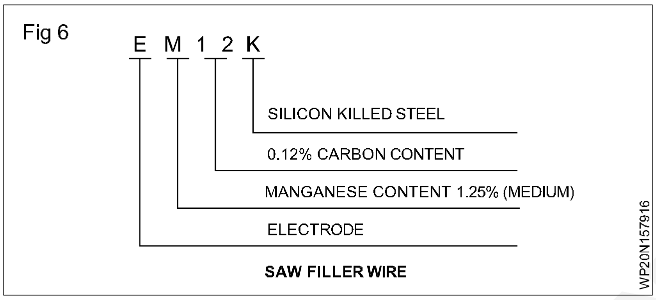
GMAW FILLER WIRE

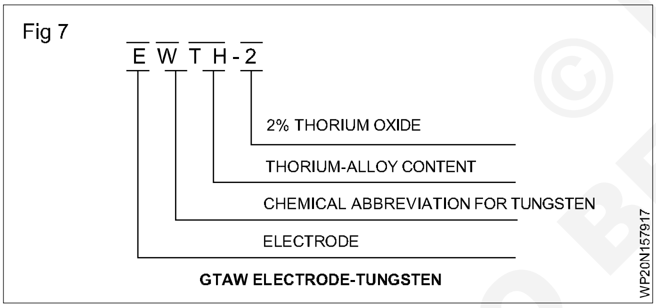
The AWS classification such as E 6010, E 7018 is printed on the flux coating near the end of the electrode. It indicates that the electrode manufacturer has qualified the electrode to the AWS specification for mechanical and chemical properties. The identification consists of an 'E', which stands for electrode, followed by four or five digits.

The first two or three digits refer to the minimum tensile strength of the deposited weld metal. These numbers state the tensile strength in thousands of pounds per square inch. For example, '70' means that the tensile strength of the deposited weld metal in at least 70,000 psi. The next digit refers to the positions in which the electrode can be used. A '1' denotes that the electrode is suitable for use in any (all) positions. A '2' means that the electrode can be used only in the flat or horizontal fillet positions. The last digit describes the usability of the electrode by the type of flux coating and recommended current conditions (AC, DCEP or DCEN). The electrodes ending in '8' are classified as low hydrogen types and are used in AC or DCEP. The electrodes ending in 'O (Zero)' are classified as cellulose coating, deep penetration used in DCEP (E6010). (Figs 4,5,6 & 7)









Electrode identification

The electrode classification number is imprinted or stamped on the electrode covering filler wire within 65 mm of the grip end of the electrode.

All manual electrodes shall be properly identifiable upto the time of usage, each electrode being distinguishable by a coding marked near the grip end. Electrodes without a code marking shall not be used.

Electrode storage

Electrodes, filler wires and fluxes shall be stored in a dry storage room in accordance with the manufacturer's instructions. Basic low hydrogen electrodes, after removal from the containers, shall be baked in ovens. The baking ovens and the holding ovens shall have automatic heat controls and a temperature read-out display..

Deposition of Root Pass

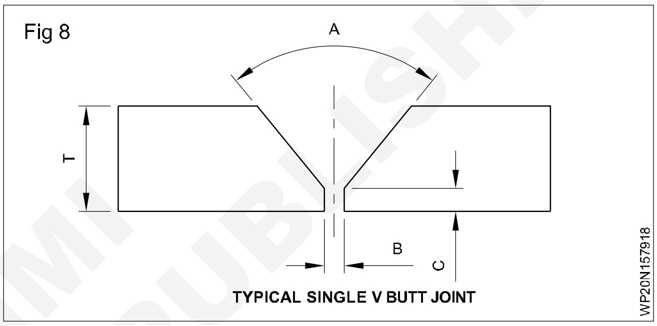
The root pass is the most important weld that must be made in completing this joint. Start the root pass at either the 5 o'clock or 7 o'clock position and proceed across the bottom to the top of the pipe joint. Stop either at the 11 o'clock or 1 o'clock position.

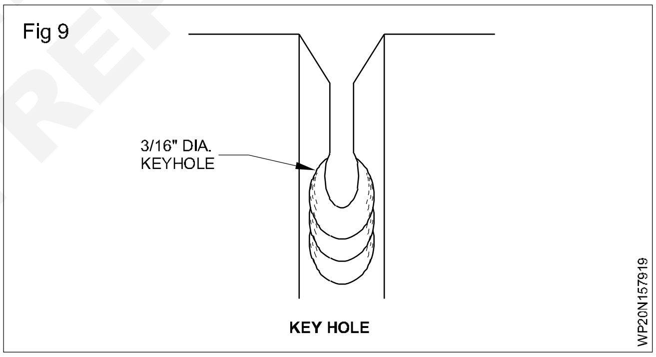
When welding a root pass, the keyhole is necessary in order to obtain the required weld penetration. While welding the root pass, the welder must pay careful attention to the keyhole and watch for changes in size.

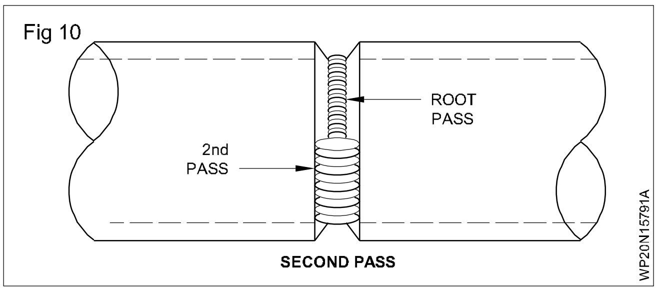
The same sequence is followed on the other side.

Remove the external line up clamp after 50% completion of root bead equally distributed around the joint. After the entire root bead has been completed, it should be thoroughly inspected for visible welding defects.

T. Thickness, A 60° 70°, B ±5mm, C 1 5 ± 0.75mm (Figs 8,9 & 10)







Second (HOT) Pass

Second pass is also called " hot pass" Select 3.20 mm electrode and a current setting of 100 - 120 amperes.

Deposit the second (hot) pass in the same sequence as in root pass.

Time lapse between completion of root and commencement of second pass is to be maximum 5 minutes.

Inspect the root side for any burn through defect which will be occur if the root pass thickness is less.

Deposition of 3rd and 4th (Final) Pass

Clean and wire brush the welds thoroughly.

The electrode should at all times be pointed towards the centre of the pipe's circumference or should be perpendicular to the pipe surface.

Deposit the third pass using slight side to side movement.

Fill the crater at the end of weld.

Remove the slag, spatters and clean the weld bead.

Welding Technique 5G Down Hill Position

Pipe joints are often used in industries which include pipeline projects, refineries, tanks, etc.

In butt joints the letter 'G' is used to signify a groove joint (edges are beveled) and a number is assigned to signify the welding position. In 5G-Multiple positions (flat, vertical and overhead) pipe is fixed, groove weld, pipe axis is horizontal and is not rotated. Welding shall be done without rotating the pipe.

Shielded Metal Arc Welding (SMAW)

SMAW is one of the popular methods for welding pipe both in the shop and in the field. Standard welding power sources which produce direct current such as a rectifier, inverter or an engine driven machine may be used. Welding may be done in 5G position and the direction of welding may be downhill or downward.

Pipe Welding Electrodes

E6010 This type of electrode is frequently selected for joining pipe and are generally capable of welding in the vertical position with either uphill or downhill progression.

Procedure for Welding Heavy Wall Pipes in 5G and 6G Position Welding

Objectives: At the end of this lesson you shall be able to
- **perform edge preperation of pipes**
- **describe 15 G 5G-6G welding position.**

Welding out of position is rarely easy- and rarely the most efficient. But when welding on pipe, there is often no other option. The fabrication of smaller diameter pipe systems, such as those found in power plants or oil refineries, as well as their maintenance and repair in later years, frequently require welding in the 5G and 6G positions- fixed-horizontal and 45-degree-fixed positions, specifically. The same holds true in the construction of larger diameter onshore transmission pipelines, which are generally welded in the 5G (horizontal) position and require welding both vertical-up and vertical - down depending on the chosen filler metal.Both applications require skilled, certified welding operators to manage the task, as well as the right filler metal for the job.

In past years, many pipe fabrication and repair applications ,regardless of the diameter of the material, relied on the use of SMAW (shielded metal arc welding) or stick electrodes. Not only do these filler metals provide the necessary chemical , but they are also widely accepted and specified for these jobs.Despite that, stick welding is a notoriously slow process due to the frequent stick electrode changeovers it requires.Welding operators can typically weld only 10 to 12 inches with a stick electrode before needing to replace it.

In recent years, however, advancements in filler metal technology have brought forth tubular wire options (flux-cored and metal -cored) that provide excellent mechanical and chemical properties - particularly good resistance to cracking - and they also can improve productivity on the out-of-position welding required on many pipe applications.

Welding in 5G and 6G positions on smaller diameter pipe

Smaller diameter pipe - 10 inches or smaller - is commonly found in applications ranging from HVAC and high-pressure steam to process piping, including pipe spools.This pipe is most often thin (Schedule 40, for example and can be composed of materials such as carbon dteel, low alloy steel, chrome - moly or stainless steel.

During the fabrication process, and for repairs as well, welding operators often must weld the pipe in place, in either the 5G or 6G position. In the 5G position, the pipe is fixed at one or both ends and the welding operator must travel in one of two directions, either vertical-up or vertical-down. Depending on the location of the pipe, the application may also require welding either overhead or in a flat position. Welding small diameter pipe in the 6G position is even more difficult. In this position, which is typically found in sub-assembly applications, the pipe is fixed at a 45-degree angle.

Both the 5G and 6G positions pose definite challenges to the welding operator. In addition to requiring specific training and certification, welding defects such as lack of fusion,slag entrapment and lack of penetration are always a possibility. Poor weld bead appearance can also occur when welding in these difficult position.

Selecting a metal-cored and/or gas-shielded flux-cored wire that provides good out - of - position welding capabilities can increase productivity compared to welding with stick electrodes and simplify training associated with welding in the 5G and 6G positions.

For root passes in both positions, metal-cored wires combined with a modified short circuit process are good option.American Welding Society (AWS) E70C-6M,E80C-Ni1,E90C-K3,and E100C-K3 metal-cored wires work well depending on the material.Metal-cored wires offer faster travel speeds than other types of wires, as well as higher deposition rates, making them a good alternative for increasing productivity on out -of-position pipe applications. These wires also bridge gaps that are common in pipe applications to help ensure high-quality welds.

Other benefits include eliminating lack of fusion and/or lack of penetration by providing thicker root passes, reducing spatter and subsequent post-weld cleaning; and simplified training.Because processes like RMD maintain a consistent arc length even at varying wire stick-out, welding operators who may not be as skilled at maintaining wire stick-out can still have good control of the process. This feature is especially beneficial since some novice welding operators are prone to increasing wire stick-out when welding out of position.

On fill and cap passes, .035- or .045-inch diameter gas-shielded flux-cored wires with an American Welding Society (AWS) E71T-1 classification are appropriate for welding smaller diameter pipe. These wires not only offer reliable out-of-position welding capabilities, including good weld puddle control, but they also provide excellent bead appearance and slag release. Wires such as AWS E71T-1/T-9/T- 12M/J, E81T1-B2C H4/-B2M H4 and E91T1-B3C H4/-B3M H4 help improve productivity compared to stick electrodes.

Welding in 5G on larger diameter pipe

Similar advantages can be found with tubular wires when welding on larger diameter pipe, such as that used for onshore transmission pipelines. This pipe averages 24 inches or more in diameter, with some distribution lines falling in the 12-16 inch diameter range. These typically require welding in the 5G positon(since the pipe is already put in place in the field).and in many cases today, the material filler metals that can provide low hydrogen weld deposits capable of mitigating weld cracking.

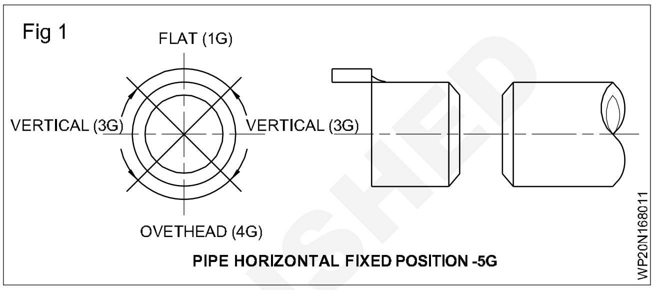
Gas-shielded flux-cored wires for larger diameter pipe have proven to be an effective alternative to stick welding for gaining productivity on pipline applications. These wires are often used in .045-inch diameters on automated and semi-automatic pipe applications and feature a rutile (or T-1) slag system that results in an easy-to-remove slag and low spatter levels. These features make the wires well-suited for welding on multi-pass applications;they require minimal cleanup between passes or after welding to increase productivity further.Many of them feature much lower hydrogen levels than many stick electrodes - as low as 4 ml per 100 g of weld metal (compared to 16 ml per 100 g or more for EXX10 cellulosic stick electrodes) - to help reduce cracking and downtime for rework. Good gas-shielded flux-cored wires (for standard and high-strength pipe) are those classified as AWS E71T-1/T-9/12J H4, E101T1-GM and E111T1-GM H4. These wires produce a good bead appearance and provide reliable weld penetration to prevent issues like lack of fusion or under-bead cracking. As with wires for smaller diameter pipe, they can be used for fill and cap passes when combined with a modified short circuit welding process (as described previously) and a metal-cored wire for the root pass. The result is good gap bridging and better tolerance to high-low misalignment often found in pipeline applications. The combination of a modified short circuit process and metal-cored wire root pass also eliminates the need for a "hot pass" required with stick electrodes,thereby speeding welding time.

Self-shielded flux-cored wires are also an option for increasing productivity on out-of-position pipe welding. These wires are formulated specifically to weld vertical down and feature low hydrogen levels (around 8 ml per 100 g of weld metal). These wires offer high impact strengths at low temperature and resist cracking, helping to minimize rework time and maximize productivity. Because they require no shielding gas, they are also easier and quicker to set up on the jobsite. Good options for out-of-position pipe welding include AWS E71T8-Ni1J H8 and E81T8-Ni21 H8. Both wires are typically used in 1/16- or 5/64-inch diameters when welding on larger diameter pipe and offer an easy-to-remove slag that lessens interpass cleaning.

Final considerations

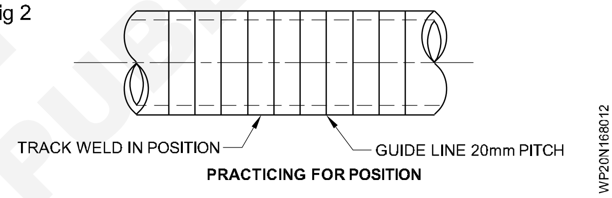
Making the change to a tubular wire for out-of-position pipe welding applications can yield significant productivity gains. As with any modification in the welding operation, however, it is important to evaluate every factor before proceeding. Working with a knowledgeable welding distributor is a good first step in the process. It can help ensure that the chosen wires best match the base material for the application and that an already difficult task doesn't become more so.

Fig 1



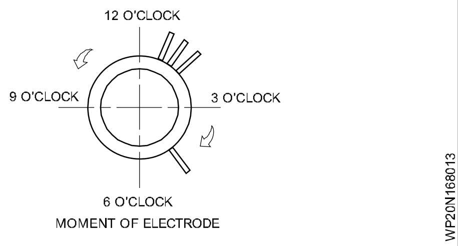
PIPE HORIZONTAL FIXED POSITION -5G

Fig 2



PRACTICING FOR POSITION

Fig 3



MOMENT OF ELECTRODE

CG & M **Related Theory for Exercise 1.6.83**

Welder (Pipe) - GTAW & GMAW

Welding Symbols

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

- **define and explain weld slope and weld rotation with respect to butt and fillet joint**
- **illustrate the various weld positions with respect to slope and rotation as per I.S.**

Refer Lesson 1.2.21

Procedure for Welding of thin Wall Pipes in down hill position

Objectives: At the end of this lesson you shall be able to
• describe the setting pipes for weldings.

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 1) keeping the welding arc within an area between vertical and 10° from the vertical in the direction of welding Fig 2 . (Use a helmet type screen).

Fig 1

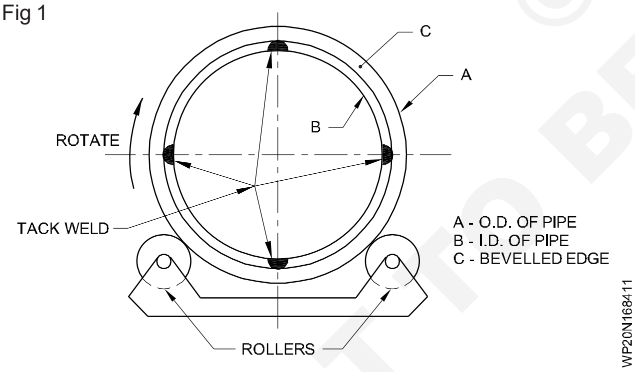
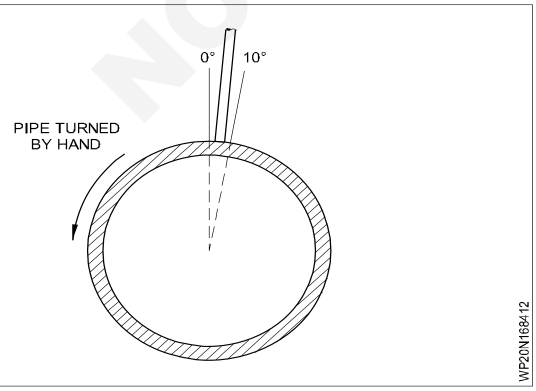


Fig 2

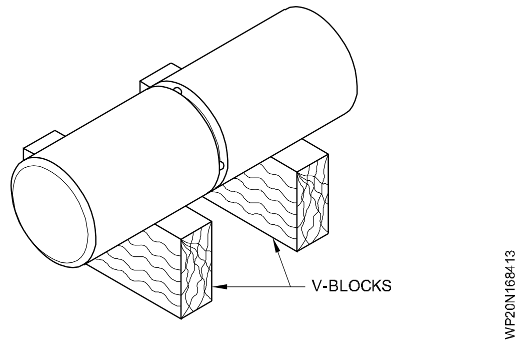


- Direct the electrode centrally at the root of the joint and in line with the radius of the pipe at the point of welding.
- Strike the arc near the top dead centre and hold the arc length as short as possible. Continue to weld as the pipe is rotated manually at steady speed.
- Deposit first run by weaving 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.

Welding of a pipe butt (IG position i.e. by rotation) by segmental welding.

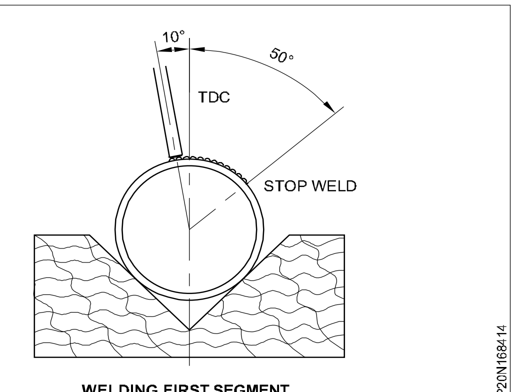
- The edges of the pipe are bevelled to 35 to 40° angle with a root gap of 2.5 mm.
- Tack the pipe as before and support the assembly on two vee blocks. (Fig 3)

Fig 3



- 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 4)
- 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.

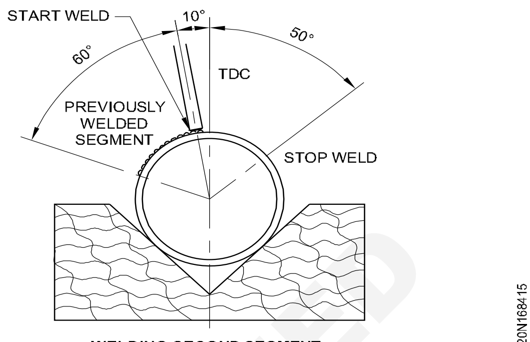
Fig 4



WELDING FIRST SEGMENT

- Strike the arc on the end of the previous weld run and establish a weld pool.
- Weld a further 60° segment. (Fig 5)
- Continue welding in segments until the root run has been completed.
- Move the pipe until the mid point of the segments is at TDC.
- Strike the arc and deposit the second (filling) run, use a side-to-side weaving position to fill the preparation and to achieve fusion of the pipe edges.
- Complete the filling run in 60° segments.

Fig 5



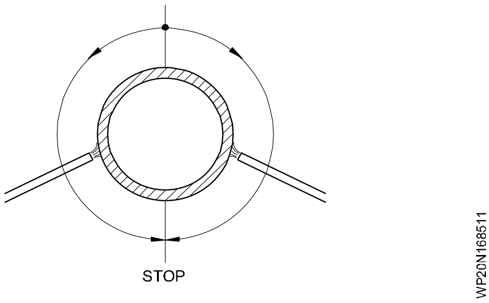
WELDING SECOND SEGMENT

Procedure for Welding Pipe in 2G position

Objectives: At the end of this lesson you shall be able to
- **state different fixed pipe welding positions**
- **explain different methods of pipe welding in 2G position**
- **explain the welding producer of M.S. pipe butt joint by arc in fixed (5G) position.**

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 1). 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.

Fig 1



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 2)

In the 6G position welding is usually done by using one of the methods i.e. uphill or downhill welding. (Fig 3)

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

Fig 2

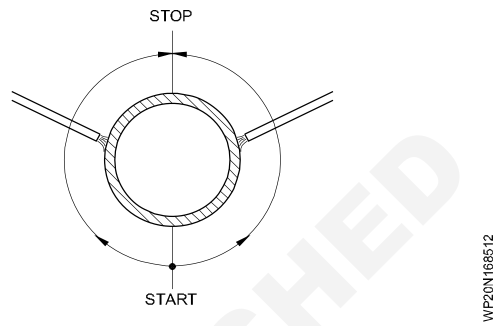
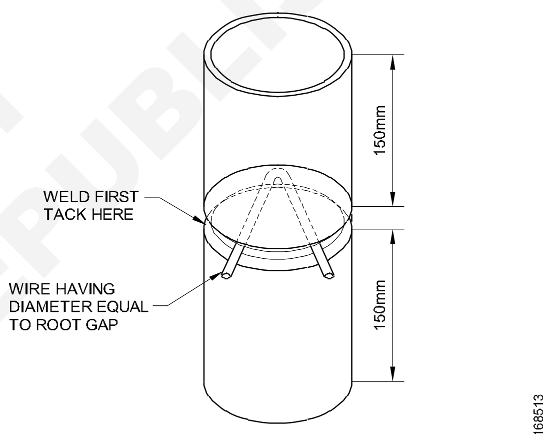


Fig 3



USE OF BEND WIRE OF SPACER TO SET ROOT GAP

Welding Procedure for Complicated Pipe Joint T Joints with Intersecton, Top bottom and side Y Joint.

Objectives: At the end of this lesson you shall be able to
- **develop and layout the pattern for 90° "T" pipe of equal diameter by parallel line method**
- **welding procedure for T and Y joint.**

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

Draw the front view as shown in Fig 1.

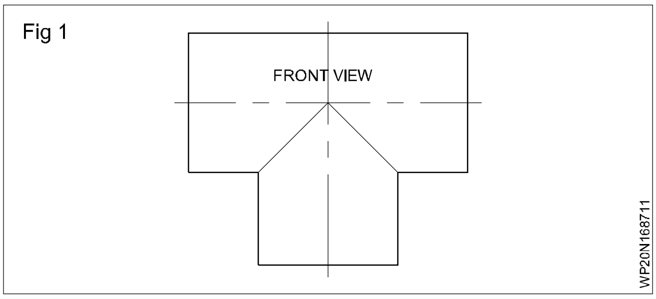


Fig 1

Draw the side view as shown in Fig 2.

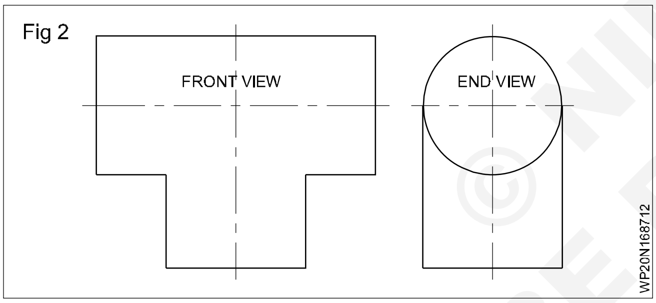


Fig 2

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

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

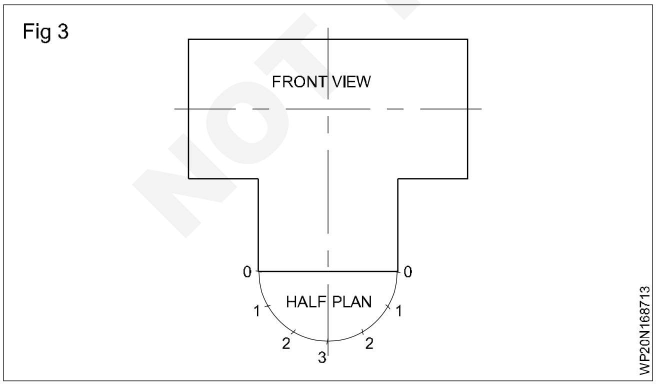


Fig 3

Divide a semi-circle in side view into six equal parts and number as 3, 2, 1, 0, 1, 2, 3 as shown in Fig 4.

Draw the perpendicular lines from each point of the semi-circle of the view as shown in Fig 5.

Draw horizontal lines from the side view towards the front view as shown in Fig 6.

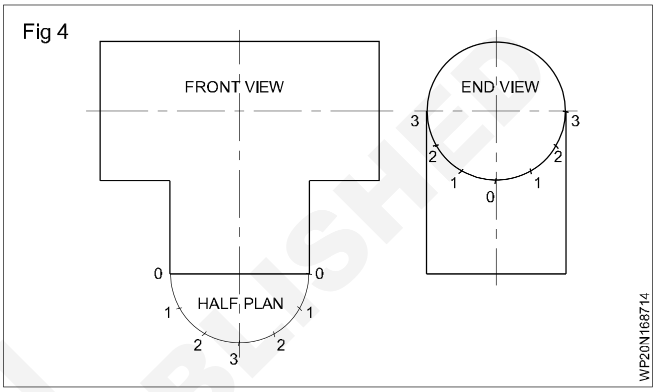


Fig 4

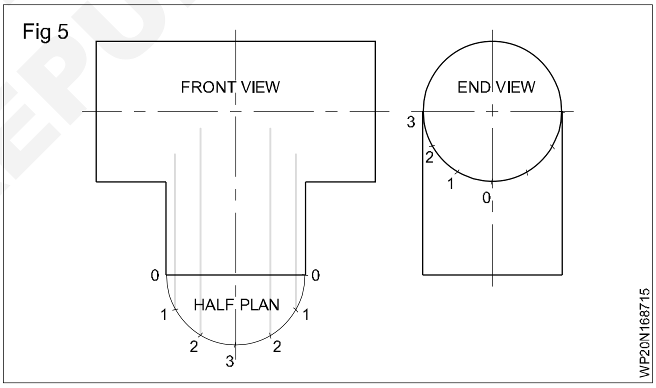


Fig 5

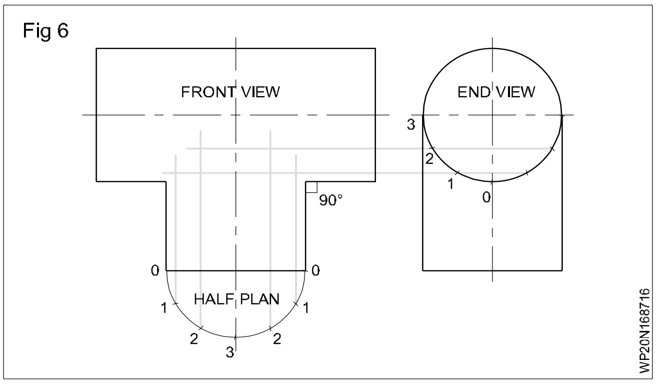


Fig 6

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

Join these points to get the line of intersection of "T" pipe as shown in Fig 7.

Extend the base line of the side view and mark the end point as 0. Fig 8

Fig 7

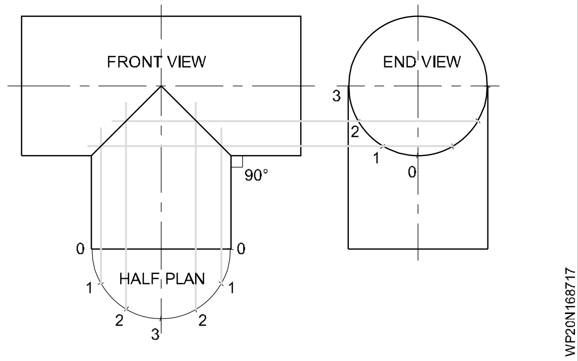


Fig 8

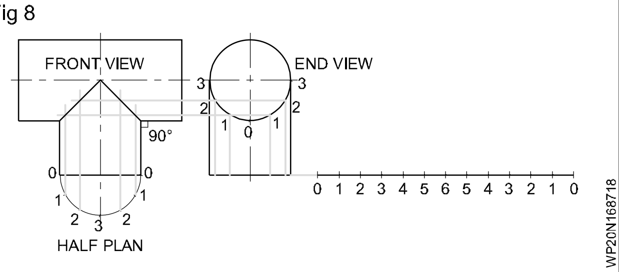
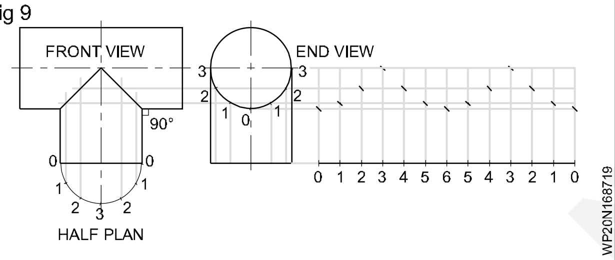


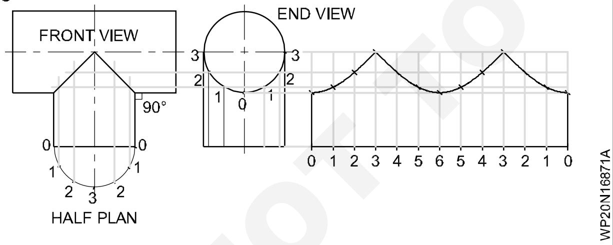
Fig 9



Draw perpendicular lines from these points and draw horizontal lines from the points on the line of intersection of "T". These line meet at their respective points. (Fig 9)

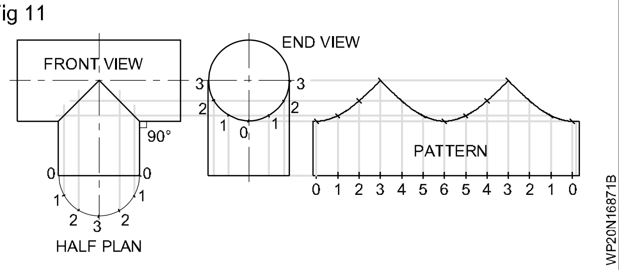
Join these points by free hand curve. (Fig 10)

Fig 10



Provide locked grooved joint allowance as shown in Fig 11.

Fig 11

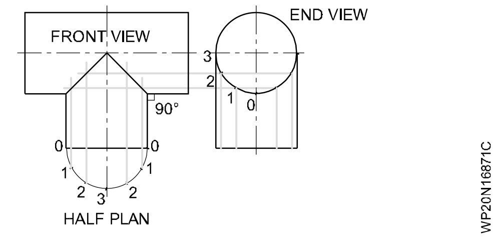


Check the pattern once again and cut. Thus you get the pattern for branch pipe.

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

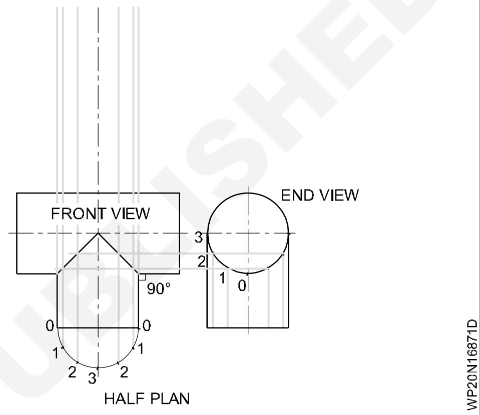
Draw the front view and end view. Fig 12

Fig 12



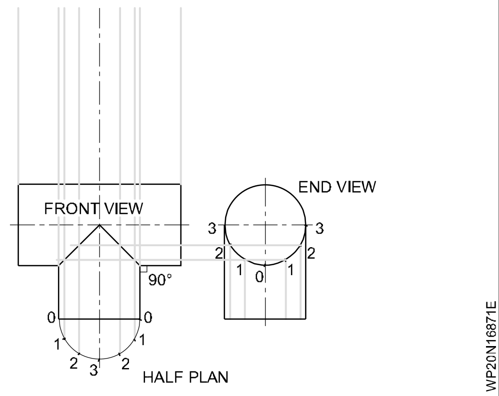
Extend the vertical lines 0, 1, 2, 3, 1, 0 of branch pipe from the front view as shown in Fig 13.

Fig 13



Extend the two extreme end vertical lines of the main pipe from the front view as shown in Fig 14.

Fig 14



On one of these lines, take point "0" as starting point and mark points 0, 1, 2, 3, 2, 1, 0, 1, 2, 3, 2, 1, 0 at equal distances equal to one division of the semi-circle and draw horizontal lines from these points. Fig 15

Now these horizontal lines meet the vertical lines at their respective points as shown in Fig 16.

Join these points by free hand curve and get the pattern for the main pipe. Fig 17

Provide the locked grooved joint allowances as shown in Fig 17.

Fig 15

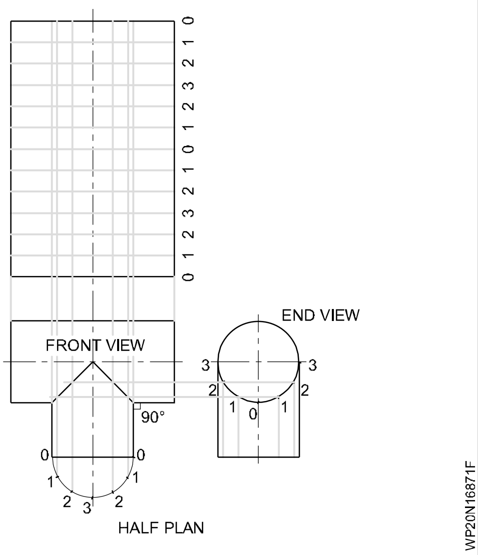


Fig 17

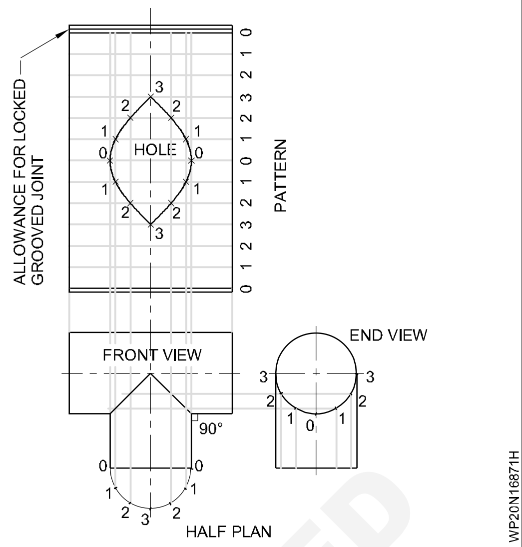
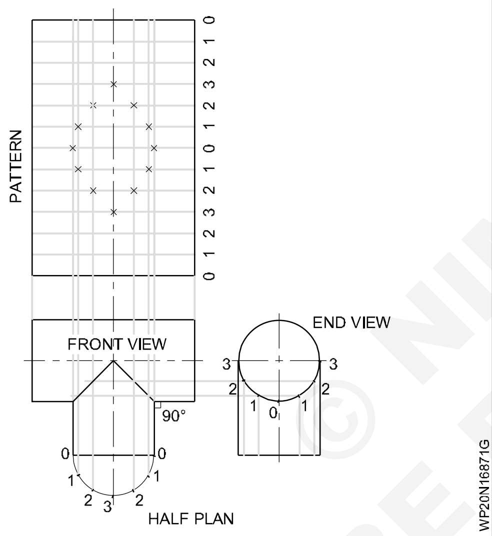


Fig 16



Development of a pipe "Y" joint

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

- **develop and able to layout the pattern for "Y" joint pipes intersecting at 120°**
- **develop and layout the pattern for "Y" joint pipes branching at 90°.**

Development of "Y" joint pipes intersecting at 120°: Draw the development of intersecting cylinders of dia. 30 mm at 120°. (Fig 1)

All the cylindrical pipes are of same diameter and intersecting each at equal angles. Hence in this case the development of all the pipes are same and so the development of one pipe will represent other pipes.

- Draw the plan and elevation of the pipe 'A' and mark the division on the plan. (Fig 1b)
- Draw the vertical projectors from the plan to front view to meet the line of intersection.
- Draw horizontal projectors from these points on to the development.
- Mark the intersecting points and join with a smooth curve to complete the required development.

Development of 'Y' joint branching at 90°: Three cylindrical pipes of X, Y, Z form a 'Y' piece. (Fig 2) Draw the lateral surface development of each pipe.

In the three pipes XYZ, Y & Z are similar in size and shape, hence their developments are also similar.

- Draw the development of pipe 'X' as in the previous Related Theory Exercise.
- Draw the elevation and plan of pipe 'Y' as shown.
- Divide the plan circle into 16 equal parts.
- Project the points to the elevation.
- Draw the rectangle ABCD in which AB is equal to D.
- Draw the development of pipe Y as shown in Fig 2.

Making 'T' Welding

It is very important to control the molten bath during welding, as invisible pores and slag will cause leaks in welded joints. During welding, the welding electrode angle

Fig 1

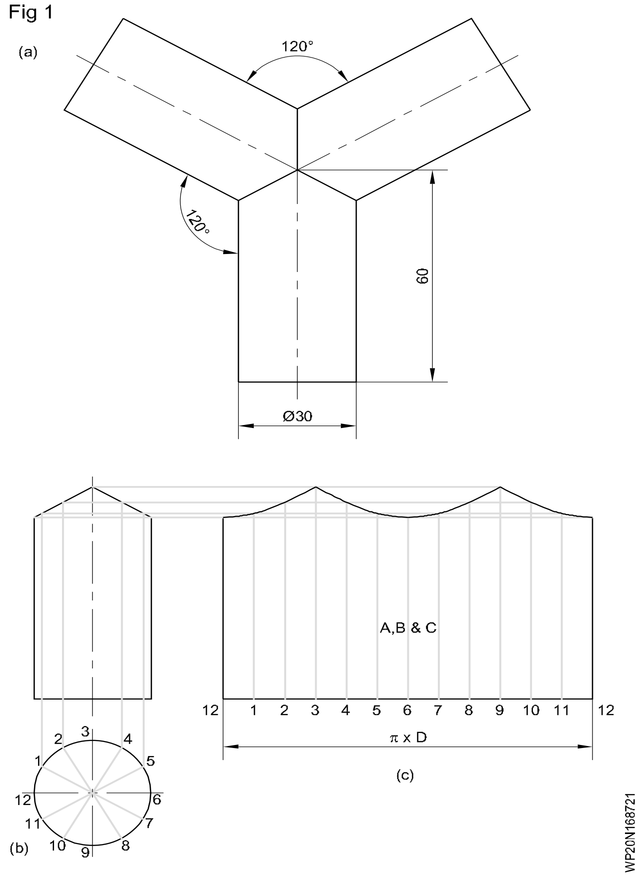
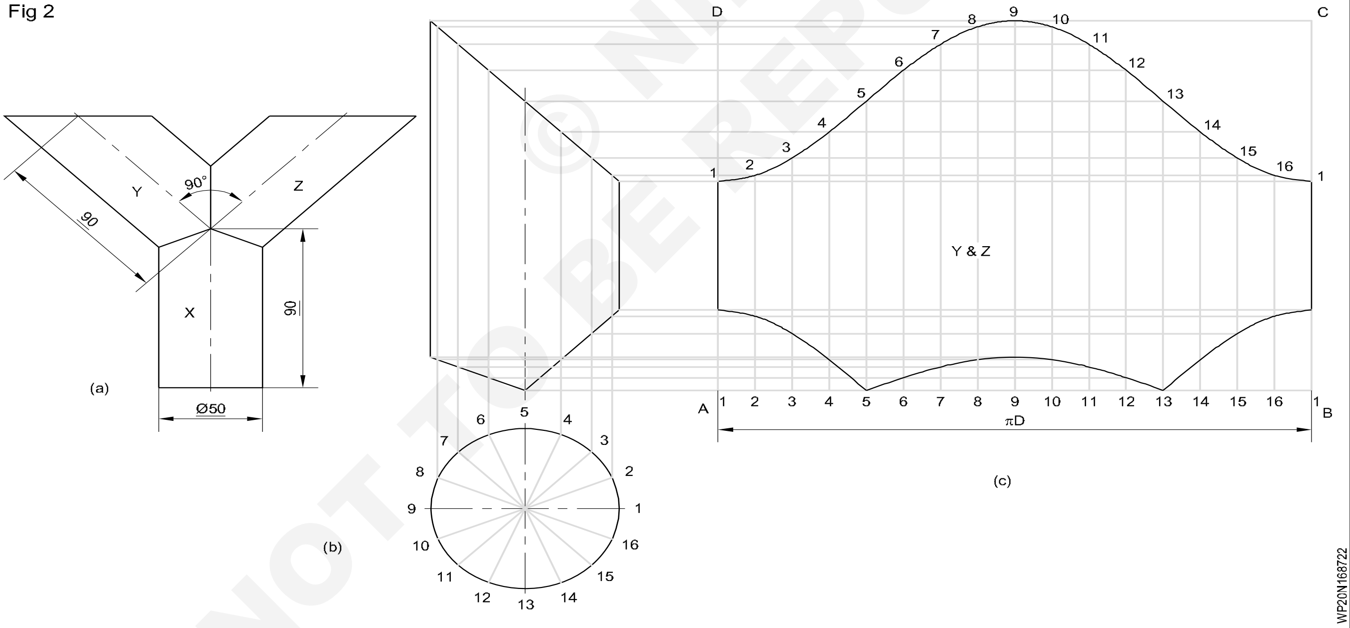


Fig 2



is different at each point. For this reason, the electrode should be held at an angle of 75-80' to the instrument surface. It is a must for successful welding to pipes.

In horizontal welding of pipes, the electrode is started from the upper point and welded by turning. It should be welded without any gaps at the start and endpoints of the electrode. In electric arc welding, sufficient curvature temperature is achieved with amperage setting and the use of appropriate electrodes.

The arc length should be equal to the diameter of the electrode. It is very important to keep this distance under control by the welder depending on the electrode spinning speed. Welding speed is also one of the important factors affecting the shape and penetration of the weld seam. Increasing the speed causes a decrease in the width of the weld seam and a decrease in penetration. The decrease in the welding speed causes the weld seam to pile up.

Cleaning the Weld Seam

While the welding to pipes is being completed, the entire perimeter seam should be completed by cleaning the slag at the endpoints of the seam and maintaining the welding parameters. The welding joint should be cleaned with steel wire brushes as the gases emitted during the combustion of the electrode will cause corrosion by combining with the humidity of the air around the weld joint area.

Preparation of Large Diameter Pipes for Welding

Cutting

The pipes must be cut in the dimensions and position of the place to be installed. Commonly used cutting methods; with oxy gas, cutting electrodes, plasma, cutter of a hand grinder, band and hydraulic saws, cutting tools, etc. done by methods.

Cleaning

As a result of cutting operations, burrs can form inside the pipes. For the burrs not to cause blockages in future operations like performing welding to pipes, burrs and foreign matter (oil, rust, paint) residues must be cleaned. To clean them, it is necessary to use chisels, files, hand, and stationary grinders, wire brushes, and sandpapers, and chemicals. For the strength of the weld, no foreign matter residue should be left.

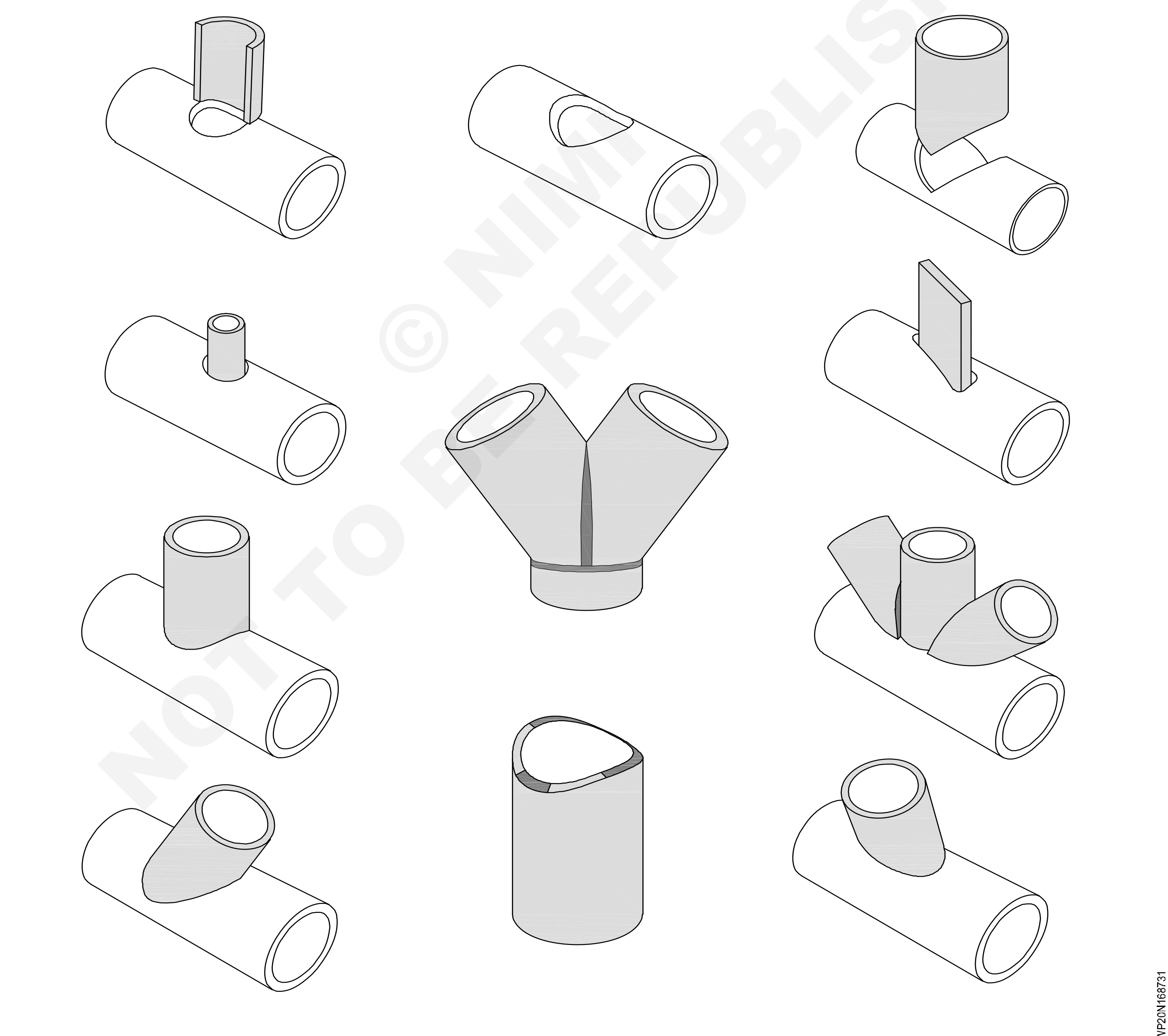
Lapping

The cut and cleaned pipes must be lapped together before being welded. Otherwise, welding errors may be encountered. To do the lapping process, we can use the machines usually utilized for weld beveling and cleaning.

Intersection and Beveling

Welding to pipes is not always done end-to-end (linearly). Pipes are laid in ways such as angled turns in different directions, the intersection of pipes coming from different directions, and the joining of pipes of different diameters. In such cases, it is necessary to remove the intersection. Pipes with a wall thickness of more than 5 mm must also be welded. In such cases, we use special beveling methods. The value of the bevel angle is between 50-90".

Fig 1

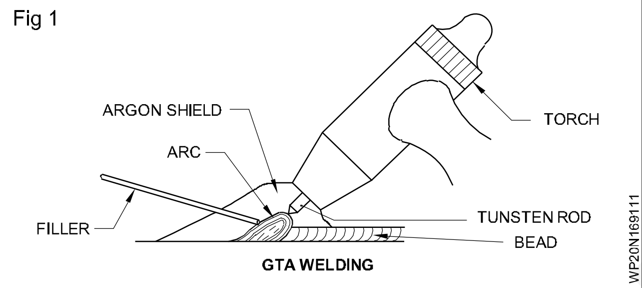


Introduction to GTAW welding - Advantages, Equipment, Electrode

Objectives: At the end of this lesson you shall be able to
- **state the principle of TIG welding process**
- **state its application**
- **identify a TIG welding equipment**
- **name the parts of a TIG welding equipment**
- **state the purpose of different parts.**

Introduction to TIG welding: The Gas Tungsten Arc Welding (GTAW) process fuses metals by heating them between a non consumable (does not melt) tungsten electrode and workpiece. The heat necessary for fusion (mixing or combining of molten metals) is provided by an arcing electric current between the tungsten electrode and the base metal. Fig 1

Fig 1



This type of welding is usually done with a single electrode. The tungsten electrode and the weld zone (area being welded) are shielded from the atmosphere (air around it) by an inert gas, such as argon or helium. Filler metal may or may not be used. This process is also called TIG (Tungsten Inert Gas) welding. Gas tungsten arc welding, is particularly used when welding stainless steel, aluminium, titanium and many other non-ferrous metals.

- An AC or DC arc welding machine. Fig. 2 & 3
- 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 rods
- Optional accessories
- A water cooling system with hoses for heavy duty welding operations
- Foot rheostat (switch)
- Arc timers

Fig 2

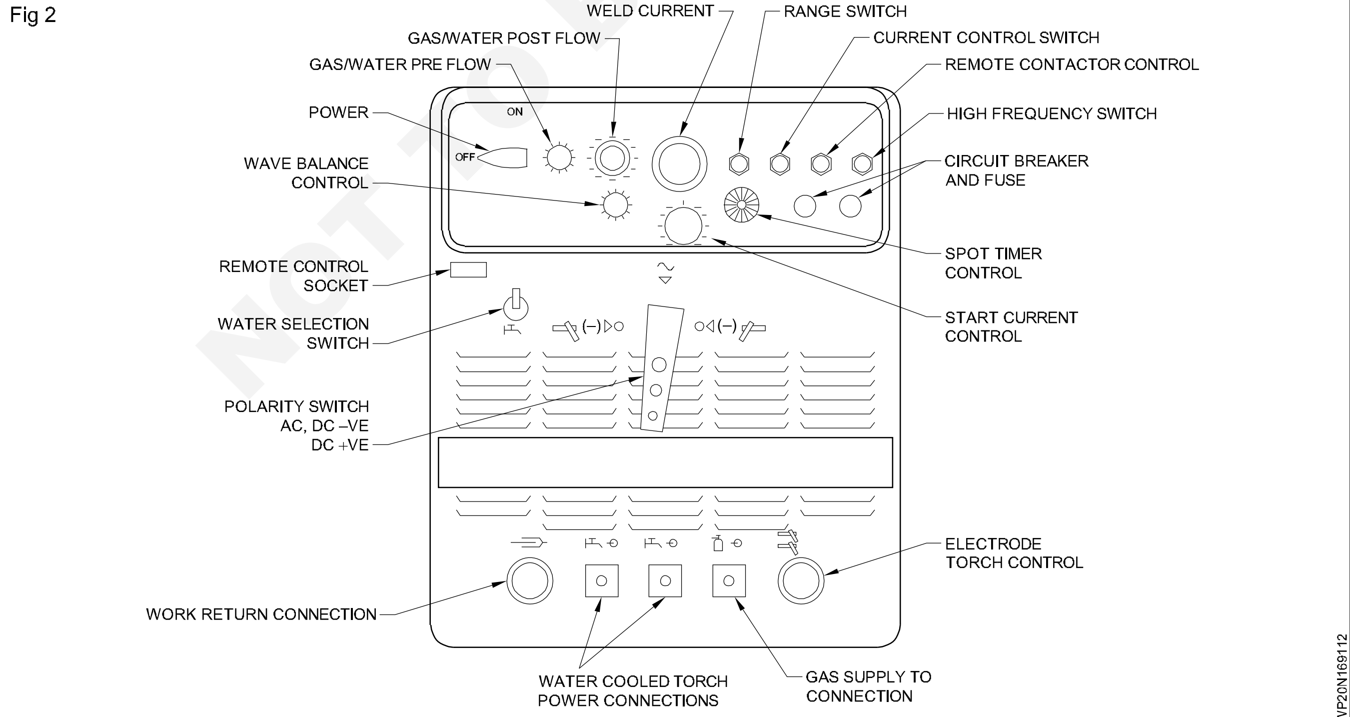
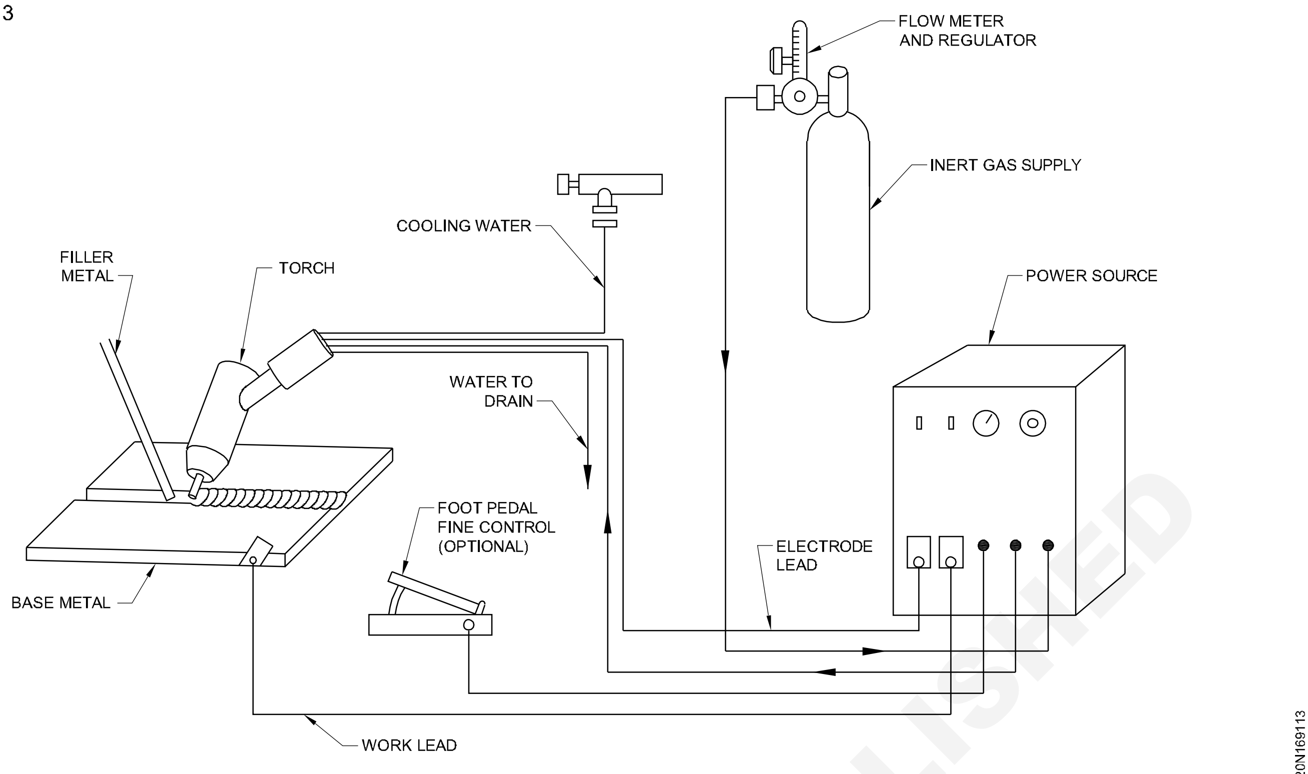


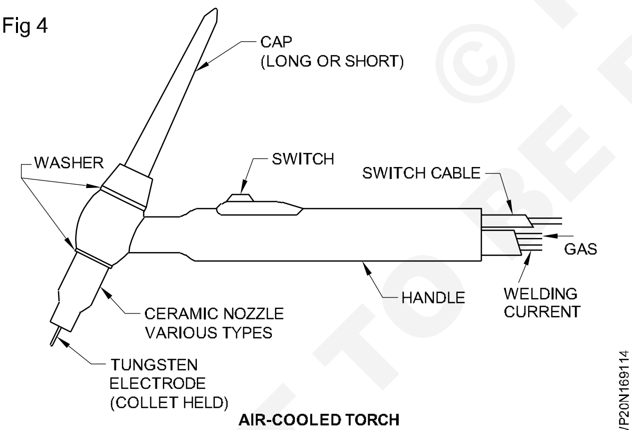
Fig 3



A DIAGRAMMATIC DRAWING OF A COMPLETE GAS TUNGSTEN ARC WELDING

Torch: There is a variety of torches available varying from light weight air cooled to heavy duty water cooled types. Fig 4. The main factors to be considered in choosing a torch are:

Fig 4



AIR-COOLED TORCH

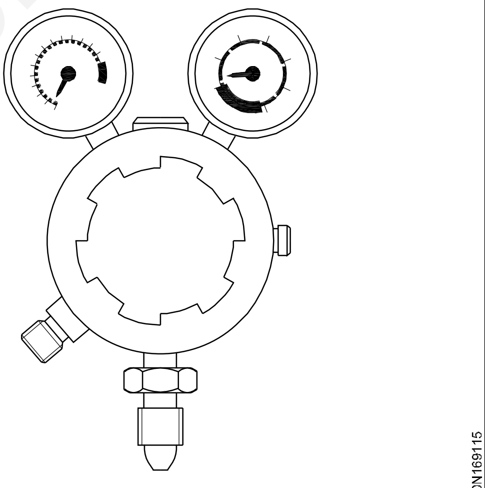
Current carrying capacity for the work in hand

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.

Gas regulator, flowmeter (Figs 5& 6): 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.

Fig 5



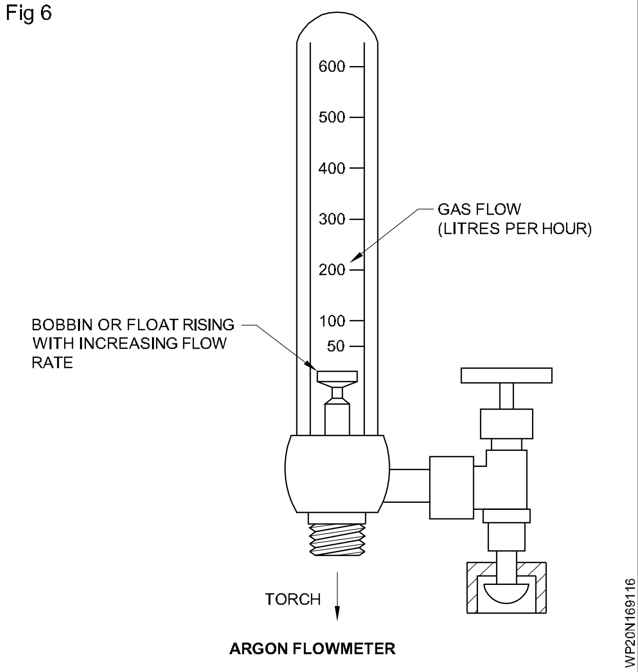
TWO STAGE ARGON REGULATOR

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.

Parts of water cooled torch Fig 7

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

Fig 6



ARGON FLOWMETER

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)

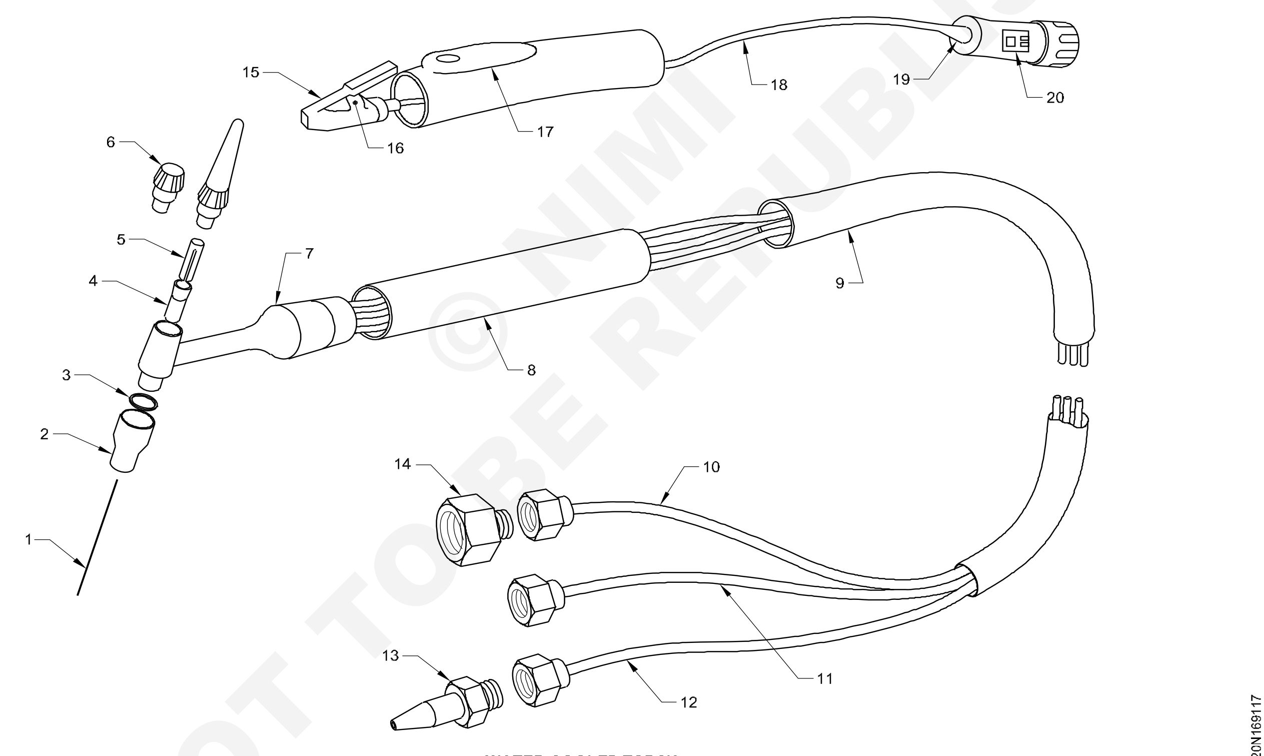
19 Insulating sleeve

20 Plug

TIG welding process

TIG process introduces only heat to the part being welded without depositing the metal. With this process the 'filler' metal is only added when it is needed and this need not be

Fig 7



WATER COOLED TORCH

linked to the welding current.TIG welding process neither adds nor subtracts elements from the metal which it simply brings to fusion.Hence the process is highly suitable for joining reactivemetals like stainless steel, aluminium, magnesium etc.This process is most suitable for the following materials.Stainless steel 0.5-3mm thickness unprepared.Aluminium and its alloys of 1.5 - 8mm thickness.Copper, cupro-nickel and aluminium bronze.Carbon steels and low alloy steels.Highly reactive materials like Titanium and Magnesium and their alloys.TIG welding process offers exceptionally perfect clean weld and an absence of spatter.These advantages make TIG the high quality welding process which is the easiest to automate for the production of joints of small dimensions or very difficult to access.TIG welding process produces sound weld because there is very little smoke, fumes or sparks. Since the shielding gas around the arc is transparent, the welder can observe the weld easily.Arc temperature is as high as 6000^{0}C and hence welding preparations which means more economical use of filler wire and higher welding speed. Shielding gases Argon, Helium are totally inert and non-active. Welding done by this process is always clean and without any oxidation.Suitability for joining/welding reactive materials is excellent.

Power sources

TIG welding power sources have come a long way from the basic transformer types of power sources which were used with add-on units to enable the power source to be used as a TIG unit, eg high frequency unit and/or DC rectifying units.

The basics of TIG welding has almost remained the same, but the advent of technology TIG welding power sources have made the TIG processes more controllable and more portable.

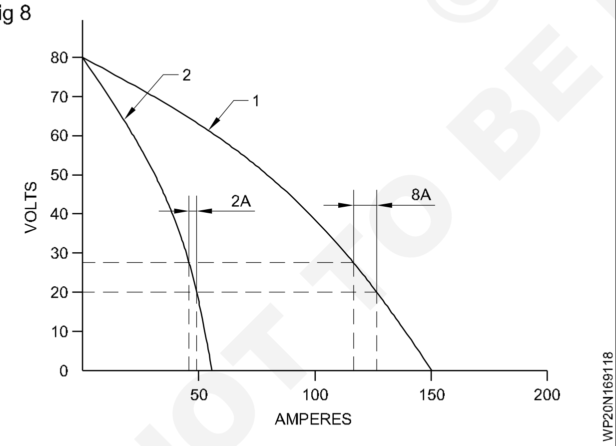
The one thing that all TIGs have in common is that they are CC (Constant Current) type power sources. This means only output adjustment will control the power source amps. The voltage will be up or down depending on the resistance of the welding arc.

Characteristerics of power fource :The output slope or voltampere curve A, a change from 20 volts to 25 volts will result in a decrease in amperage from 135 amps to 126 amps. With a change of 25 percent in voltage, only a 6.7 percent change occurs in the welding current in curve A. Thus if the welder varies the length of the arc, causing a change in voltage, there will be very little change in the current and the weld quality will be maintained. The current in this machine, even though it varies slightly is considered constant (Fig 1).

This is called drooping characteristic power source. Also called constant current (CC)power source.

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

Fig 8

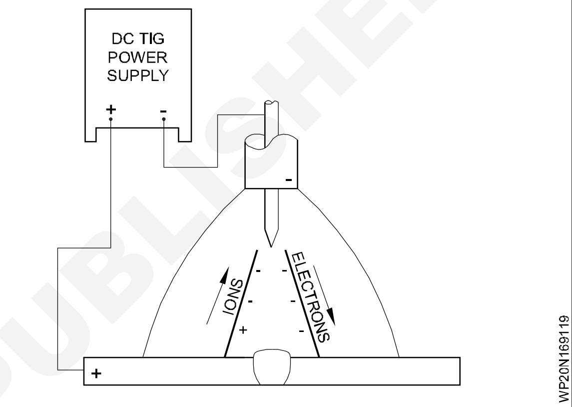


Types of welding current used for GTAW

When TIG welding, there are three choices of welding current. They are: Direct Current Straight Polarity, Direct Current Reverse Polarity, and Alternating Current with High Frequency stabilisation. Each of these has its applications, advantages, and disadvantages. A look at each type and its uses will help the operator select the best current type for the job. The type of current used will have a great effect on the penetration pattern as well as the bead configuration. The diagrams below, show arc characteristics of each current polarity type.

DCSP - Direct Current Straight Polarity (Fig 2) : (The tungsten electrode is connected to the negative terminal). This type of connection is the most widely used in the DC type welding current connections. With the tungsten being connected to the negative terminal it will only receive 30% of the welding energy (heat). This means the tungsten will run a lot cooler than DCRP. The resulting weld will have good penetration and a narrow profile.

Fig 9



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

DCRP - Direct Current Reverse Polarity (Fig 3) : (the tungsten electrode is connected to the positive terminal). This type of connection is used very rarely because most heat is on the tungsten, thus the tungsten can easily overheat and burn away. DCRP produces a shallow, wide profile and is mainly used on very light material at low amps.

GTAW Torches

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

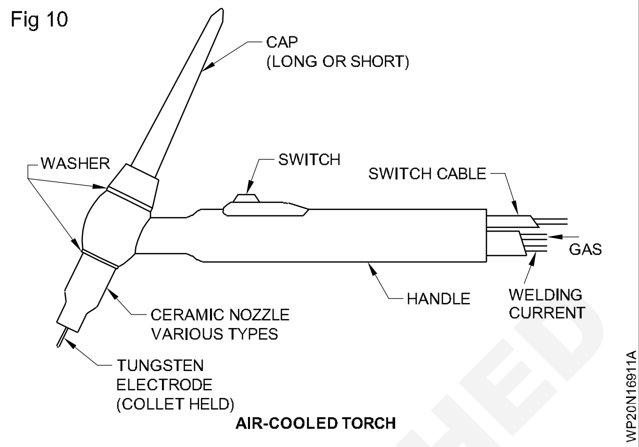
Torch: There is a variety of torches available varying from light weight air cooled to heavy duty water cooled types. Fig.1 & 2. The main factors to be considered in choosing a torch are:

- Current carrying capacity for the work in hand

- Weight, balance and accessibility of the torch head to the work in hand.

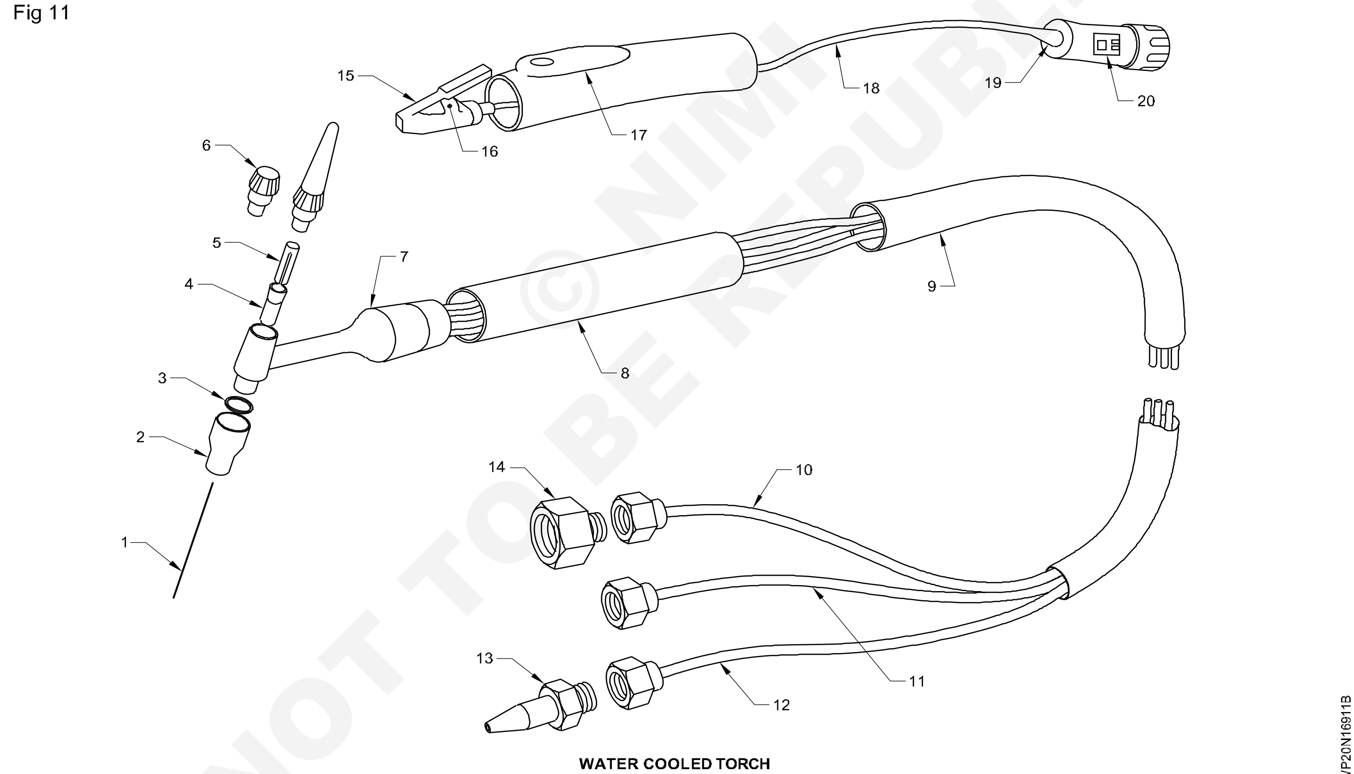
The torch body holds a top loading compression-type collet assembly which accommodates electrodes of various diameters. They are securely gripped, yet the collet is easily slackened for removal or reposition of the electrode. As the thickness of plate to be welded increases, size of torch and electrode diameter must increase to deal with the larger welding currents required.

Fig 10



AIR-COOLED TORCH

Fig 11



WATER COOLED TORCH

Parts of water cooled torch Fig 2

1 Thoriated or Zirconiated tungsten electrode
2 Ceramic shield/nozzle
3 "O" ring
4 Collet holder
5 Collet
6 Electrode cap (short & long)
7 Body assembly
8 Sheath
9 Hose assembly cover
10 Argon hose assembly
11 Water hose assembly
12 Power cable assembly
13 Adaptor (power cable)
14 Adaptor (argon gas hose)
15 Switch actuator
16 Switch
17 Switch retaining sheath
18 Cable (2 core)
19 Insulating sleeve
20 Plug

The function of the TIG torch is to

1 hold the electrode tungsten
2 deliver welding current to the tungsten via a welding power cable
3 deliver shielding gas to the TIG torch nozzle. The nozzle then directs the shielding gas to cover the weldpool protecting it from contamination from the surrounding air.
4 often will be the way of getting the welder control circuit to the operation, eg on/off and/or amperage control.
5 the TIG torch can be watercooled. Hoses in the TIG lead will supply cooling water to the TIG torch head assembly.
6 the TIG torch length will allow a distance from the TIG power source and workpiece.

TIG torches come in different styles depending on the brand being selected. But they all have things in common -

1 aircooled or watercooled
2 current rating. The operator must select the correct amperage rating TIG torch.

Cooling of the TIG torch

Some torches are constructed in such a way that it is the flowing shielding gas that cools the torch. However, the torch also gives off heat to the surrounding air.

Other torches are constructed with cooling tubes. Water-cooled torches are mainly used for welding with larger current intensities and AC-welding.

Usually a water-cooled TIG torch is smaller than an air-cooled torch designed to the same maximum current intensities

Using a TIG torch that is not sufficiently rated for the machine may result in the TIG torch overheating. A TIG torch wiith an excessive rating may be larger and heavier than a lower amperage TIG torch.

The TIG torch is made up of

1 **Leads -** The lead will be set up for either aircooled or watercooled. It will be at a length suitable to do the job, eg 4 metre, 8 metre, etc. The lead will be made up of a power cable, gas hose and water leads in and out if the TIG torch is watercooled. The lead may also include a control lead.
2 **Collet -** To hold the tungstan rods. Collet may vary with different brands of TIG torches.
3 **Ceramic Nozzles -** The nozzle's job is to direct the correct gas flow over the weldpool.
4 **Back Caps -** The back cap is the storage area for excess tungsten. They can come in different lengths depending on the space the torch may have to get into (eg. long, medium and short caps).

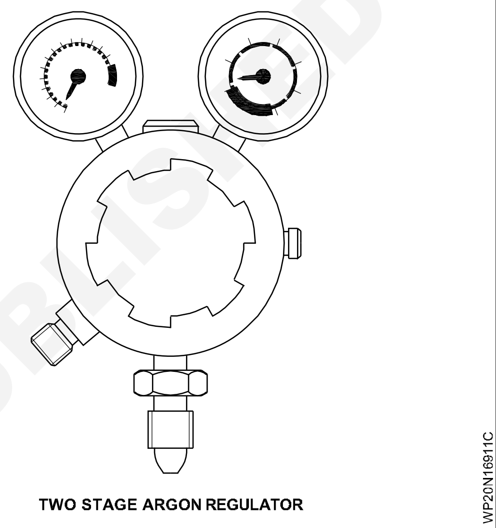
Please make sure when ordering a TIG torch to tell the supplier the amperage rating, whether water- or air-cooled, and the fitting that is to go on the end of the TIG torch lead suitable to fit the TIG power source it will be used from. This may include power cable fit up, gas fittings and control plug fittings.

Gas Regulator & Flowmeter

Gas regulator, flowmeter (Fig 3 & 4): The gas regulator reduces the pressure in the argon cylinder from 175 or 200 bar down to 0-3.5 bar for supply to the torch.

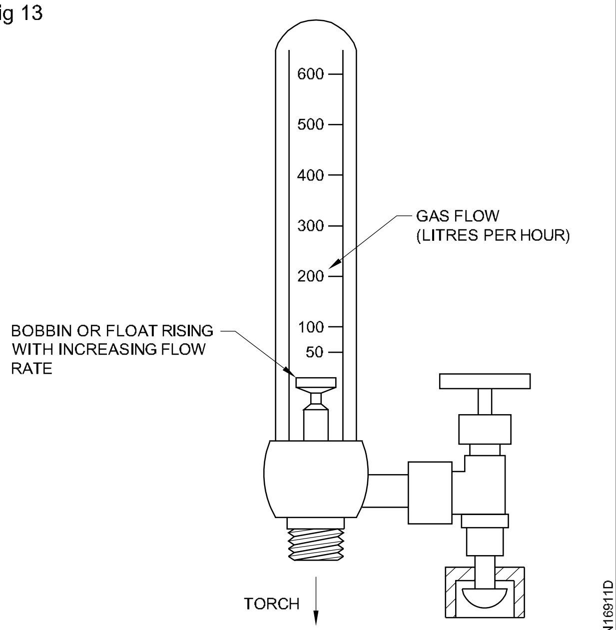
The flowmeter which has a manually operated needle valve, controls the argon flow from 0-600 litres/hour to 0-2100 litres/hour according to type.

Fig 12



TWO STAGE ARGON REGULATOR

Fig 13



ARGON FLOWMETER

GTAW electrodes

Objectives: At the end of this lesson you shall be able to
- **state the types of electrodes**
- **state the colour codification.**

Electrodes for TIG Welding

For TIG welding the applied electrode is mainly made of tungsten.

Pure tungsten is a very heat resistance material with a fusion point of approximately 3,380^{0}C.

By alloying tungsten with a few per cent of a metal oxide the conductivity of the electrode can be increased which has the advantage that it can thereby resist a higher current load.

The alloyed tungsten electrodes therefore have a longer lifetime and better ignition properties than electrodes of pure tungsten.

The most frequently used metal oxides used for alloying of tungsten are:

- Thorium oxide 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

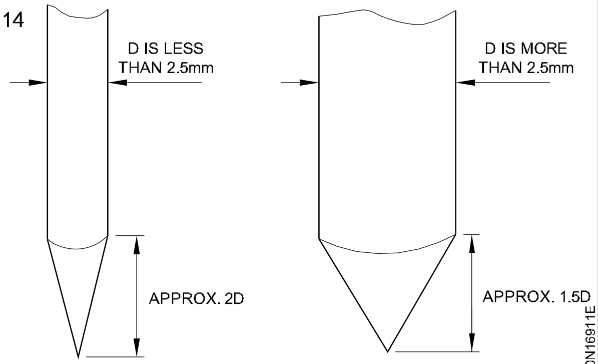
An important condition for obtaining a good result of TIG welding is that the point of the tungsten electrode must be ground correctly.

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).

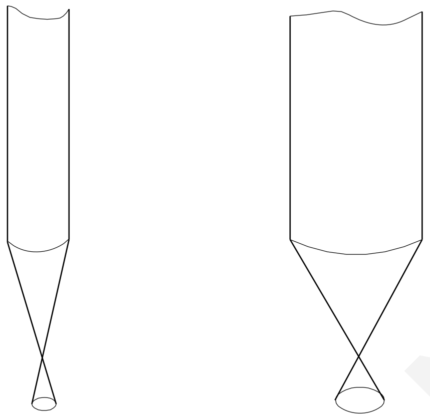
Fig 14



EXAMPLE OF GRINDING OF TUNGSTEN ELECTRODES FOR DC WELDING

The pointed angle also has an influence of the penetration depth of the weld (Fig 2).

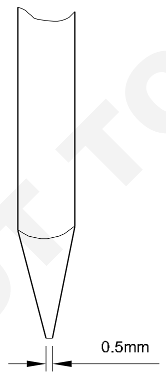
Fig 15



CONNECTION BETWEEN THE POINTED ANGLE AND THE WELD POOL

Blunting the electrode point to make a flat area with a diameter of about 0.5 mm can increase the lifetime of the tungsten electrode (Fig 3).

Fig 16



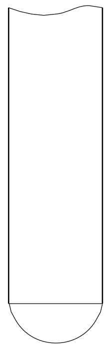
FLAT ELECTRODE POINT

For AC TIG welding the tungsten electrode is rounded as during the welding process it is so heavily loaded that it is melted into a half globular form (Fig 4).

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 17



TUNGSTEN ELECTRODE FOR AC WELDING

Fig 18

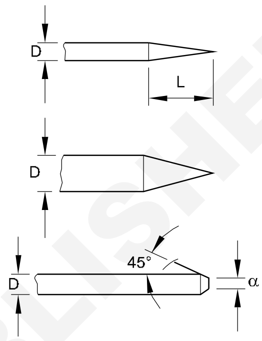
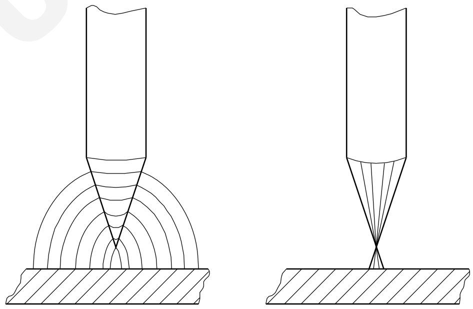
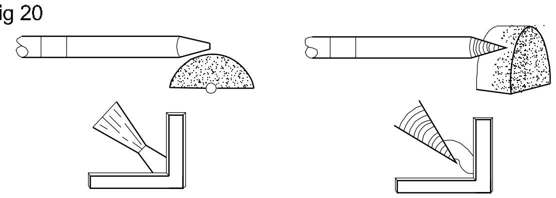


Fig 19



WRONG GRINDING RIGHT GRINDING

Fig 20



IDEAL TUNGSTEN PREPARATION STABLE ARC

WRONG TUNGSTEN PREPARATION WANDERING ARC

Electrode condition: Fig. 8 shows tungsten electrode conditions associated with TIG welding.

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 With alternating current, the tip of the flat cylindrical electrode melts slightly taking on a hemispherical shape (called 'ball shape' by welders) which is considered desirable for welding aluminium and magnesium. (Fig. 1b) If a droplet shape is formed, it indicates that the recommended current density limit has been exceeded.

Penetration and bead width of the weld are directly influenced by the cone angle of the electrode tip.

With direct current, thoriated tungsten electrodes must be pointed, especially if the current density is low. The smaller the cone angle the deeper the penetration.

Increasing the cone angle between 30° and 120° produces a decrease in bead width. It can be shown that the decrease is greater than the root width for angles greater than 60. For general use with direct current (electrode negative), the following angles are widely adopted.

For edge welds: full penetration using currents of 50-200A: 30° - 60°

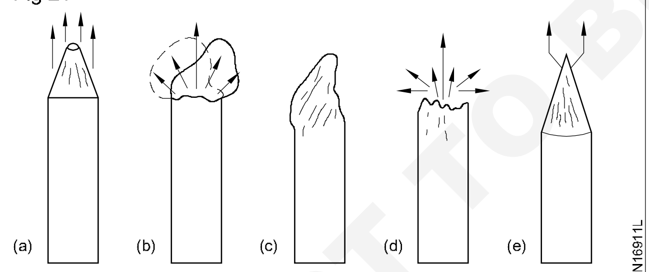
For edge welds: full penetration with tighter preparation tolerances and currents of 50-200A: 90° - 120°.

Current density: The table below gives acceptable operating current ranges for different electrode diameters, according to their type and the current form.

mm	Alternating current		Direct current (electrode negative)	
	Pure tungsten	Thoriated tungsten	Pure tungsten	Thoriated tungsten
1	5-50A	8-70	10-70A	10-80A
1.6	40-80A	50-100A	50-100A	50-120A
2	60-110A	60-180A	90-160A	90-190A
3	90-180A	150-270A	140-260A	170-300A
4	160-240A	220-320A	220-380A	260-450A
5	200-340A	300-400A	350-550A	400-650A
6	300-450A	350-550A	500-700A	600-800A
7	400-600A	500-700A		
8	550-750A	650-800A		

Electrode condition: Fig.2 shows tungsten electrode conditions associated with TIG welding.

Fig 21



SEVERAL ELECTRODE CONDITIONS OBSERVED DURING TIG

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 'virbrates' during welding. Welding is therefore difficult, if not impossible.

c The electrode has been used without protection of argon shielding gas. The flow has been cut off too soon. The electrode has turned blue, is contaminated with oxygen and disintegrates rapidly. It is necessary to reshape it.

d This fault occurs mostly in the welding of light alloys with an electrode of thoriated tungsten and a low current. The current must be increased to form a ball shape at the electrode tip. If this is not done the arc will remain 'erratic.

e Electrode point too sharp. Rapid wear occurs since the point carries current densities which are too high. This leads to systematic inclusions of tungsten in the weld which are highly visible on radiographics.

Shielding Gases used for GTAW

Objectives: At the end of this lesson you shall be able to
- **state the properties of argon gas**
- **compare the performance characteristics of argon and helium gas for TIG welding**
- **identify an argon gas cylinder and ceramic nozzles**
- **state the uses of argon and helium gas.**

hielding 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.

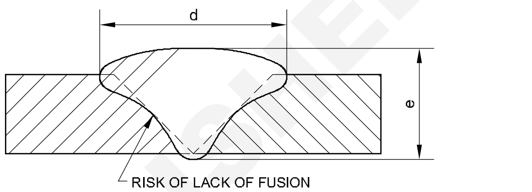
Quality : Argon gas of welding quality should be used.

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



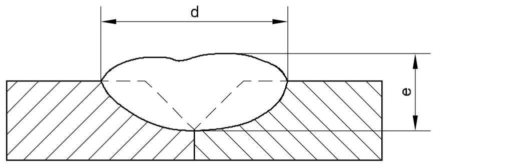
PROFILE TYPICAL OF ARGON SHIELDED WELD ($\frac{d}{e}$ = 2.5)

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)

Argon gas gives more penetration than helium gas.

Characteristics and comparative performance of argon and helium as shielding gases

Argon

Low arc voltage : Results in less heat; thus argon is used almost exclusively for manual welding of metals less than 1.6mm thick.

Good cleaning action: Preferred for metals with refractory oxide skins, such as aluminium alloys or ferrous alloys containing a high percentage of aluminium.

Easy arc starting: Particularly important in welding of thin metal.

three times the tungsten diameter to provide adequate shielding gas coverage. (For example, if tungsten is 1.6 mm diameter, gas cup should be a minimum of 5 mm. diameter.

Tungsten extension is the distance the tungsten extends out gas cup of torch.

The tungsten extension should be no greater than the inside diameter of the gas cup.

Arc length is the distance from the tungsten to the workpiece.

Tungsten Tip Preparation (Fig 2)
Tungsten Extension (Fig 3)
Tungsten Grinding

Shape by grinding longitudinally (never radially). Remove the sharp point to leave a truncated point with a flat spot. Diameter of flat spot determines amperage capacity.

The included angle determines weld bead shape and size. Generally, as the included angle increases, penetration increases and bead width decreases.

Use a medium (60 grit or finer) aluminium oxide wheel.

Comparision Between Argon and Helium Shielding

Argon	Helium
1 Smoother arc.	1 Smaller heat affected zone.
2 Easy starting.	2 Best for thicker metal welding due to higher arc voltage.
3 Best for thinner metal welding due to lower arc voltage.	3 Better for welding at higher speed.
4 Good cleaning action while welding Al.	4 Gives better coverage in vertical and overhead positions.
5 Heavier than air - Lower flow rates.	5 When used in back shieldings flatens the root face.
6 Lowe cost, more availability.	
7 Better for welding dissimilar metals.	
8 Better control of puddle on positional joints.	

CG & M Welder (Pipe) - GTAW & GMAW — Related Theory for Exercise 1.6.97

Importance of Preheating, Post Heating and Post Weld Heat Treatment

Objectives: At the end of this lesson you shall be able to
- **At the end of this lesson you shall be able to**
- **Explain the effects of weldable quality on ferreres and non-ferrous metals.**
- **State the purpose of preheating**
- **Explain the method of preheating**
- **Describe the types of preheating**
- **Explain the purpose of post-heating a bigger Job**
- **Describe the maintenance of inter-pass temperature**

Refer Lesson 1.3.46

Welding Metallurgy - Weld Stress

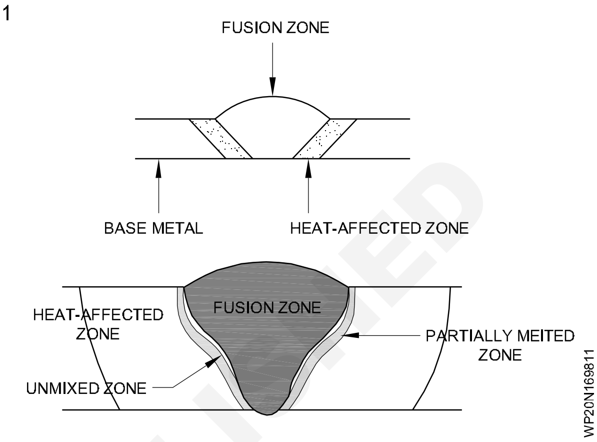
Objectives: At the end of this lesson you shall be able to
- **state the basic Metallurgy**
- **explain the process of Metallurgy.**

Metallurgy is the science and study of metals, especially involving welding. Everyone should know basic metallurgy before they weld. When welding, you can alter the steel you are working on affecting it adversely. A good example is stainless which is alloyed with chromium to make it rust-resistant, and nickel to make it hard. If you burn the chromium out of the steel when welding, it will then rust. Stainless will also warp very easily from the heat if precautions are not taken.Welding metallurgy involves the chemical, mechanical, and physical properties of metals.Chemical-One form of chemical metallurgy most everyone has heard of is rust. Rust is the oxidation of metal, or where oxygen gets into the metal and corrodes it. There is also corrosion where the atmosphere wastes away the metal. And in welding we are concerned with reduction, which is the removal of oxygen from the molten puddle.Mechanical - Mechanical metallurgy involves the way that metal acts under stresses and loads. Welding rods are numbered with the first 2 or 3 numbers telling the tensile strength of the rod per square inch of deposited metal. Tensile strength is the ability to resist being pulled apart. There are many different loads and stresses involving brittleness, toughness, ductility, malleability, plasticity, shear, and others.Physical - Physical properties in metallurgy involve the metals being affected by the heat applied when Grain size affects strength in metals, and grain size can be affected when welding. A good welder needs to know the thermal conductivity, melting point, and grain characteristics of the metal they are going to weld on.Welding metallurgy describes a microcosm of metallurgical processes occurring in and around a weld that influence the microstructure, properties, and weldability of the material due to the rapid heating and cooling rates associated with most welding processes, metallurgical reactions often occur under transient, non- equilibrium conditions.

The cooling rate and chemical composition affect the microstructure of the welded joint. The mechanical properties of a welded joint depend on the microstructure produced by welding are melting and solidification Metallurgical Processes Nucleation and growth Phase transformations Segregation and diffusion Precipitation Recrystallization and grain growth Liquation mechanisms Embrittlement Thermal expansion, contraction, and residual stress The microstructure can vary from region to region in a weld & Microstructure has a profound effect on weld properties.

Region of the weld that is completely melted and resolidified Microstructure dependent on composition and solidification conditions Local variations in composition Distinct from other regions of the weld

Fig 1



May exhibit three regions

- Composite zone
- Transition zone
- Unmixed zone

Material properties

- Melting point
- Thermal conductivity
- Surface tension
- Marangoni effect

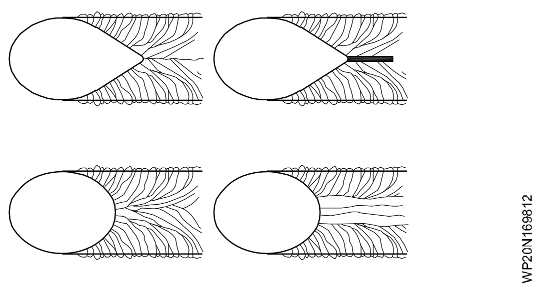
Process parameters - Heat input

Travel speed

Heat flow conditions

- 2-D (full penetration)
- 3-D (partial penetration)

Fig 2



Distortion and Control

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

Refer Lesson 1.2.33

Flux Cored Arc Welding (FCAW)

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

Flux Cored Arc Welding (FCAW) Fig.1 is an arc welding process in which the heat for welding is produced by an arc established between the flux cored tubular consumable electrode wire and the workpiece.

There are two major versions of the process, namely self shielded type (in which the flux performs all the functions of shielding) and the 'gas shielded type', which requires additional gas shielding.

The gas shielded type FCAW is widely employed for welding of carbon steel, low alloy steel and stainless steel in flat, horizontal and overhead positions.

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)

Classification of flux cored wires: The basic functions of the flux contained within the tubular wire include providing protective slag on the weld bead, introducing the required alloying elements and deoxygenerators into the weld pool and providing stability to the arc, besides producing the required shielding medium to protect the arc and weld pool.

Flux cored wires are now available for welding of plain carbon steel, low alloy steel and stainless steel and also for hard facing applications. These wires based on the nature of flux, may be classified as rutile gas shielded, basic gas shielded, metal cored and self shielded.

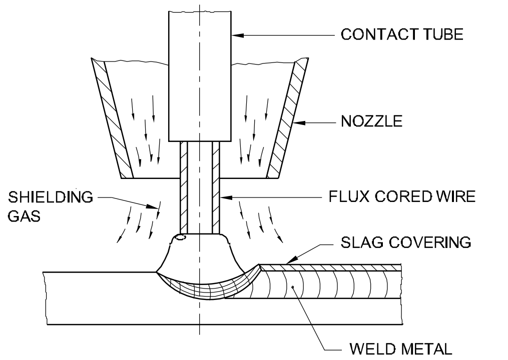
Rutile gas shielded wires have extremely good arc running characteristics, excellent positional welding capabilities and good slag removal and mechanical properties.

Basic gas shielded wires give reasonable arc characteristics, excellent tolerance to operating parameters and very good mechanical properties.

Metal cored wires contain very little mineral flux, the major constituent being iron powder and ferro alloys. These wires give smooth spray transfer in Argon/CO_2 gas mixtures. They generate minimum slag and are suitable for mechanised welding applications. Self shielded wires are available for general purpose down hand welding.

The flux cored wires are available in both seamless and folded types. The seamless type is generally coated with copper, whereas the folded type wires (i.e. close butt and overlapped type) are treated with special compounds.

Fig 1



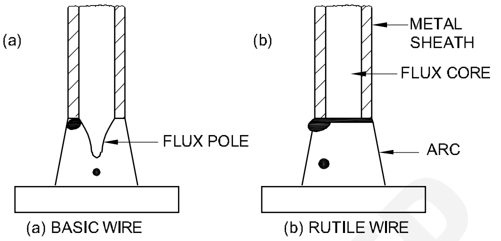
FLUX CORED ARC WELDING

Deposition rate and efficiency: Deposition rate is defined as the weight of metal deposited per unit time. The deposition efficiency is defined as the ratio of weight of weld metal effectively deposited to the weight of wire consumed.

In GMAW welding the deposition efficiency is generally between 93% to 97% and in FCAW the corresponding figure is between 80% to 86%. These values are determined by the spatter losses and slag formation. The low deposition efficiency in the case FCAW is due to the slag formation.

Generally the spatter loss can be minimised by using Argon/CO_2 mixed gas instead of CO_2 gas.

Fig 2



APPEARANCE OF FLUX POLE

Introduction to GMAW & Flex cored arc welding, equipment accessories

Objectives: At the end of this lesson you shall be able to
- **state the main difference between shielded metal arc welding and Co_2 welding**
- **state the principle of Co_2 welding.**

Introduction to Co_2 welding: Fusion welding of metal plates and sheets is the best method of joining metals because in this process the welded joint will possess the same properties and strength as the base metal.

Without a perfectly shielded arc and molten puddle, the atmospheric oxygen and nitrogen will get absorbed by the molten metal. This will result in weak and porous welds.

In shielded metal arc welding (SMAW) the arc and molten metal are protected/shielded by the gases produced by the burning of the flux coated on the electrode.

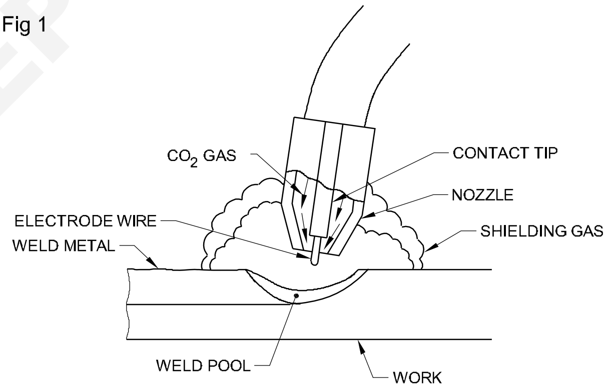
The above mentioned shielding action can be done by passing an inert gas such as argon, helium, carbon-dioxide through the welding torch/gun. The arc is produced between the base metal and a bare wire consumable electrode fed continously through the torch.

Principle of GMA welding: In this welding process, an arc is struck between a continuously fed consumable bare wire electrode and the base metal. The heated base metal, the molten filler metal and the arc are shielded by the flow of inert/noninert gas passing through the welding torch/gun. (Fig.1)

If an inert gas is used to protect the arc produced by a consumable metal electrode, this process is called Metal Inert Gas Welding (MIG).

When carbon-dioxide is used for shielding purposes, it is not fully inert and it partly becomes an active gas. So Co_2 welding is also called as Metal Active Gas (MAG) welding.

Fig 1



PRINCIPLE OF CO_2 WELDING

MIG/MAG welding is a name with respect to gas used for shields purpose

On the other hand Gas Metal Arc Welding is the common name.

Basic Equipment for a Typical GMAW Semiau- Tomatic Setup (Fig 2)

- Welding Power Source - provides welding power.
- Wire Feeders - controls supply of wire to welding gun.
- Supply of Electrode Wire.
- Welding Gun - delivers electrode wire and shielding gas to the weld puddle.
- Shielding Gas Cylinder - provides a supply of shielding gas to the arc.

GMAW wire feed unit

Objectives: At the end of this lesson you shall be able to
- **state the functions of wire feeder and different types of drive rollers.**

Wire Feeder (Fig 1)

The wire feeder is the part of the MIG/MAG welding set up that:

i Controls the speed of the wire electrode and pushes this wire from the feeder through the welding torch to the workpiece.

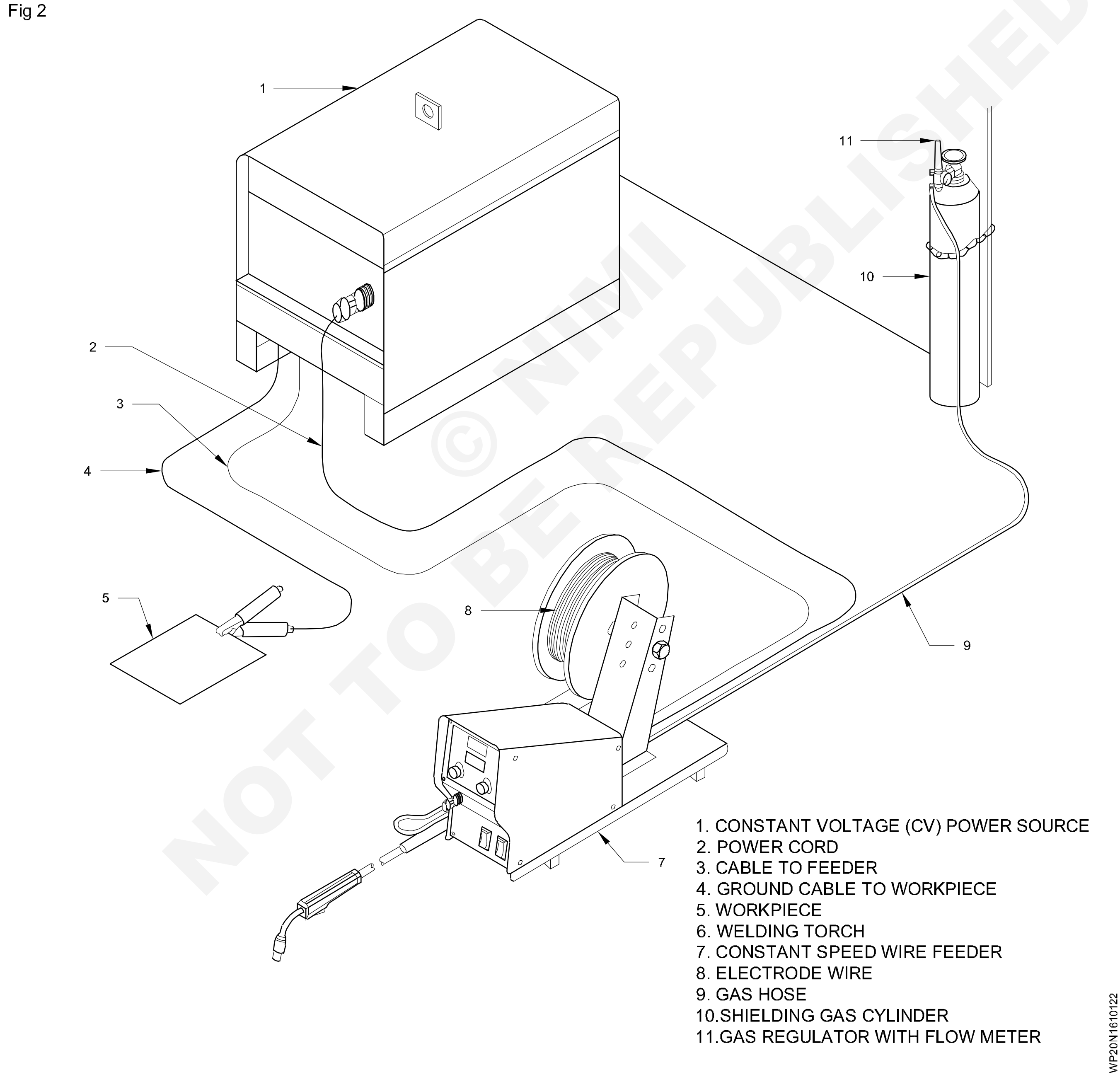
ii Provides the path for welding current to be passed from the welding power source through the interconnecting lead to the feeder and then to the welding torch.

iii Provides gas flow control through a solenoid valve. The gas is fed down from the gas regulator to the weld area via the feeder and then the MIG welding torch.

Wire feeders come in many different shapes and sizes, but they all do the same basic job roles. Feeders can be separated from the power source or built into the power source itself. Feeders are made up of different parts, each having a different job role.

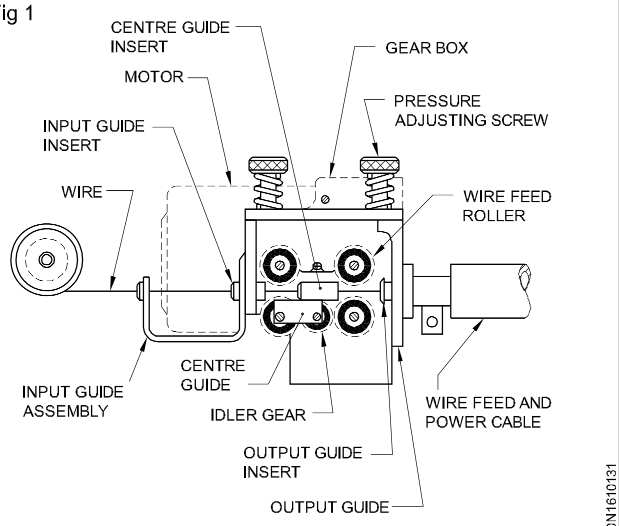
Wire spool holder. This is designed to hold the spool of the correct wire size in place on the feeder to ensure the wire electrode is on the correct input angle for the drive roller to be able to do its job properly.

Fig 2



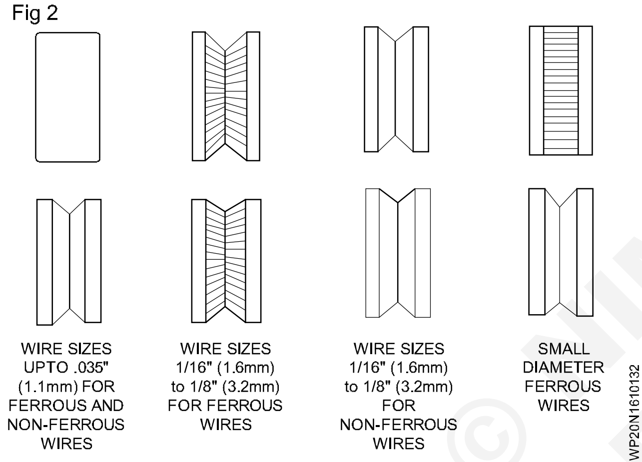
Drive Motor MIG/MAG welding relies on smooth and constant wire feed. The wire drive motor has the job of turning the drive rollers (this can be one or more sets of

Fig 1



A SIMPLIFIED WIRE FEED MECHANISM FOR GMAW

Fig 2



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 & 2A). The rollers need to be selected by :

i the wire size

ii the type of wire to be fed. Each type of wire may need a different style of roller groove – eg

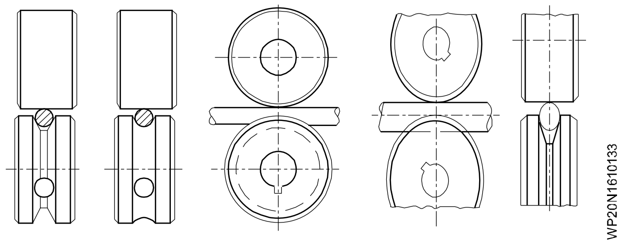
V rollers for steel and other hard wires

V-Knurled for Fluxcored wire

U-Grooved for aluminium and other soft wires

The idea of using the correct roller is to have a good wire drive without crushing the wire. The pressure roller is also

Fig 3



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.

All the wire guides on the input and output side of rollers must be

i lined up to feed the wire straight into the rollers

ii lined up in a way as to make sure the wire is lined with the grooves in the drive rollers

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

Wire Feed Controls

The wire feeder will have its own built-in control system. The number of controls that will be built into the feeder will depend on the type of feeder but the most common are

i) **Wire speed** – this control is the adjustment for how fast the drive rollers will turn and as stated earlier, the faster the wire speed for each wire size the more amperage the power source will produce. The wire speed controls can be labelled as wire speed, eg ipm (inches per minute) or mpm(metre per minute), or as a percentage from the slowest speed being zero to the highest speed being 100%. Usually mpm will be the range of 1 m/min to 25 m/min.

The amperage being set by the wire speed setting will also have an effect on the speed of travel and the deposition rate of the wire (how fast the weld metal is being put onto the weldpiece); with the advantage of, the higher the amperage the thicker the material that can be welded.

ii) **Purge switch**. Some feeders have a purge switch. This is to allow the gas flow setting to be set on the gas regulator without turning of the wire feed roller or without any welding power being turned on.

iii) **Burnback.** Burnback is the setting of the degree that the wire electrode will melt back towards the contact tip at the completion of the weld. If there is too much burnback the wire electrode will melt back onto the contact tip, possibly damaging it. If there is not enough burnback set, the wire electrode will not melt away from the weldpool and can be left stuck to the weld metal.

iii) **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 equipment and accessories

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

MIG welding power sources have come a long way from the basic transformer type power source to the highly electronic and sophisticated types we see around today.

Even though the technology of MIG welding has changed, the principles of the MIG power source have, in most cases, not. The MIG power sources use mains power and converts that mains power into CV (constant voltage), DC (direct current) power suitable for the MIG welding process.

MIG welding power sources control voltage – this is done by either voltage stepped switches, wind handles, or electronically. The amperage that the power source produces is controlled by the cross sectional area of the wire electrode and the wire speed, ie the higher the wire speed for each wire size, the higher the amperage the power source will produce.

Because the output of the MIG power source is DC (direct current) the terminals on the front will have + positive and negative on the output side. The principles of electric circuits states that 70% of the heat is always on the positive side.

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

The characteristics volt, ampere curves (A & B) are shown in Fig.1.

Curve A (For SMAW): On the output slope or voltampere curve A, a change from 20 volts to 25 volts will result in a decrease in amperage from 135 amps to 126 amps. With a change of 25 percent in voltage, only a 6.7 percent change occurs in the welding current in curve A. Thus if the welder varies the length of the arc, causing a change in voltage, there will be very little change in the current and the weld quality will be maintained. The current in this machine, even though it varies slightly is considered constant.

This is called drooping characteristic power source. Also called constant current (CC)power source.

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

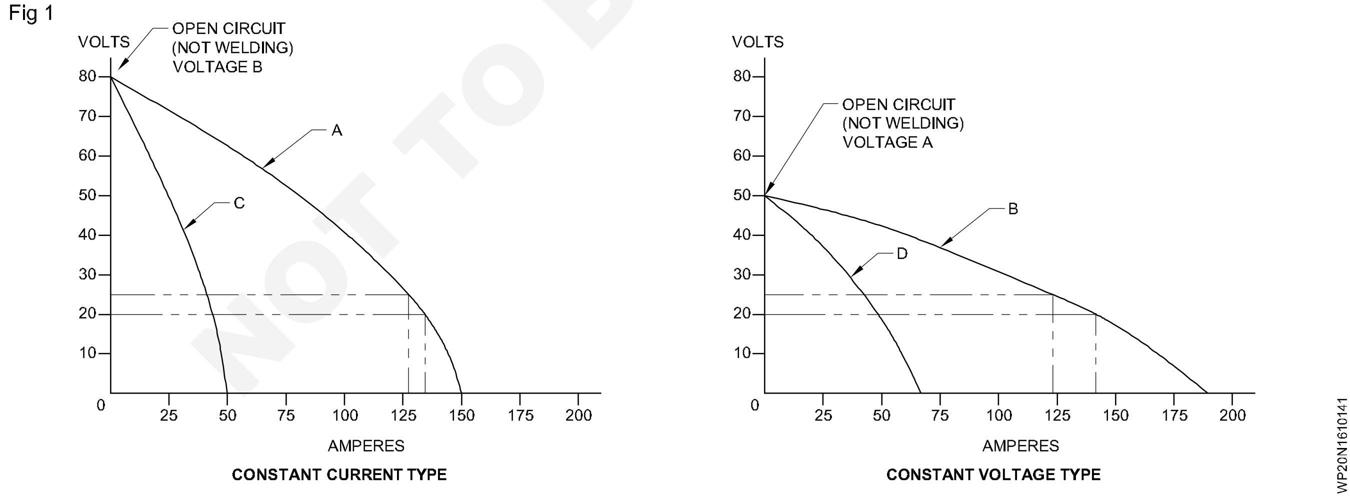
Curve B (For GMAW): The open circuit voltage curve for a setting of 50 volts on the machine is shown as curve B in the Fig.1. The same 20 volt to 25 volt (25 percent) change in the welding voltage will result in a drop in current from 142 amps to 124 amps or 13.3 percent. This slower sloping volt ampere curve output causes a large change in amperage with the same small change in voltage. A welder may wish to have this slower sloping (flatter) volt-ampere output curve.

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

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

With a flatter output slope the welder can control the molten pool and electrode melt rate by making small changes in the arc length. Control of the molten pool and electrode melt rate are most important when welding in the horizontal, vertical and overhead positions.

Fig 1



Advantages, disadvantages of GMAW over SMAW process and applications

Objectives: At the end of this lesson you shall be able to
- **state the advantages and disadvantages of Co_2 welding over shielded metal arc welding process**
- **state the applications of Co_2 welding.**

Advantages: Welding is economical due to less edge preparation and no stub loss.

Produces joints with deep penetration.

Thin and thick materials can be welded.

It can be used for welding of carbon steels, alloy steel, stainless steel, copper and its alloys, aluminium and its alloys.

Welding in all positions can be done.

Deposition rate is more.

No solid flux is used. So needs no cleaning of slag after each run.

Reduced distortion.

Disadvantages

Welding equipment is costly, more complex and less portable.

Since air drifts may disturb free flow of the shielding gas, GMAW may not work well in outdoor welding.

Applications: This process can be used for welding carbon, steel alloy steels, stainless steel, aluminium, copper, nickel and their alloys, titanium etc.

Light and heavy fabrication work.

This process is successfully used in ship building fabrication of pressure vessels and automobile industries.

Shielding gases for GMAW

Objectives: At the end of this lesson you shall be able to
- **state the different types of shielding gases used in Gas Metal Arc Welding (GMAW) process**
- **state the effects of different shielded gases and gas mixtures on ferrous and non-ferrous metals**
- **select the inert gas or gas mixtures for welding different metals using different modes of metal transfer**
- **explain why a gas heater is used in Co_2 welding plant.**

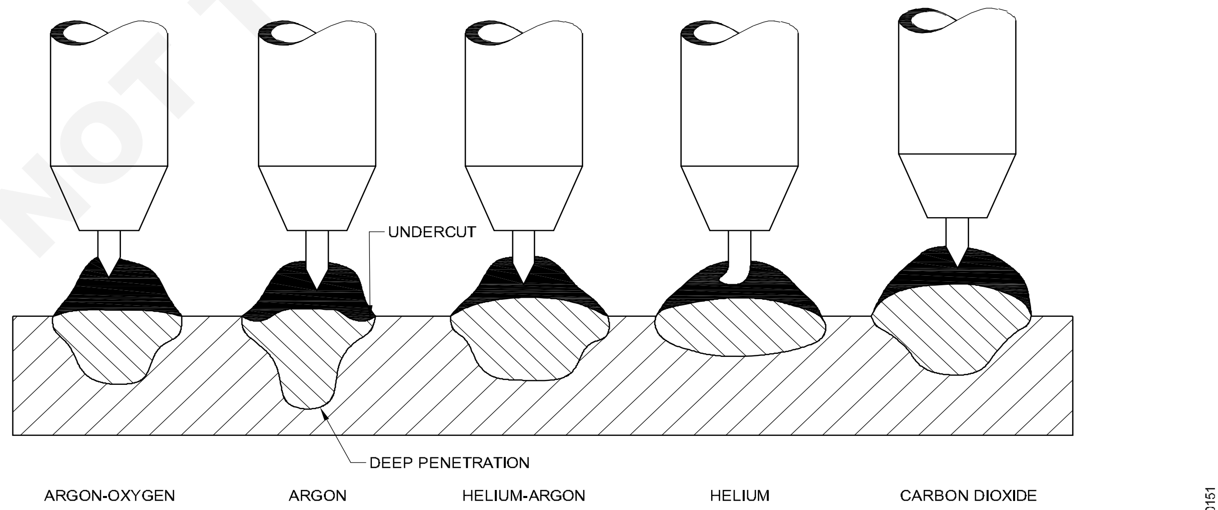
There are three types of shielding gases used for GMAW. They are inert gases, reactive gases and gas mixtures.

Inert gases: Pure Argon and Helium gas are excellent for protecting the arc, metal electrode and weld metal from contamination. Argon and helium are generally used for GMAW of non ferrous metals. Helium has very good conductivity and conducts heat better than argon. Therefore helium is choosen for welding thicker metals as well as high conductivity metals like copper and aluminium.

For thinner metal welding, lower conductivity argon is the better choice. Also argon is often used for welding out of position because of its lower thermal conductivity. Argon gas is 10 times heavier than helium gas, hence less argon gas is required to provide a good shield as compared to helium gas.

The weld bead contour and penetration are also affected by the gas used. Welds made with argon generally have deeper penetration. They also have a tendency to under cut at the edges. Welds made with helium have wider and thicker beads. Fig1 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.

Carbondioxide: Carbondioxide (CO_2) has a higher thermal heat conductivity than argon. This gas requires a higher voltage than argon. Since it is heavy, it covers the weld well. Therefore less gas is needed.

CO_2 gas is cheaper than argon. This price difference will vary in various locations. Beads made with CO_2 have a very good contour. The beads are wide and have deep penetration and no undercutting.

The arc in a CO_2 atmosphere is unstable and a great deal of spattering occurs. This is reduced by holding a short arc. Deoxidizers like aluminium, manganese or silicon are often used.

The deoxidizers remove the oxygen from the weld metal. Good ventilation is required when using pure CO_2. About 7-12 percent of the CO_2 becomes CO (carbon monoxide) in the arc. The amount increases with the arc length.

A 25% higher current is used with CO_2 than with argon or helium. This causes more agitation of the weld puddle, hence entrapped gases raises to the surface of the weld, so low weld porosity.

Argon carbondioxide: CO_2 in argon gas makes the molten metal in the arc crater more fluid. This helps to eliminate undercutting when GMA welding carbon steels.

CO_2 also stabilizes the arc, reduces spatter and promotes a straight line (axial) metal transfer through the arc.

Argon-Oxygen: Argon-oxygen gas mixtures are used on low alloy carbon and stainless steels. A 1-5 percent oxygen mixture will produce beads with wider, less finger shaped, penetration. Oxygen also improves the weld contour, makes the weld pool more fluid and eliminates undercutting.

Oxygen seems to stabilize the arc and reduce spatter. The use of oxygen will cause the metal surface to oxidise slightly. This oxidization will generally not reduce the strength or appearance of the weld to an unacceptable level. If more than 2% oxygen is used with low alloy steel, a more expensive electrode wire with additional deoxidisers must be used.

The desirable rate of gas flow will depend on the type of electrode wire, speed and current being used and the metal transfer mode.

As a rule small weld pools 10 L/min

medium weld pools 15 L/min

and large spray weld pools 20-25 L/min

Too much gas flow can be just as bad as not having enough. The reason being that if the gas flow is too high it will come out of the MIG Torch.

Suggested gases and gas mixtures for use in GMAW spray transfer

Metal	Shielding gas	Advantages
Aluminium	Argon	0.1 in.(2.5mm) thick; best metal transfer and arc stability; least spatter
	75% Helium 25% argon	1-3 in.(25-76mm) thick; higher heat input than argon
Copper, nickel and alloys	Argon	Provide good wetting;good control of weld pool for thickness up to 1/8 in.(3.2mm)
Magnesium	Argon	Excellent cleaning action
Carbon Steel,	Argon 5-8% CO_2	Good arc stability; produces a more fluid and controllable weld pool; good coalescence and bead contour, minimizes undercutting ; permits higher speeds compared with argon.
Low alloy Steel	Argon 2% oxygen	Minimizes undercutting; provides good toughness
Stainless Steel	Argon 1% oxygen	Good arc stability; produces a more fluid and controllable weld pool, good coalescence and bead contour, minimizes under cutting on heavier stainless steels
	Argon 2% oxygen	Provides better arc stability, coalescence and welding speed than 1% oxygen mixture for thinner stainless steel materials

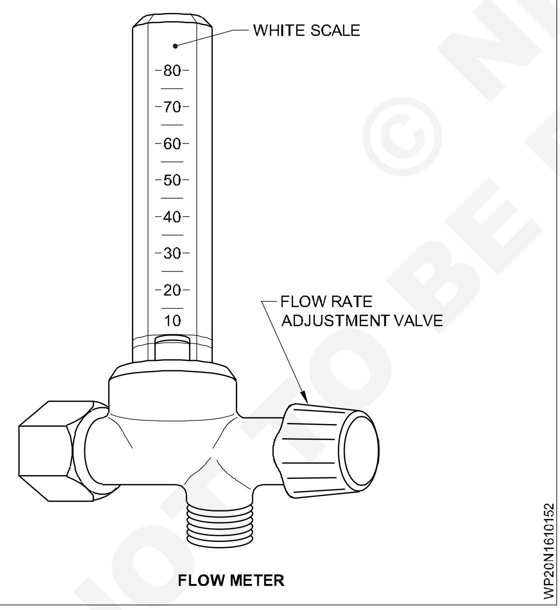
Suggested gases and gas mixtures for use in GMAW short circuiting transfer

Metal	Shielding gas	Advantages
Aluminium copper, magnesium, nickel and their alloys	Argon and argon helium	Argon satisfactory on sheet metal argon-helium preferred on thicker sheet metal
Carbon steel	Argon 20-25% CO_2	Less than 1/8 in.(3.2mm) thick; high welding speeds without melt through; minimum distortion and spatter; good penetration
	CO_2	Deeper penetration; faster welding speeds;minimum cost
Stainless Steel	90% helium 7.5% argon 2.5% CO_2	No effect on corrosion resistance small heat affected zone; no undercutting; minimum distortion; good arc stability

Co_2 gas cylinder and regulator: The shielding gas required for GMAW/Co_2 welding is supplied from a gas cylinder through an outlet valve and regulator.

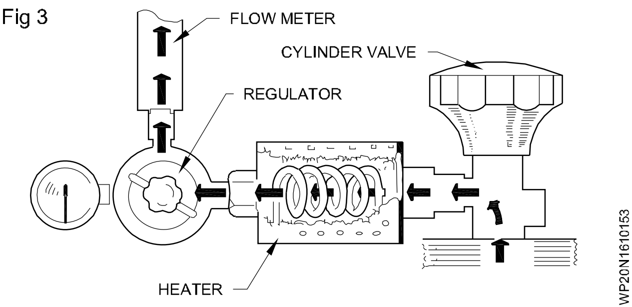
Gas flow meter: It is a unit which has graduations marked on the glass tube. A flow rate adjustment valve fixed to the flow meter controls the rate of flow of inert gas/Co_2 gas to the welding gun in litre per minute. Fig. 2.

Fig 2



Gas Preheater for CO_2 welding (Fig 3): Carbondioxide is filled in cylinders in liquid form. i.e., the CO_2 at room temperature and high pressure condenses into liquid form. Therefore while welding the liquid CO_2 has to be in gaseous form as they enter into the welding torch. CO_2 liquid boils and expands into gas as it passes through the regulator. This causes the gas to cool. If moisture is present in the regulator inlet, it will condense and freeze in the regulator, causing blocking of the gas passage. Therefore to avoid cooling a gas heater is connected to the cylinder to increase the temperature of the gas leaving the cylinder. Hence a uniform gas flow is maintained during welding.

Fig 3



Types of Metal Transfer and Welding Parameters in GMAW

Objectives: At the end of this lesson you shall be able to
- **state the advantages and disadvantages of Co_2 welding over shielded metal arc welding process**
- **state the applications of Co_2 welding.**

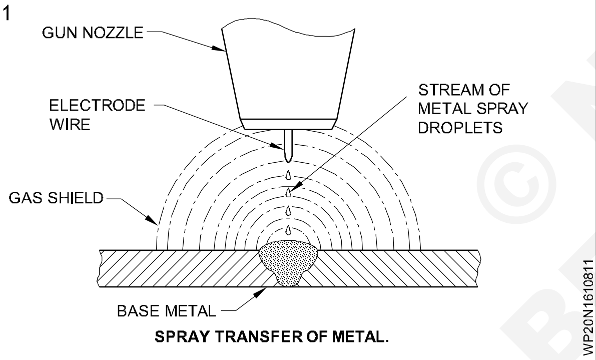
Types of metal transfer: In GMAW/Co_2 welding process, the weld metal is transferred from the electrode wire to the base metal in different methods/modes. Though there are many methods, only the following four methods are used popularly used in industries.

- Spray transfer (Free flight)
- Globular transfer (Intermediate)
- Short circuit or Dip transfer
- Pulsed transfer

The type of metal transfer that occurs will depend on the electrode wire size, shielding gas, **arc voltage** and welding current.

Spray transfer: In spray transfer very fine droplets of the electrode wire are rapidly projected through the arc from the end of the electrode to the workpiece. (Fig 1) Spray transfer requires high current density (28 to 32V).

Fig 1



SPRAY TRANSFER OF METAL.

To obtain a good spray mode of welding shielding gases containing a blend of argon is used. The spray method of metal transfer can be used with most of the common welding wire electrodes (eg mild steel, aluminium, stainless steel).

The advantages of metal spray transfer are

i) high deposition rates
ii) good travel speeds
iii) good looking weld appearance
iv) little weld spatter
v) good weld fusion
vi) very good on heavy sections

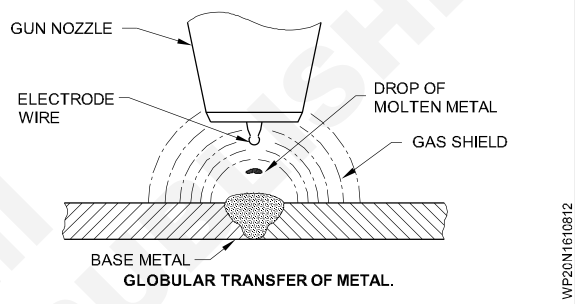
The disadvantages of the spray mode are

i) higher capacity power source needed
ii) weld position is limited to flat and horizontal fillet
iii) the cost of using a more expensive mixed gas
iv) higher radiated heat is produced so extra protection is needed

Globular transfer: In globular transfer, only a few drops are transferred per second at low current values, while many drops are transferred at high current values. This transfer occurs when the welding current is low. (Fig 2). The voltage range is 23 to 27V.

The spatter produced in this transfer is more and hence it is less preferred. But this is a good transfer method for using co_2 gas as a shielding gas.

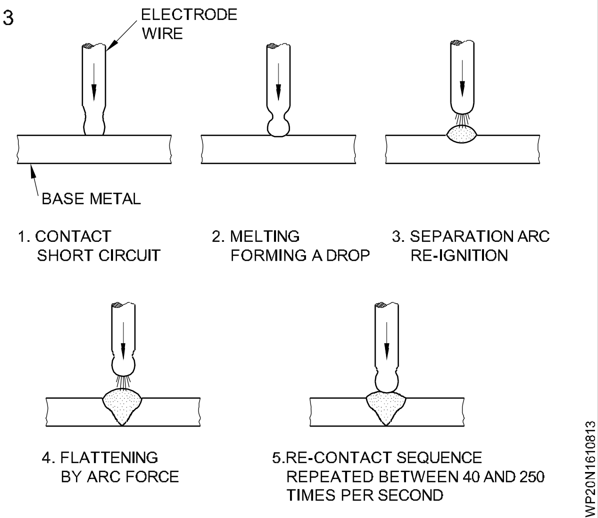
Fig 2



GLOBULAR TRANSFER OF METAL.

Short circuit transfer (DIP transfer): In short circuit transfer, as the molten wire is transferred to the weld, each drop touches the weld puddle before it breaks away from the advancing electrode wire. The circuit is shorted and the arc is extinguished. (Fig 3). The voltage range is 16 to 22V.

Fig 3

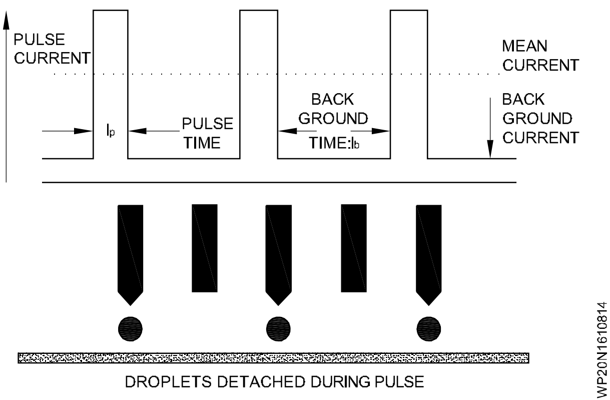


It permits welding thinner sections with greater ease, and is extremely practical for welding in all positions.

Pulsed Spray Transfer (Fig 4)

Pulsed spray transfer has a steady stream of metal droplets crossing the welding arc. The pulsed power source supplies the welding arc with two types of welding current.

Fig 4



1) Peak current - this current allows the formation of metal droplets which then cross the welding arc.

2) Background current - the background current will keep the arc alive, but doesn't allow for any weld metal transfer.

Pulsed spray transfer allows time for the weld puddle to freeze a little on the background current cycle, which allows for

i) more control of the weld puddle.

ii) more time for impurities to float to the top of the weld pool resulting in cleaner and stronger welds.

Advantages

i) able to spray thinner metals

ii) less heat input

iii) stronger welds

iv) more weld control

v) out-of-position welding

vi) Little spatters

Disadvantages

i) higher set up costs

ii) needs operator training

iii) lower deposition rate

Burn-off characteristics of filler wire in GMAW

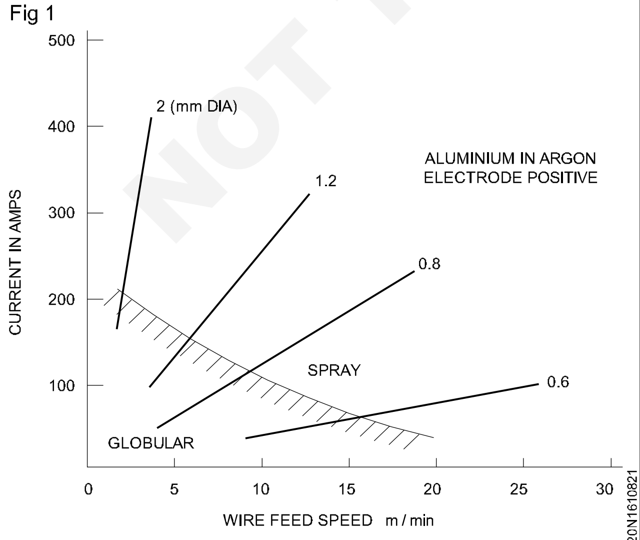
Objectives: At the end of this lesson you shall be able to

- **get familiar with wire burn off characteristics of different filler wires and shielding gases**
- **explain the principles of self regulating arc length in GMAW/Co_2 welding.**

Wire burn-off characteristics: A linear relationship exists between the rate at which the wire is fed into the arc and the current required to melt it off to maintain a constant arc length. This is known as the burn off characteristics, and it differs for different filler wire composition and diameters.

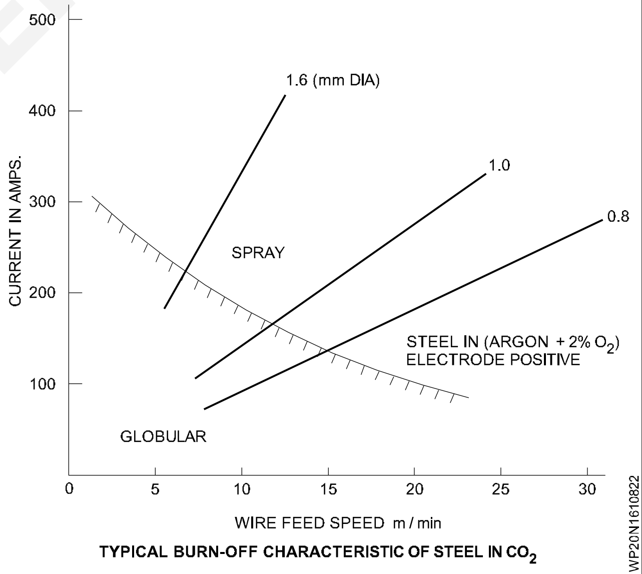
Fig.1 & 2 shows the typical burn off characteristics of aluminium in argon and steel in CO_2 respectively. It can be observed from the figure that to alter the welding current a proportionate increase in the wire feed rate is required. The amount of current drawn by the arc depends on the wire diameter, wire material and the feed rate.

Fig 1



TYPICAL BURN-OFF CHARACTERISCTIC OF ALUMINIUM ARGON

Fig 2



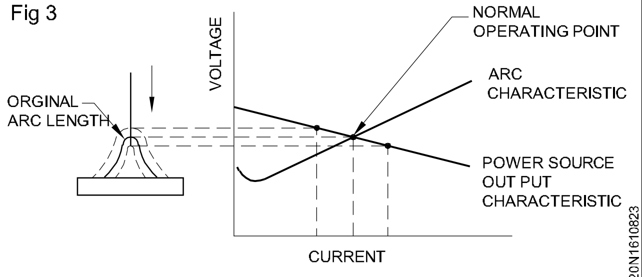
TYPICAL BURN-OFF CHARACTERISTIC OF STEEL IN CO_2

For a given wire material, at the same wire feed rate, the smaller diameter wires draw less current compared to the bigger diameter wires.

Principles of self regulating arc length in GMAW/CO_2 welding: The wire melting rate is a function of the welding current. That means to vary the wire melting rate, the welding current must be varied. The variation of the wire melting rate with current is best achieved in the constant voltage source compared to a constant current power source.

Constant voltage power source provides 'self regulation' of the arc length can be explained by referring Fig.3 The 'operating point' is determined by the output characteristics of the power source and the arc characteristics. For example, if the arc length is increased, results in slower burn off rate and consequently the arc length will be adjusted to the original level. On the other hand if the arc length is shortened it results in increase in current and a faster burn off rate and the arc length will be adjusted to the original level. This self adjustment will operate successfully only if the change in current produced by voltage variation is sufficiently large to produce a large change in the burn off rate.

Fig 3



PRINCIPLE OF SELF REGULATING OF THE ARC LENGTH

GMAW parameters/variables

GMA welding process parameters/variables

The following parameters must be considered in the welding procedure of GMAW/Co_2 welding.

Electrode size

Rate of wire feed (Welding current)

Arc voltage

Stick out

welding position

Shielding gas

Travel speed

electrode position

Electrode: Best results are obtained by using the proper size wire for the thickness of the metal to be welded and the position in which the welding is to be done.

Electrode wires should be of the same composition as that of the material being welded.

Basic wire diameters are 0.8 mm, 1.0 mm, 1.2 mm, 1.6 mm and 2.4 mm.

Welding current: The wire feed speed will control the current. A wide range of current values can be used with each wire diameter. This permits welding metal of various thicknesses without having to change the wire diameter. The current selected should be high enough to secure the desired penetration and low enough to avoid under-cutting or burn through.

The success of GMA welding is due to the concentration of high current density at the electrode tip.

General data on current selection is given in the table given below.

The current varies as the wire feed varies.

Ranges of wire feed rate in CO_2 welding

(Current is shown in brackets)

Wire feed speed, m/min]

Wire dia. (mm)	Spray type arcs (28 - 32 V)	Short circuiting arcs (16-22 V)
0.8	5.0-15 (150-250 amps)	2.5-7.5 (60-160 amps)
1.2	5.0-15 (200-350 amps)	2.0-3.8 (100-175 amps)
1.6	5.0-8.8 (350-500 amps)	1.5-2.0 (120-180 amps)

Arc voltage: This is a very important variable in GMAW/Co_2 welding process, mainly because it determines the type of metal transfer by influencing the rate of droplet transfer across the arc. The arc voltage to be used depends on the base metal thickness, type of joint, electrode composition and size, shielding gas composition, welding position, type of weld and other factors.

For details refer to the table of General Guide to Welding Conditions.

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

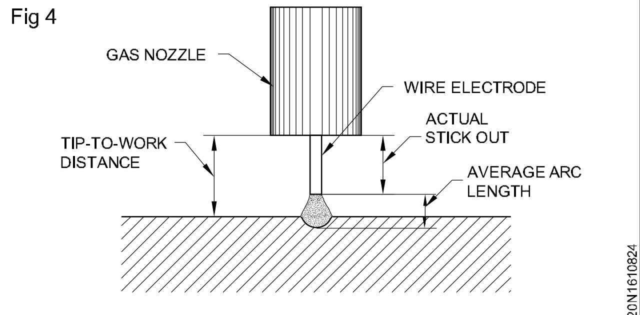
If the arc travel speed is lowered, the weld pool becomes larger and shallower. As the travel speed is increased, the heat input rate of the arc is decreased; consequently there is decreased penetration and narrower weld bead. When the travel speed is excessive, undercutting occurs along the weld bead, because the deposition of the filler metal is not sufficient to fill the paths melted by the arc.

Stick out: It is the distance between the end of the contact tube and the tip of the electrode. (Fig 1)

Too long a stick out results in excess weld metal being deposited at low arc heat, giving rise to badly shaped weld and shallow penetration.

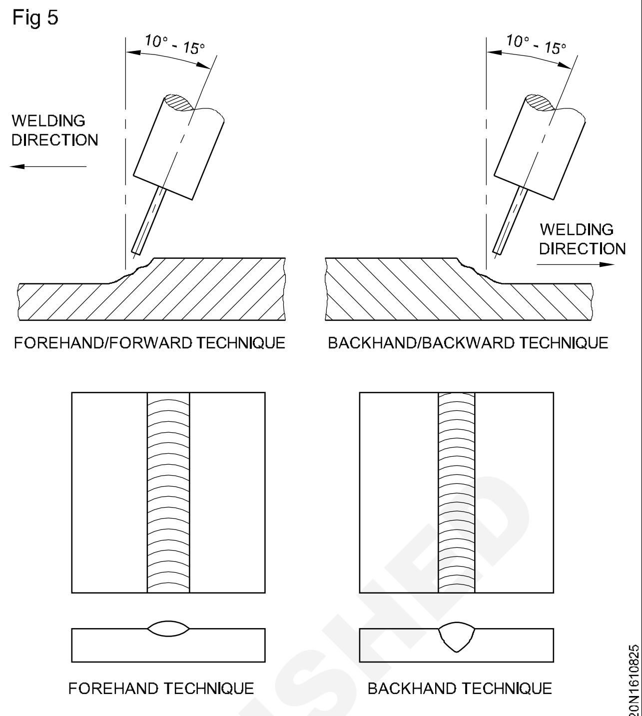
When the stick out is too short, excessive spatter gets deposited on the nozzle, which can restrict the shielding gas flow and cause porosity in the weld.

Recommended stick out is 6 to 13 mm for a short circuiting arc, and 13 to 25 mm for the spray transfer arc.



CORRECT WIRE STICK OUT IS IMPORTANT TO ACHIEVE SOUND WELDS

Electrode position: In all welding processes, the position of the gun and electrode with respect to the joint affects the weld bead shape and penetration. The welding can be done either by using Forehand/Forward technique or by using Backhand/ Backward technique. The gun angles are usually maintained within 10 to 15° as shown in Fig 2.



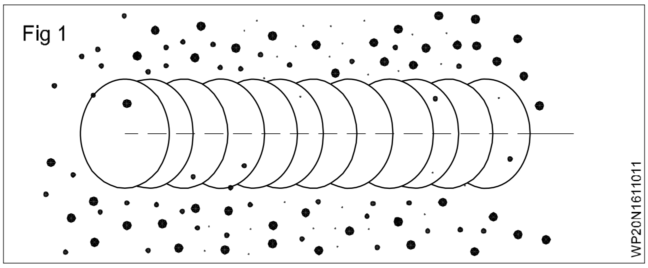
ELECTRODE ANGLE AND ITS EFFECTS ON WELD BEAD

Types of Welding defects cause and Remedies

Objectives: At the end of this lesson you shall be able to
- **state the weld defect, explain the causes and remedy if the defects**
- **state the non - destructive testing methods.**

Excessive Spatter

Fig 1

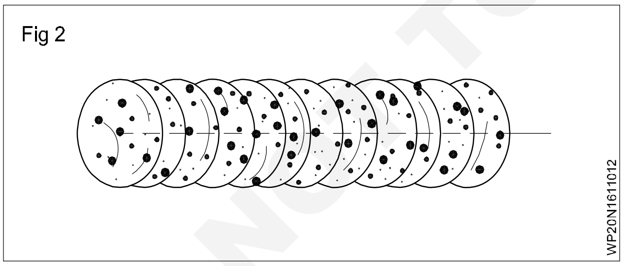


Excessive Spatter : scattering of molten metal particles that cool to solid form near weld bead.

Possible Causes	Corrective Actions
Wire feed speed too high.	Select lower wire feed speed.
Voltage too high.	Select lower voltage range.
Electrode extension (stickout) too long.	Use shorter electrode extension (stickout).
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 feeeder or liner.

Porosity

Fig 2



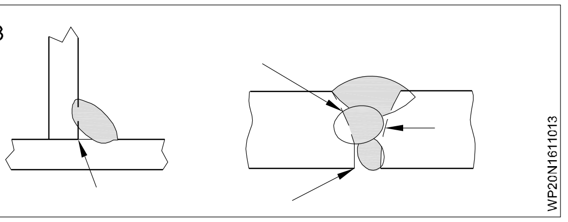
Porosity — small cavities or holes resulting from gas pockets in weld metal.

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. work	Remove all grease, oil, moisture, rust, paint, coatings, and dirt from surface before welding.
	Use a more highly deoxidizing welding wire.
Welding wire extends too far out of	Be sure welding wire extends not more than (13 mm) beyond nozzle. nozzle.

Incomplete Fusion

Fig 3

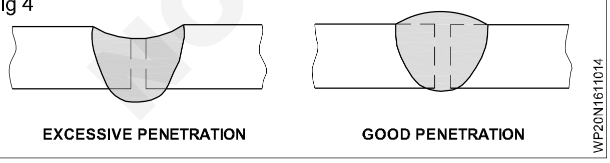


Incomplete Fusion — failure of weld metal to fuse completely with base metal or a preceeding weld bead.

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 tech nique.
	Keep arc on leading edge of weld puddle.
	Use correct gun angle of 0 to 15 degrees.

Excessive Penetration

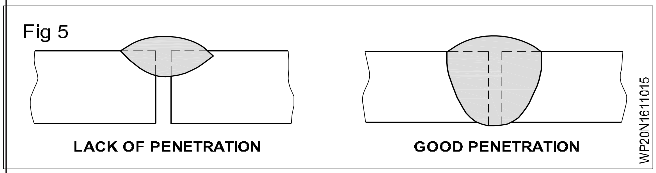
Fig 4



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.

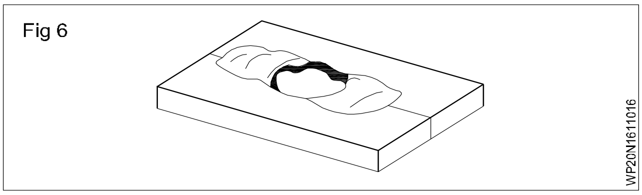
Lack of Penetration



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

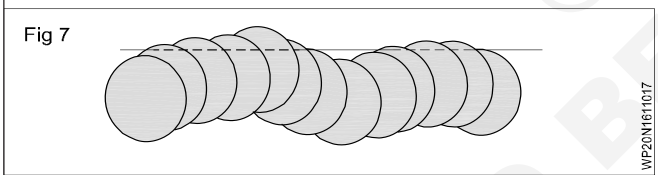


Burn-Through — weld metal melting

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

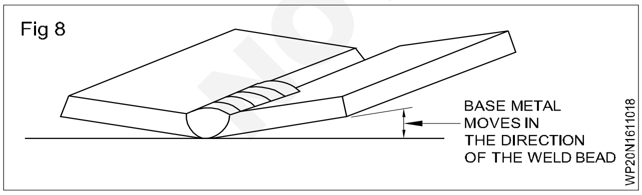


Waviness of Bead — weld metal that is not parallel and does not cover joint formed by base metal.

Possible Causes	Corrective Actions
Unsteady hand.	Support hand on solid surface or use two hands.

Distortion

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.

Inspection of Weld (NDT) - Visual Inspection

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of inspection and testing of weld**
- **describe the different stages of visual inspection**
- **explain the check points of visual inspection**
- **state types of testing of welds.**

Necessity of inspection: The purpose of inspection is to locate and determine the type of weld fault, strength and quality of joint and quality of workmanship.

Types of tests

- Non-destructive test (NDT)
- Destructive test
- Semi destructive test

Determining the quality of the weld without destroying the weld is called a non-destructive test (NDT). The job can be used after the test. The test to be carried out on welded specimens by cutting the job and destroying it is called destructive test. The job cannot be used after the test.

Sometimes the quality of a welded joint is tested by grinding, drilling, etching, filing etc. for finding machinability, microstructure etc. These tests are called semi-destructive tests. The tested job can be used after the test by rewelding the small area damaged during the test.

Visual inspection (non-destructive test): Visual inspection is observing the weld externally using simple hand tools and gauges to know whether there is any external weld defects. This is one of the important inspection methods without much expense. This method of inspection needs a magnifying glass, a steel rule, try square and weld gauges. Visual inspection is made in three stages namely:

- before welding
- during welding
- after welding

Visual inspection before welding

(The operator must be familiar with the type of work, electrode and welding machine)

The following factors are to be ensured.

The material to be welded is of weldable quality.

The edges have been properly prepared for welding as per thickness of the plate.

Proper cleaning of the base metal.

Setting of proper root gap.

Proper procedure to be followed to control distortion.

Proper selection of blow pipe nozzle and filler rod, flux and flame.

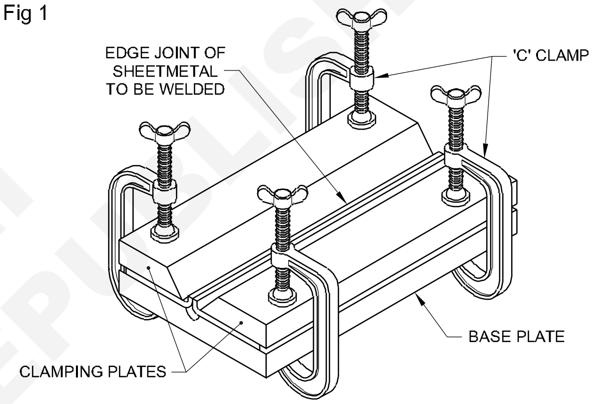
Polarity of the electrodes in the case of DC welding current.

Whether the cable connections are tight.

Current setting according to the size of the electrode and position of welding.

Whether any jigs and fixtures are necessary to ensure proper alignment. (Fig 1)

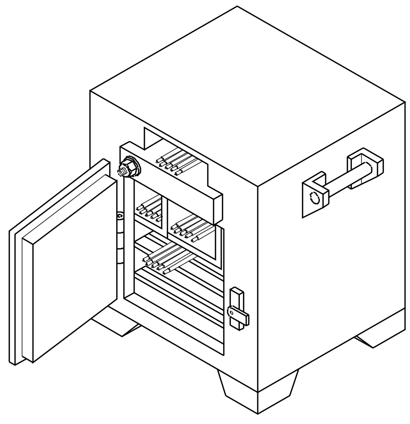
Fig 1



CLAMPING PIECES BETWEEN HEAVY BLOCKS WILL KEEP THEM STRAIGHT.

Proper facilities should exist for storing and drying of the electrodes. (Fig 2)

Fig 2



ELECTRODE DRYING OVAN

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.

Methods of non-destructive tests

Objectives: At the end of this lesson you shall be able to
- **explain the non-destructive testing methods**
- **explain the uses of the common non-destructive methods**
- **explain the uses of special non-destructive testing.**

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

Common non-destructive testing

– Visual inspection

– Leak or pressure test

– Stethoscopic test (Sound)

Special non-destructive tests

– Magnetic particle test

– Liquid penetrant test

– Radiography (X-ray) test

– Gamma ray test

– Ultrasonic test

Visual inspection: Visual inspection is the simplest, fastest, economical and most commonly used test for detecting defects on the surface of the welded job. The weld surface and joint are examined visually with naked eyes preferably with the help of a magnifying lens. Visual examination can help in detecting the following defects on the surface of the weld.

– Porosity

– Surface defects like surface cracks, external slag inclusions, overlap, spatters, unfilled crater, misalignment, distortion etc.

– Undercut

– Improper profile and dimensional accuracy

– Poor weld appearance

– Incomplete penetration.

Leak or pressure test: This test is used to test welded pressure vessels, tanks and pipelines to determine if leaks are present. The welded vessel, after closing all its outlets, is subjected to internal pressure using water, air or kerosene. The internal pressure depends upon the working pressure which the welded joint has to withstand. The internal pressure may be raised to two times the working pressure of the vessel. The weld may be tested as follows.

1 The pressure on the gauge may be noted immediately after applying the internal pressure and again after, say, 12 to 24 hours. Any drop in pressure reading indicates a leak.

2 After generating air pressure in the vessel, soap solution may be applied on the weld seam and carefully inspected for bubbles which would indicate leak.

Stethoscopic (sound) test: The principle of this test is that defect-free weld metal gives a good ringing sound when struck with a hammer whereas a weld metal containing defects gives a flat sound.

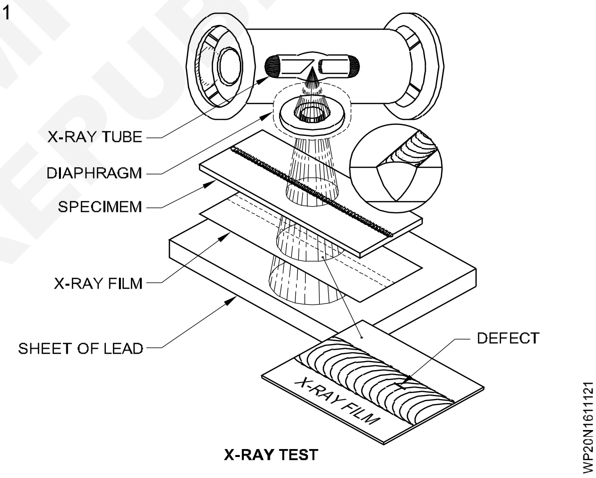
An ordinary physician's stethoscope and a hammer may be used to magnify and identify the sound.

Structural welds and welds in pressure vessels have been successfully tested using this method.

Radiographic test: This test is also called X-ray or gamma ray test.

X-ray test: In this test internal photographs of the welds are taken. The test specimen is placed in between the X-ray unit and film. (Fig 1) Then the X-ray is passed. If there is any hidden defect, that will be seen in the film after developing it. Defects appear in the same manner as bone fractures of human beings appear in X-ray films. Below the X-ray film a lead sheet is kept to arrest the flow of X-ray further from the X-ray testing machine.

Fig 1



X-RAY TEST

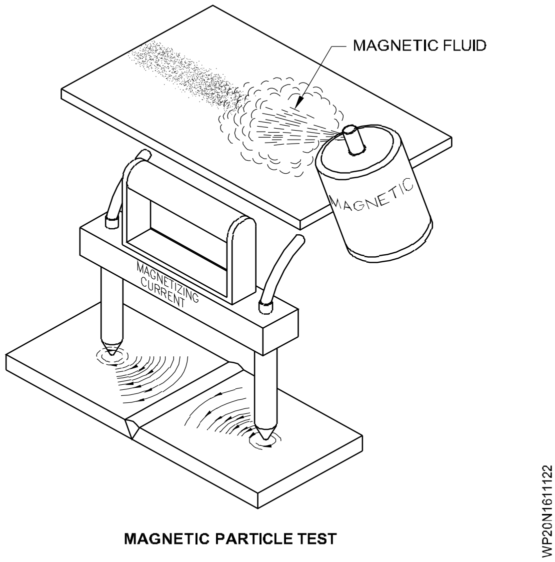
Gamma ray test: The short invisible rays given off by radium and radium compounds like cobalt 60 etc. are known as gamma rays. These rays penertrate greater thickness of steel than x-rays and the chief advantage of this process is portability. This test can be done at places where electricity is not available. These tests are used on high quality jobs like boilers and high pressure vessels and penstock pipes and nuclear vessels.

Magnetic particle test: This test is used to detect surface defects as well as sub-surface (up to 6 mm depth) defects in ferrous materials.

A liquid containing iron powder is first sprayed over the joint to be tested. When this test piece is magnetised, the iron particles will gather at the edges of the defect (crack or flaw) and can be seen as dark hair line marks with naked eyes. (Figs 2 & 3)

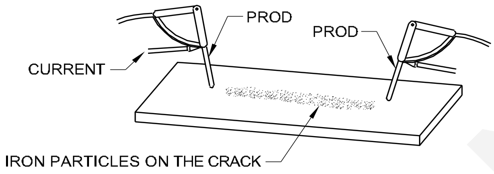
Liquid penetrant test; This test is based on the principle that coloured liquid dyes and fluorescent liquid penetrate into the cracks and are used to check for surface defects in metals, plastics, ceramics and glass. A solution of the coloured dye is sprayed on the clean welded joint and allowed to soak.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

Fig 2



MAGNETIC PARTICLE TEST

Fig 3

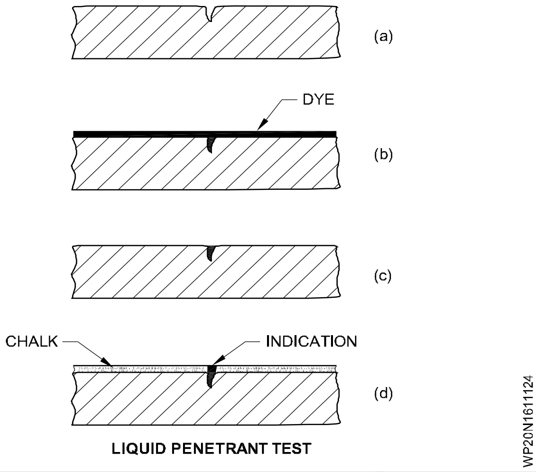


A liquid developer (white in colour) is then sprayed on the weld. The coloured dye comes out in the shape of surface defects into the white developer coating. The defect can be seen in normal light with naked eyes. (Fig 4)

Ultrasonic test: Sound waves of high frequency are used in this test. This test is used to find out the discontinuities in the weldment. The sound waves can penetrate from a very small thickness of plate to 6 to 10 metres of steel.

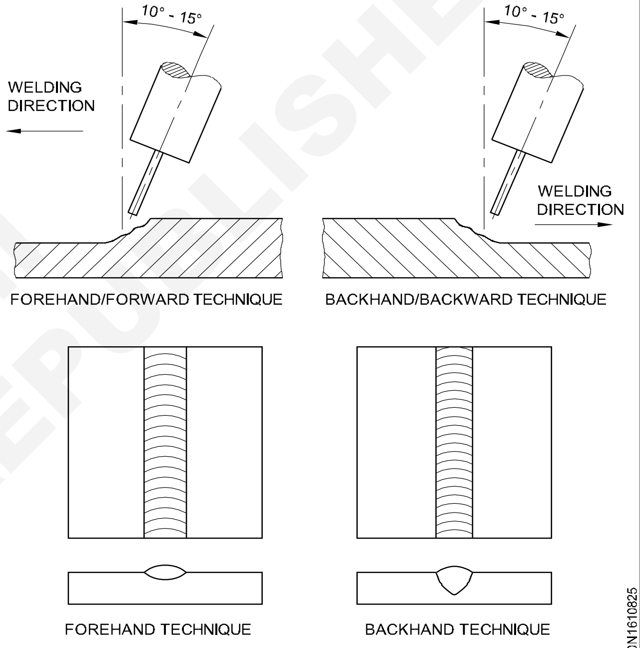
A sound wave producing transmitter is placed on the job. The echo of the sound waves is directly shown on the calibrated screen attached with the ultrasonic testing unit. (Fig 5)

Fig 4



LIQUID PENETRANT TEST

Fig 5



ELECTRODE ANGLE AND ITS EFFECTS ON WELD BEAD

Introduction to Plastic Welding (PP, PE & pvc) lib Parametal & Check

Objectives: At the end of this lesson you shall be able to
- **explain plastic welding processes**
- **narrate application each process**
- **state ise parametar of plastic welding.**

Plastics welding is the process of joining two pieces of Thermoplastics at heated state and under a pressure as a result of cross-linking of their polymer molecules. The work pieces are fused together with or without filler material. The joint forms when the parts are cooled below the Glass Transition Temperature for amorphous polymers or below the melting temperature for crystalline polymers.

Thermosets thermosetting resines in cured condition cannot be welded, since cross-linking of their molecules has completed.

Plastics welding processes

- Hot Gas Welding
- Hot Plate Welding
- Ultrasonic Welding
- Spin Welding
- Vibration Welding

Hot Gas Welding

Hot Gas Welding is a plastics welding process, utilizing heat of hot gas stream. The gas usually air is heated by electric heating elements mounted within the welding gun. The torch welding gun directs the heated gas toward the work piece surfaces and a rod of filler material. The edges of the joined parts and the filler rod material are fused together and pressed. The polymer molecules are cross-linked when the work pieces cool down, forming a strong joint.

Hot Gas Welding is manually operated process requiring high level of the operator skill. Some polymers (e.g. Low Density Polyethylene (LDPE), High Density Polyethylene (HDPE)) oxidize at incresed temperature therefore they are welded by hot Nitrogen.

Applications of Hot Gas Welding

- Containers
- Tanks for storage chemicals
- Ventilation ducting
- Tubes
- Repair works.

Hot Plate Welding Hot Plate Welding is a plastics welding process, utilizing heat of hot plate placed between the surfaces to be joined. The work pieces, pressed to the plate, heat up and soften. After a predetermined time the plate is removed, the parts are brought to the contact, pressed and fused together. Their polymer molecules are cross-linked when the work pieces cool down, forming a strong joint.

Hot plates are made mainly of Aluminum alloys. A hot plate is equipped with an electric heating elements and a thermocouple providing temperature control of the plate surface.

Applications of Hot Plate Welding

- Components of domestic electric devices (dishwashers, washing mashines, vacuum cleaners)
- Pipes
- Automotive components (lights, fuel tanks, reservoirs, batteries).

Advantages of Hot Plate Welding

- Easily automated
- High quality tight joints
- Large and comples parts may be welded
- Hot plate provides conforming the joined surfaces.

Disadvantages of Hot Plate Welding

- Long welding cycle: up to 20 sec. for small parts and up to 30 min. for large parts.
- Relatively large amount of flash (excess material) forms.

Ultrasonic Welding

Ultrasonic Welding is a plastics welding process, in which two work pieces are bonded as a result of a pressure exerted to the welded parts combined with application of high frequency acoustic vibration (ultrasonic). Ultrasonic vibration transmitted by a metal tool horn, sonotrode causes oscillating flexing of the material and friction between the parts, which results in a closer contact between the two surfaces with simultaneous local heating of the contact area. The plastic melts in the contact area, the polymer molecules are cross-linked, forming a strong joint.Ultrasonic Welding cycle takes about 1 sec. The frequency of acoustic vibrations is in the range 20 to 70 kHz commonly 20-40 kHz. The ampltude of the acoustic vibrations is about 0.002" (0.05 mm). Thickness of the welded parts is limited by the power of the ultrasonic generator.Ultrasonic Welding is used mainly for processing amorphous polymers (Polysterene (PS), Acrylonitrile-Butadiene-Styrene (ABS).

Applications of Ultrasonic Welding

- Medical equipment (filters, face mask, valves, cardiometry reservoir)
- Automotive components (glove boxes doors, filters, valves, airflow sensors)
- Appliance (vacuum cleaner, steam iron, dishwasher components)
- Electrical equipment (switches, terminal blocks,connectors)
- Electronic and computer components
- Toys.

Advantages of Ultrasonic Welding

- Short welding cycle
- Easily automated and controllable
- Small amount of flash forms
- Low energy consumption

Disadvantages of Ultrasonic Welding

- Only small and thin parts may be welded
- Tool design is required.

Spin Welding

Spin Welding is a plastics welding process, in which two cylindrical parts are brought in contact by a friction pressure when one of them rotates. Friction between the parts results in heating their ends. After a predetermined time the rotation stops and the molten regions of the work pieces are fused together under an axial pressure applied until the joint is cooled down.Spin Welding is similar to Friction Welding (FRW).Spin Welding is used for manufacturing aerosol bottles, floats and other circular parts.

Advantages of Spin Welding

- Reproducibility
- Large parts may be welded
- High quality weld
- Oxidizing polymers may be welded.

Disadvantages of Spin Welding

- At least one of the parts to be welded should have a circular symmetry
- Minimum rigidity required.

Vibration Welding

Vibration Welding is plastics welding process, in which two work pieces are vibrated at certain frequency and ampltude. The parts rubb each other under a pressure causing a friction between their surfaces, which generates heat. The heat results in melting polymer in the joint region. The work pieces are fused together and after a predetermined time the vibration stops. The polymer molecules are cross-linked when the work pieces cool down, forming a strong joint.

Vibration Welding cycle is very short (milliseconds). The frequency of acoustic vibrations is in the range 100 to 500 Hz (commonly 100-240 Hz). The ampltude of the vibrations is about 0.02-0.2" (0.5-5 mm).

Most polymers (amorphous, semicrystalline and crystalline) produced various fabrication methods (Thermoforming, Extrusion, Injection molding, Blow molding, Compression molding, Transfer molding) may be welded by Vibration Welding.

Vibration Welding is used in automotive and domestic appliance industries.

Advantages of Vibration Welding

- Oxidizing polymers may be welded
- Easily automated
- High productivity
- Large and complex parts may be welded.

Disadvantages of Vibration Welding

- Relatively expensive equipment
- Minimum rigidity required.

The 3 Parameters for Plastic Welding

There are three essential parameters for a plastic weld temperature, pressure, and time.

Temperature

All thermoplastics have a specific temperature range for effective welding. The plastic manufacturer can often give you an appropriate range of welding temperatures for their material. However it is important to know that the perfect welding temperature for the application can vary depending on environmental conditions such as temperature or sunlight exposure. For example, if you are plastic welding in a colder than normal environment you may need to slightly increase your welding temperature. For hand welding, the air flow temperature is the only set point to consider. With extrusion welding there are different set points for both the air temperature and the temperature of the extruded If your temperature is too low, you won't get enough weld penetration and your welding rod/extrudate and base material will not blend together properly. If your temperature is too high, you will degrade the plastic and again the materials will not blend together properly. In either case, your weld will not be the strongest possible.

Pressure

A weld's strength comes from the proper blending of the plasticized base material with the plasticized welding or filler rod this is not possible if the pressure is too high or too low.

The correct pressure when hand welding is learned through feel, practice, and experience.

When extrusion welding, the required welding pressure is applied via the plasticized filler pushing between the base material and the welding shoe. Excessive pressure is characterized by excessive overfill behind the welding shoe and excessive root expulsion. Inadequate pressure is characterized by inadequate filling of weld (if the weld area is not filled, it has nothing to push against to provide pressure) and poor root penetration.

Time

The time required for a plastic weld is determined by the speed of welding. Too fast and the materials do not have sufficient time to plasticize and the pressure is applied for too short of a time too slow and the plastic will overheat and begin to degrade. It is important to keep a constant speed when welding to ensure uniform results.

When plastic welding, speed is determined by the rate at which the materials plasticize and we get a proper preheat. For hand welding, this is learned through feel, practice, and experience. When extrusion welding, we determine at what speed we are getting an adequate preheat and then we adjust our extrusion rate to ensure we are adequately filling the welding groove at this speed.

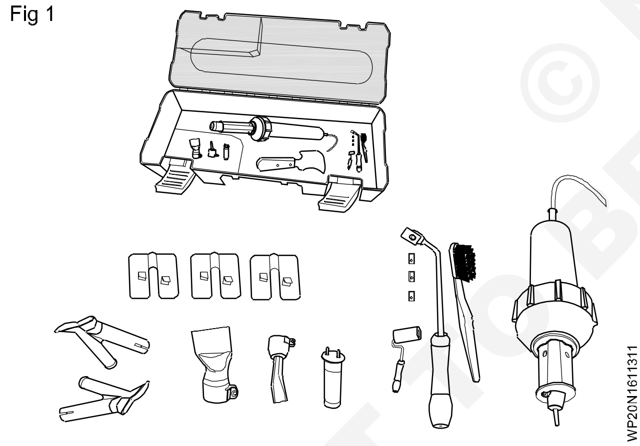
Welding temperatures of the individual plastics ABS (acrylonitrile-butadiene-styrene)

Welding ABS is possible without any problems. The air temperature should be in the range of +270°C and +310°C to weld ABS plastics.

PS (polystyrene)

Polystyrene can also be welded very well. The air temperature for welding polystyrene should be between +270°C and +310°C.

Fig 1



PE (polyethylene)

Polyethylene cannot be bonded with conventional adhesives, so welding PE is common practice. However, PE can be welded well and very easily. The air temperature for a weld in PE welding should be between +220°C and +280°C.

PP (polypropylene)

As with polyethylene, bonding polypropylene is not straightforward. However, this does not apply to the welding of polypropylene and leads to good results. However, when welding PP, close attention should be paid to the temperature level and the heating time. Polypropylene burns quite quickly and the burnt material deteriorates the weld. The air temperature for PP welding should be between +230° and +280°C.

PVC (polyvinyl chloride)

When welding PVC, close attention must also be paid to the temperature level and the heating time. PVC also burns very quickly, forming hydrochloric acid which has a strong pungent effect when inhaled. The burnt PVC surface deteriorates the quality of the weld seam and the appearance, as burnt PVC immediately dark brown to black. The air temperature for PVC welding should be between +250° and +280°C.

Fig 2

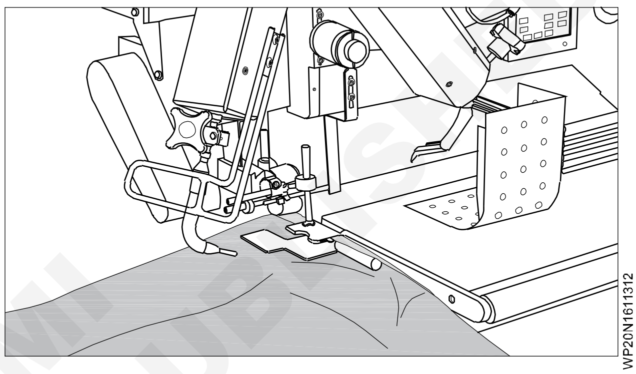


Fig 3

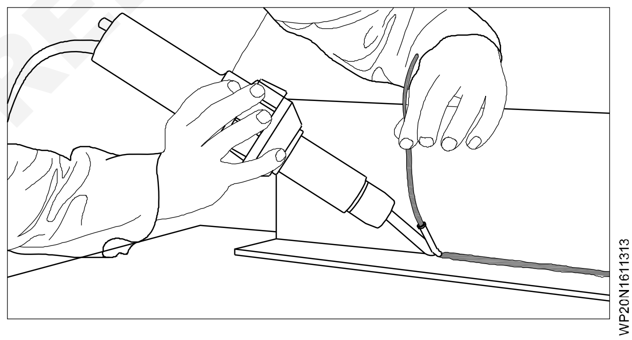
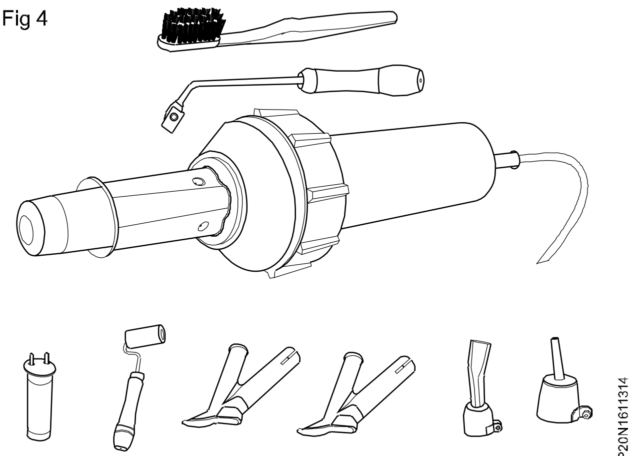


Fig 4



HOT AIR GUN KIT

Requirement for Qualification in different Codes.

Objectives: At the end of this lesson you shall be able to
- **narrate the welding standard of welding operator.**

Why Welder's need to be Qualified?

The International codes (ASME Section IX, AWS D1.1, ASME B31.3) and standards (ISO 9606 series) require the welders to be qualified when they are welding on fabrications jobs that comply with construction codes (for example ASME Section VIII) or standards (e.g. EN 15085, EN 1090).

Material Welding

The sound weld means weld that is free from welding defects such as crack, lack of fusion, lack of penetration, etc. Sound weld doe not mean free from imperfections such as porosity or slag inclusion.

These imperfections are allowed but within limits only as specified in their respective acceptance criteria in the applicable code or the standards.

The welder qualification test coupon or WQT as stated above needs to meet the weld soundness and that is verified either by performing a volumetric NDT test (such as radiographic testing or Ultrasonic testing) or by destructive testing such as bend test. Visual testing is mandatory but it is only for surface inspection.

Code and standards for Welders/ Welding Operator Qualification

Various international codes and standards are used for welder qualifications. The most commonly used Welder Qualification test codes are:

- AWS D1.1 Structural Welding – Steel : Certification : American Welding Society
- AWS D1.2, Structural Welding Code – Aluminum : Certification : American Welding Society
- ASME Section IX
- ISO 9606-1, ISO 9606-2
- CSA Standard W47.1

In this post, we will cover the most important variables that need to be considered when qualifying a welder and this is applicable to ASME Section IX, AWS D1.1 as well as ISO 9606 welder qualification.

How to Qualify a Welder Steps for Welder Qualification Test

Before you make a welder qualification Test, you need to know the following welding conditions that will guide you to choose various essential variables for WQT to guide you on How to Qualify a Welder.

- Material P Number and type (either plate or pipe)
- Electrode classification, its F-Number
- Weld thickness to be deposited
- Welding position
- Weld progression

All of the above parameters are actual parameters that the welder is going to use on the job. Based on these actual values, you can make a decision to choose:

- Material grade
- Welding position
- Material thickness & number of weld passes
- Weld progression.

Now, let us see these parameters in detail and their qualifying range in the ASME Section IX that will help you to understand the welder qualification process so you can perform the welder qualification Test task.

Step 1 - Decide the welding process

The first and utmost task beforehand you start the welding qualification test is to decide the Type of Welding looking for a welder to qualify.

It is either Stick welding or TIG or GMAW, which could be anything or a combination of two welding processes.

- Shielded Metal Arc Welding or Stick Welding
- Gas Tungsten Arc Welding or TIG
- Gas Metal Arc Welding or MIG- MAG
- Flux Cored Arc Welding
- Submerged Arc Welding

Decide the welding type either Manual or semi-automatic or automatic.

Related Reading What is Manual, Semi-Automatic, Mechanized, and Automatic Welding.

Now, once you decide on the welding process, the task becomes a bit easy as you can easily locate the essential variables for welder qualification test that are classified based on the welding process in ASME Section IX.

These variables are listed in ASME Section IX, clause QW-350. Here you will find tables from QW-352 to QW-357 for various processes.

Have a look at the essential variables listed for SMAW or stick welding in the below table (QW-353).

Table QW-353
Shielded Metal-Arc Welding (SMAW)
Essential Variables

Paragraph		Brief of Variables
QW-402 Joints	.4	– Backing
QW-403 Base Metals	.16	φ Pipe diameter
	.18	φ P-Number
QW-404 Filler Metals	.15	φ F-Number
	.30	φ t Weld deposit
QW-405 Positions	.1	+ Position
	.3	φ ↑↓ Vertical welding

You must keep in mind that a new welder qualification test is required if the welder performs welding outside these qualified essential welding variables range.

Step 3 - Gather the essential data

Now, you are on the right track to qualify a new welder. You have decided on the welding process, learn the essential variables for the selected process.

The next task is to gather the data based on your requirements (that could be from drawing or from the client-side).

Here, all the parameters that the welder going to use in actual welding need to be tabulated. For example Types of materials i.e. only carbon steel materials or stainless steel or copper alloy etc. So note down all of the following parameters.

1 **Type of joint** e.g. groove weld or fillet weld. For groove weld, as per QW402.4 for SMAW welding, removal of backing is essential variable.Related Reading: What is a Groove Weld and its different types with Symbols so if you qualified welder with backing, you can't use him to weld on without backing welds. If required so, he need to be re-qualified using WQT without backing as this is an essential variable.

2 **Base Material** - Note down the base metal, its type, grade and most important is it's P. Number (Table QW/QB-422 in ASME Section IX). Each material has a unique P. Number given by ASME Section IX. Click here to know what is P. Number.

ASME Section IX gives umbrella for a range of material qualified with a certain material. For example, if a welder weld with P No. 1 material, he is qualified for P-No. 1, 15F, 34, and P-No. 41 to P-No. 49 as permitted in QW 423.1, table shown below.

Base Metal (s) Used for Performance Qualification	Base Metals Qualified
P.No.1 through P.No.15F,P.No.34, or P.No.41 through P.No.49	P.No.1 through P.No.15F, P.No.34, and P.No.41 through P.No.49
P.No.21 through P.No.26	P.No.21 through P.No.26
P.No.51 through P.No.53 or P.No.61 or P.No.62	P.No.51 through P.No. 53 and P.No.61 and P.No.62
Any unassigned metal to the same unassigned metal	The unassigned metal to itself
Any unassigned metal to any P-Number metal	The unassigned metal to any metal assigned to the same P-Number as the qualified metal.
Any unassigned metal to any other unassigned metal	The first unassigned metal to the second unassigned metal

3 **Range of material thickness (base Metal) qualified:** Next, you need to make a summary of base metal thickness & pipe diameter if applicable, involved in the job.

Based on thickness and diameter you can choose the WQT thickness requirements for the plate, and thickness and diameter in case of a pipe WQT inline with QW-404.30.

4 **Filler Metal F- Number:** each filler wire or electrode is given an F-Number in the ASME Section IX (refer to Table QW-432 in ASME Section IX for all F-Number). The range of F-Number qualified is shown below.

Click here to learn What is ASME F-Number for filler metals is?

5 **Range of Weld thickness (t) deposit qualified:** As per QW-404.30, the thickness of weld in the WQT is the base for the thickness of weld deposit a welder can weld. The range of qualifications based on 't welded' to 't qualified' is given in the below table

6 **Selection of Welding position & weld progression:** Welding position & weld progression are essential variables for welder qualification test.

The position used by the welder for WQT decides in which positions he or she can perform the welding in the actual job.

ASME Section IX, Table QW-461.9 provides the range of welding positions qualified based on performance welding test coupon position.

QW-433 ALTERNATE F-NUMBERS FOR WELDER PERFORMANCE QUALIFICATION

The following tables identify the filler metal or electrode that the welder used during qualification testing as "Qualified With," and the electrodes or filler metals that the welder is qualified to use in production welding as "Qualified For." See Table QW-432 for the F-Number assignments.

Qualified With → / Qualified For ↓	F-No. 1 With Backing	F-No. 1 Without Backing	F-No. 2 With Backing	F-No. 2 Without Backing	F-No. 3 With Backing	F-No. 3 Without Backing	F-No. 4 With Backing	F-No. 4 Without Backing	F-No. 5 With Backing	F-No. 5 Without Backing
F-No. 1 With Backing	X	X	X	X	X	X	X	X	X	X
F-No. 1 Without Backing		X								
F-No. 2 With Backing			X	X	X	X	X	X		
F-No. 2 Without Backing				X						
F-No. 3 With Backing					X	X	X	X		
F-No. 3 Without Backing						X				
F-No. 4 With Backing							X	X		
F-No. 4 Without Backing								X		
F-No. 5 With Backing									X	X
F-No. 5 Without Backing										X

Qualified With	Qualified For
Any F-No. 6	All F-No. 6 [Note (1)]
Any F-No. 21 through F-No. 26	All F-No. 21 through F-No. 26
Any F-No. 31, F-No. 32, F-No. 33, F-No. 35, F-No. 36, or F-No. 37	Only the same F-Number as was used during the qualification test
F-No. 34 or any F-No. 41 through F-No. 46	F-No. 34 and all F-No. 41 through F-No. 46
Any F-No. 51 through F-No. 55	All F-No. 51 through F-No. 55
Any F-No. 61	All F-No. 61
Any F-No. 71 through F-No. 72	Only the same F-Number as was used during the qualification test

NOTE:
(1) Deposited weld metal made using a bare rod not covered by an SFA Specification but which conforms to an analysis listed in Table QW-442 shall be considered to be classified as F-No. 6.

Table QW-452.1(b)
Thickness of Weld Metal Qualified

Thickness, *t*, of Weld Metal in the Coupon, in. (mm) [Note (1)] and [Note (2)]	Thickness of Weld Metal Qualified [Note (3)]
All	2*t*
$^1/_2$ (13) and over with a minimum of three layers	Maximum to be welded

Table QW-461.9
Performance Qualification — Position and Diameter Limitations
(Within the Other Limitations of QW-303)

Qualification Test		Position and Type Weld Qualified [Note (1)]		
		Groove		Fillet or Tack [Note (2)]
Weld	Position	Plate and Pipe Over 24 in. (610 mm) O.D.	Pipe ≤ 24 in. (610 mm) O.D.	Plate and Pipe
Plate — Groove	1G	F	F [Note (3)]	F
	2G	F, H	F, H [Note (3)]	F, H
	3G	F, V	F [Note (3)]	F, H, V
	4G	F, O	F [Note (3)]	F, H, O
	3G and 4G	F, V, O	F [Note (3)]	All
	2G, 3G, and 4G	All	F, H [Note (3)]	All
	Special Positions (SP)	SP, F	SP, F	SP, F
Plate — Fillet	1F	...	...	F [Note (3)]
	2F	...	...	F, H [Note (3)]
	3F	...	...	F, H, V [Note (3)]
	4F	...	...	F, H, O [Note (3)]
	3F and 4F	...	...	All [Note (3)]
	Special Positions (SP)	...	...	SP, F [Note (3)]
Pipe — Groove [Note (4)]	1G	F	F	F
	2G	F, H	F, H	F, H
	5G	F, V, O	F, V, O	All
	6G	All	All	All
	2G and 5G	All	All	All
	Special Positions (SP)	SP, F	SP, F	SP, F
Pipe — Fillet [Note (4)]	1F	...	...	F
	2F	...	...	F, H
	2FR	...	...	F, H
	4F	...	...	F, H, O
	5F	...	...	All
	Special Positions (SP)	...	...	SP, F

NOTES:
(1) Positions of welding as shown in QW-461.1 and QW-461.2.

F = Flat
H = Horizontal
V = Vertical
O = Overhead
SP = Special Positions (see QW-303.3)

(2) Tack welds are not limited by pipe or tube diameters when their aggregate length does not exceed 25% of the weld circumference.
(3) Pipe $2\frac{7}{8}$ in. (73 mm) O.D. and over.
(4) See diameter restrictions in QW-452.3, QW-452.4, and QW-452.6.

Summary for Welder Qualification Test preparation.

1 Choose the Welding process applicable for Welder Qualification Test.

2 Decide welding type: either Manual or semi-automatic for Welder Qualification Test.

3 Select the WPS or Standard Welding Procedure Specifications (SWPS) to be followed.

4 Select the weld joint type, decide either with backing or without backing.

5 Decide the material type. either plate or pipe and its diameter for Welder Qualification Test.

6 Find the P-Number of the the base metal according to the WPS or WQT.

7 Find the F-Number of the the filler wire according to the WPS or WQT.

8 Thickness (t) of the weld deposit from WQT thickness and joint type. Usually, equal to base metal thickness in full penetration groove welds.

9 Decide the welding position & weld progression for Welder Qualification Test.

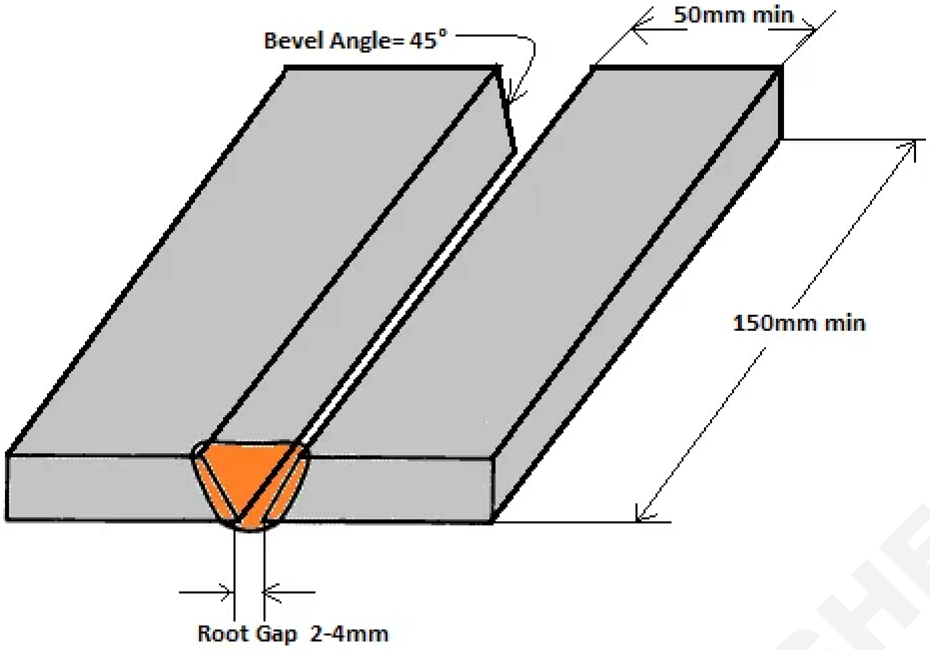
Preparation for the Performance Qualification Test Coupon or WQT.

Welder Qualification Test Piece Size.

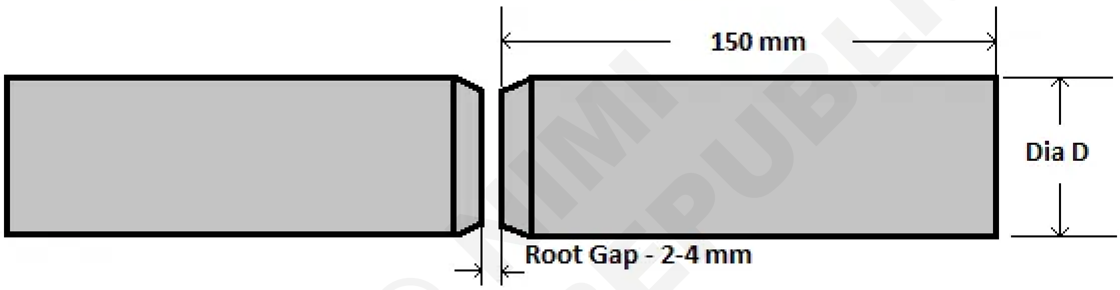
The dimensions or sizes for welder qualification test coupons according to ASME Section IX for plate weld are a minimum of 150 millimeters (6 inches) in length X more than 100 millimeters (4 inches) width for welding suitability.

Similarly, the dimensions for welder qualification of pipe test coupons according to ASME Section IX shall have a minimum length of 150 millimeters (6 inches) on each side of the weld.

The total circumferential length of pipe shall be a minimum of 150 millimeters (6 inches), for small OD multiple coupons shall be welded but not more than 4 coupons as per Section IX. The dimensions of the Plate and pipe test coupon are shown below for reference.



For Butt Weld Performance qualification



Pipe Full Penetration Joint

Validity of Welder Certification?

What is the duration for the welder certificate is Valid? Does it expire? There are many such questions, most welders or quality persons came through.

How often do Welders need to Recertify?

The American Welding Society (AWS) is a nonprofit organization that provides certification for welders. The AWS requires welders to recertify every three years.

There are two types of certification: welding performance qualification and welding operator qualification.

Welding performance qualifications prove that a welder can produce sound welds in accordance with the prescribed standards. A welding operator qualification demonstrates that a welder can operate the equipment safely and efficiently.

Recertification is important because it ensures that welders are up-to-date on the latest safety standards and procedures.

It also allows employers to verify that their employees are qualified to perform the work they were hired to do.

To learn about the validity of a welder certificate Click the below link:

Related Reading: Welder certificate validity as per ASME Section IX, AWS D1.1, and ISO 9606.

Different tests and Inspection involved in Qualification Weldments and Visual Inspection kits and gauges

Objectives: At the end of this lesson you shall be able to
- **explain the uses at weld fillet gauge.**
- **explain the uses of AWS type weld measurement gauge.**

Welding gauger: A set of individual leaves having the profile, made of, hardened and tempered , weld to straight with a clamping arrangment, The gauge is used to measure the leg size of weld reinforcement in buttwelds,(concave and convexing 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 a category of weld ins pection, to check weld profile and its required size of bead.

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

Fig 1

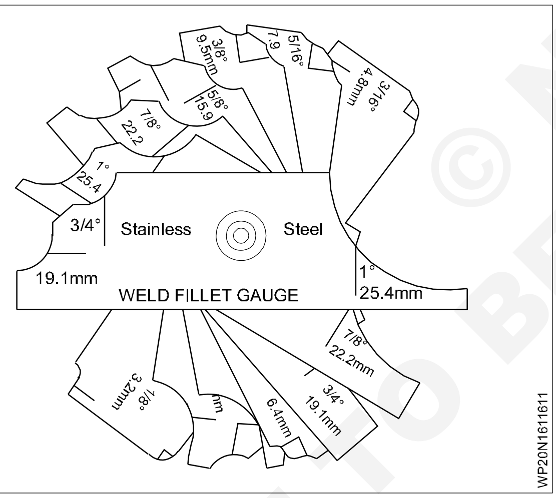
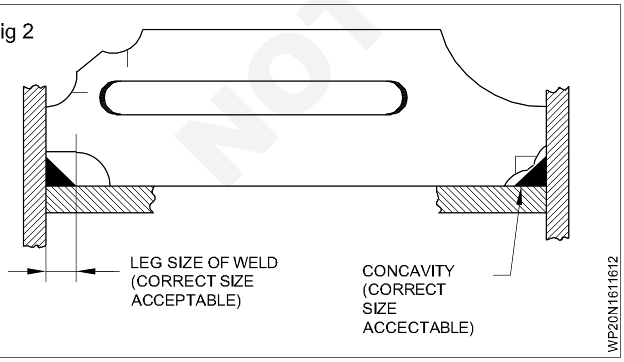


Fig 2

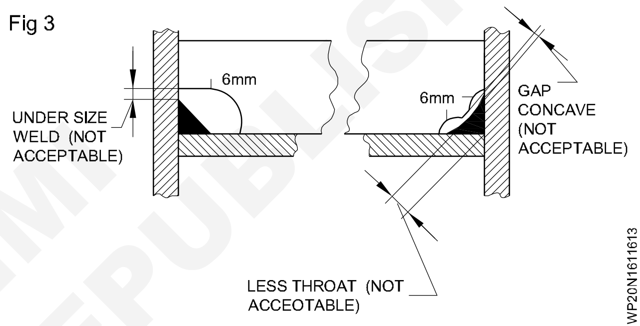


Weld fillet gauge: To check fillet weld profile for acceptable limit, the fillet weld is checked for the leg size, using weld fillet gauge. Also concaving in weld face is also to be determined by comparing the weld face adjusting the gauge. (Fig 1)

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 finshed with are end for checking the leg size and concaving of the weldface. (Fig 2)

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

Fig 3



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

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

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

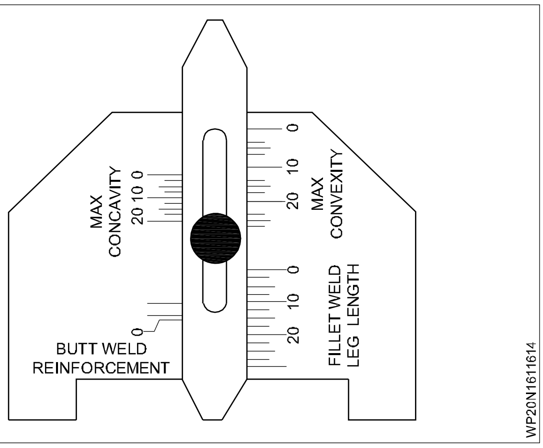
The gauges consist of struck which can be suitably altered according to the position of the used bead for fillet used butt weld.

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 1) 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 2)

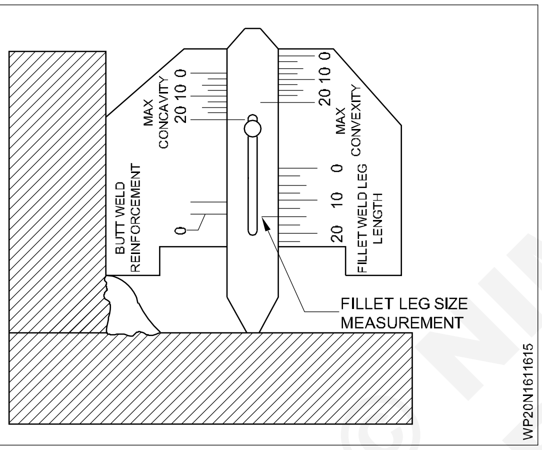
Fig 4



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

The co-incidence of the graduation scale defines the fillet issued leg measurement.

Fig 5



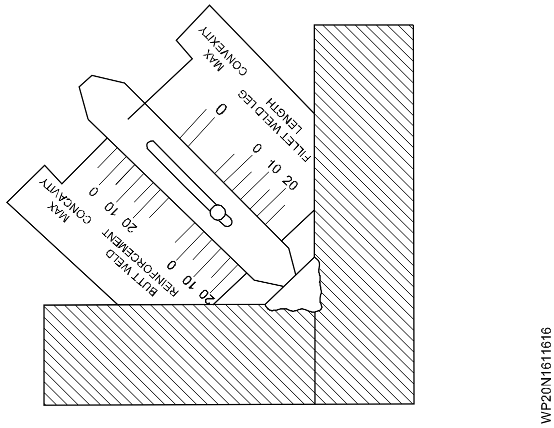
2 Acceptable size of convexity: To determaine the acceptable size of convexity, the stock portion of the gauge having 45° angle sides to which both the members of the joints is placed as shown in (fig 3)

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

3 Aceeptable 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 4.

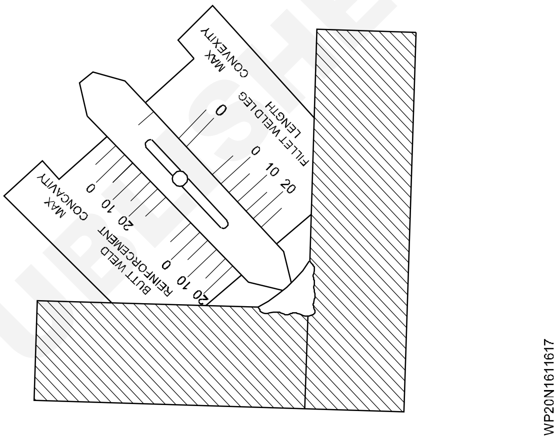
On sliding the pointer blade to touch the face of the weld determines the concavity, formed due to under fill of the weld bead as shown in Fig 4.

Fig 6



4 Acceptable reinforcement height on butt weld: To determine the acceptable size of reinforcement height on butt weld, the spode portion of the gauge, flat portion may

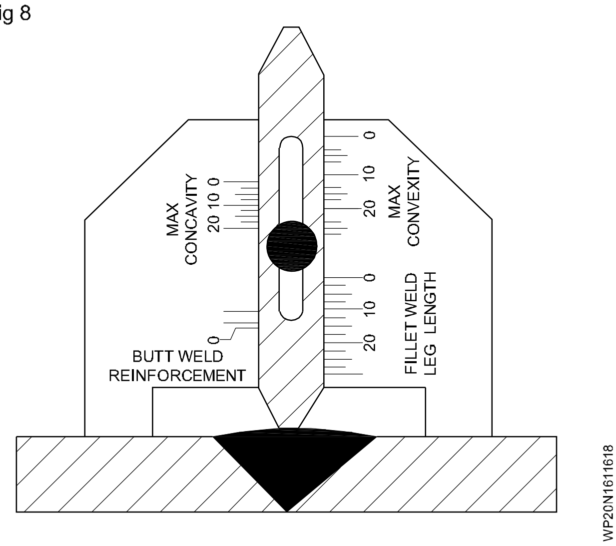
Fig 7



be scated on either size of butt weld as shown in Fig 5, on sliding the pointer blade downwards so as to touch the reinforcement placed on the butt weld.

The co-incidence of the graduated scale determines the acceptable reinforcement height of the weld bead.

Fig 8



Weld Qualify and Inspection Visual Inspections

Objectives: At the end of this lesson you shall be able to
- **state the necessity of weld qualifies and inspection**
- **explain the qualify inspection- conducted to overcome the common welding trainers.**
- **describe 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.

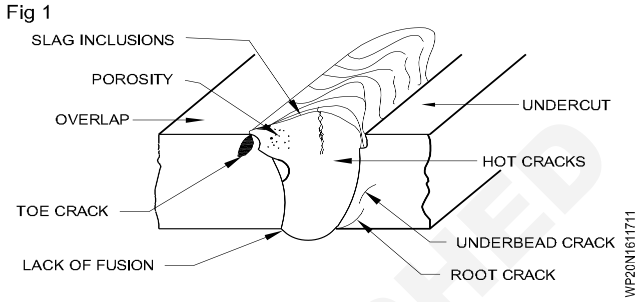
6 **Root crack:** The crack occurs at the root of a used joint

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.

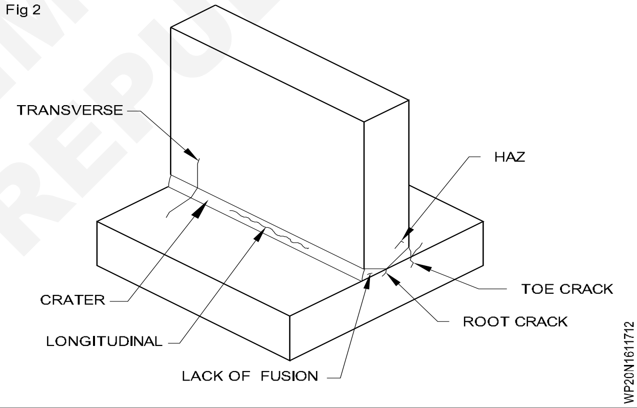
Fig 1



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

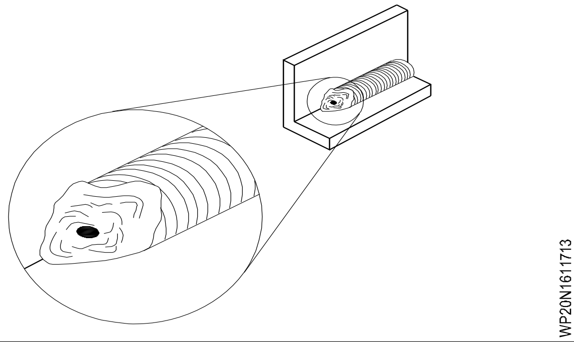


11 **Crater:** It is surface of the cavity extending into the weld bead as shown in figures.

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 gauger and its uses

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

Welding gauger: 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 a 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

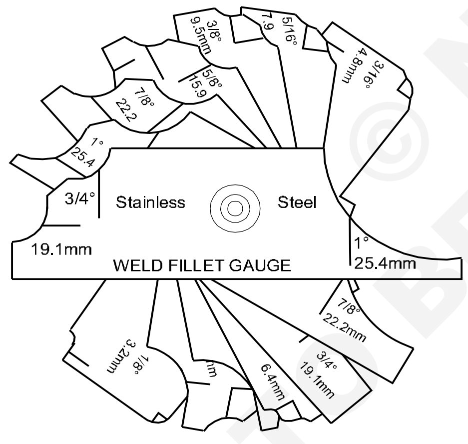


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Fig 2

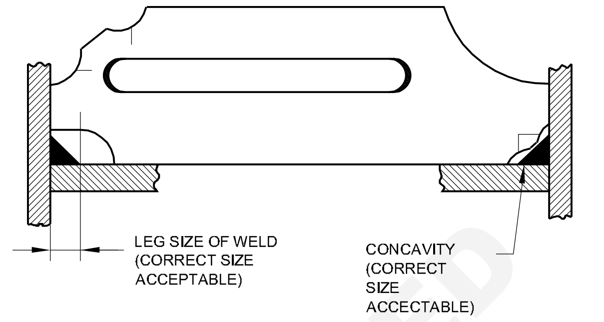
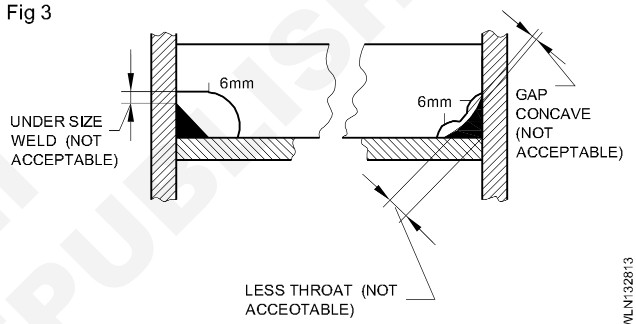


Fig 3



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According to the type of measurement the blade after positioning over the weld bead the locking screw as shown in (Fig 1) Is tightened suitably to determine the measurement .

Visual Inspection Kits and Gauges

Objectives: At the end of this lesson you shall be able to
- **state the necessity of weld qualifies and inspection**
- **explain the qualify inspection- conducted to overcome the common welding trainers.**
- **describe the appearance of good and defective welds.**

Principle

The basic procedure involved in the visual inspection is the illumination of the test specimen with the light, usually in the visible region.

It also requires the proper eye-sight of the tester. The surface of the test specimen is adequately cleaned before inspection, where the test specimen is illuminated and inspected using the naked eye (or) with the help of optical aids““such as mirrors, magnifying glasses, microscopes (or) video-cameras.

Visual Testing Requirements

- The requirements for visual tSesting typically depend on three areas
- The inspector's vision.
- To check whether the area being inspected is obstructed for the inspector.““To check the amount of light falling on the specimen using the light meter.

Defects Detected

- Presence or absence of cracks, corrosion layer, position of the cracks.
- Unfilled craters and contour of the welded parts.
- Surface porosity and general condition of the component.
- Misalignment of mated parts.

Optical Aids Used in Visual Inspection

Mirrors, Magnifying glasses., Microscopes., Borescope., Endoscope., Flexible Fibre,Optic Borescope.Telescope, Holography Circuit Television (CCTV) system.

Fig 1

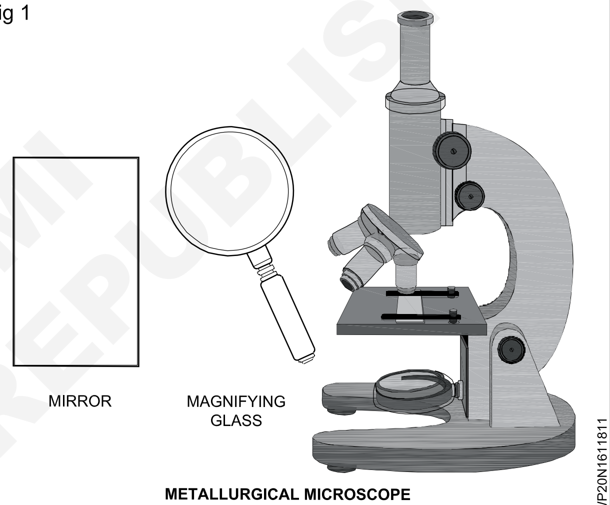


Fig 2

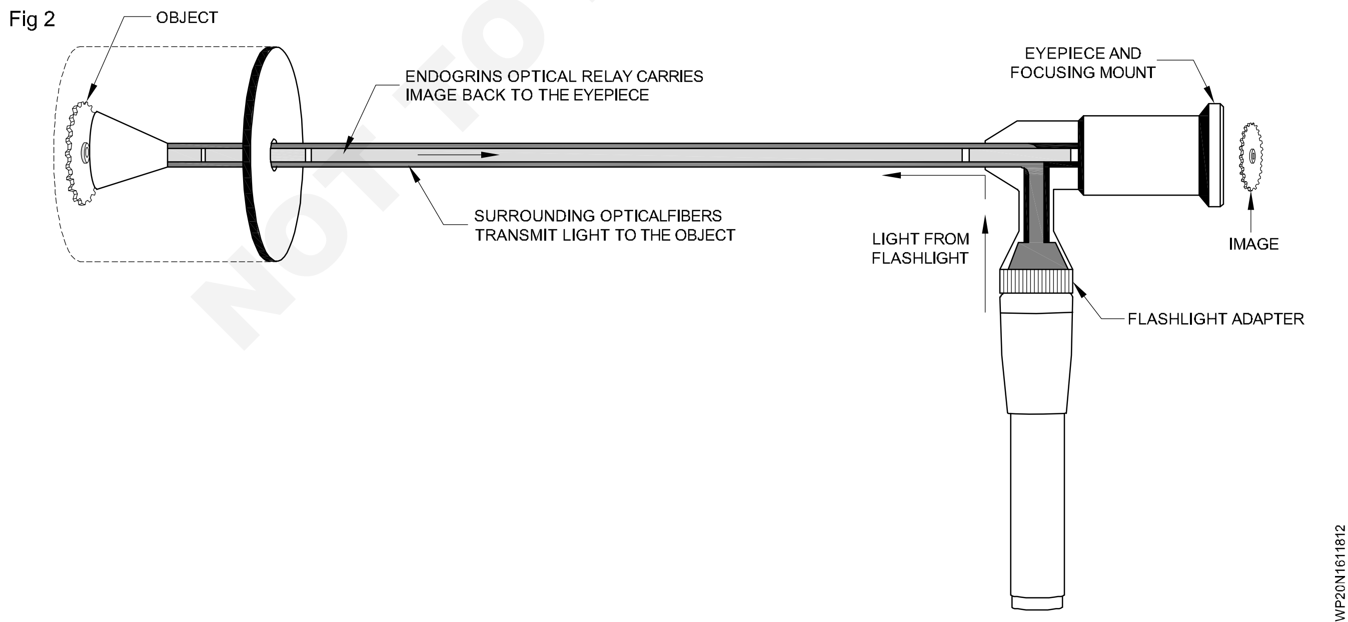
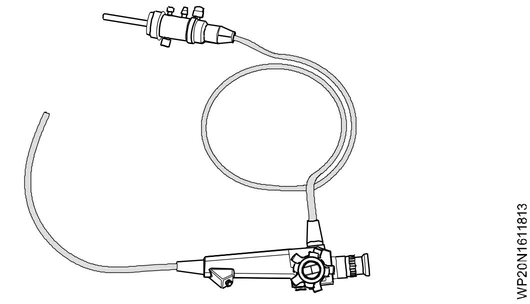


Fig 3



Pressure Welding Codes and Standards (IBR, ASME etc.)

Objectives: At the end of this lesson you shall be able to
- **explain boiler and pressure vessel codes.**

Sections of ASME Boiler and Pressure vessel Codes (BPVC)

The following list includes some of the most widely used Boiler and Pressure Vessel codes (BPVC) prepared and published by ASME.

Section I - Rules for construction of power Boilers

Section II - Materials

- Part A Ferrous Material Specifications
- Part B Nonferrous Material Specifications
- Part C Specifications for Welding, Rods, Electrodes and Filler Metals
- Part D Properties

Section III - Rules for Construction of Nuclear Facility Components.

Subsection NCA General Requirements for Divisions 1 and 2

Division 1

- Subsection NB Class 1 Components
- Subsection NC Class 2 Components
- Subsection ND Class 3 Components
- Subsection NE Class MC Components
- Subsection NF Supports
- Subsection NG Core Support Structures
- Subsection NH Class 1 Components in Elevated Temperature Service

Division 2

Code for Concrete Containment

Division 3

Containment Systems for Storage and Transport Packaging of Spent Nuclear Fuel and High-Level Radioactive Materials and Waste.

Section IV - Rules for Construction of Heating Boilers.

Section V - Nondestructive Examination.

Section VI - Recommended Rules for the Care and Operation ofHeating Boilers.

Section VII - Recommended Guidelines for the Care of Power Boilers.

Section VIII - Rules for Construction of Pressure Vessels.

Division 1 - Pressure Vessels.

Division 2 - Alternative Rules for Pressure Vessels

Division 3 - Alternative Rules for Construction of High-Pressure Vessels

Section IX - Welding and Brazing Qualifications.

Section X - Fiber-Reinforced Plastic Pressure Vessels

Section XI - Rules for Inservice Inspection of Nuclear Power Plant.

Section XII - Rules for Construction and Continued Service of Transport

Brief introduction of some of the widely used BPVC sections

Section I - Section gives requirements for the construction of

- Power Boilers, Electric Boilers, Miniature boilers
- Heat recovery steam generators (HRSG)
- Power boilers used in Locomotive, Portable and Traction type
- High-temperature water tube boilers
- Certain fired pressure vessels to be used in stationary services.

Section II - Section II is exclusively dedicated to materials and their specifications. These specifications contain requirements for chemical and mechanical properties and other necessary details. It includes four parts viz part A, part B,part C, and part D.

Part A - Ferrous Material Specifications

ls which are suitable for use in the construction of pressure vessels. The specifications provided in this part give the mechanical properties, heat treatment, heat and product chemical composition and analysis, test specimens, and methodologies of testing. They are designated by 'SA' numbers and are identical or similar to those published in ASTM specifications.

Part B-Nonferrous Material Specifications

It provides specifications for nonferrous materials. The specifications provided in this Part specify the mechanical properties, heat treatment, heat and product chemical composition and analysis, test specimens, and methodologies of testing. They are designated by SB numbers and are identical or similar to those published““in ASTM specifications.

Part C - Specifications for Welding Rods, Electrodes, and Filler Metals

It provides mechanical properties, heat treatment, heat and product chemical composition and analysis, test specimens, and methodologies of testing for welding rods, filler metals, and electrodes used in the construction of pressure vessels.

They are designated with SFA numbers which is derived from the American Welding Society (AWS) specifications.

Part D-Properties (Customary/Metric)

It provides tables for the design stress values, tensile and yield stress values, and material properties.

Section III - It provides guidelines for the construction of nuclear facility components and supports as well, Section III includes different divisions and subsections.

Section IV - Provides guidelines for design, fabrication, installation, and inspection Heating boilers, such boilers are primarily used for.

- Steam Heating
- Hot water heating
- Hot water supply boilers
- Potable water heaters

These boilers are meant for low-pressure service and are directly fired by solid or liquid fuels such as coal, oil, gas, electricity, etc.

Section V - This section is dedicated Non-Destructive tests (NDT). It provides requirements and methods for non-destructive tests. It also contains the detailed duties of authorized inspectors, manufacturer's examination responsibility, and requirements for qualification of personnel, inspection, and examination. These examination methods are key to detect the discontinuities present in the material, weld, and fabricated components. It also includes a glossary of all related terms.

Section VI - Provides guidelines for operation and maintenance of Heating boilers which are manufactured as per Section IV.

Section VI also covers guidelines for associated controls and automatic fuel burning.

Section VII - Provides guidelines for operation, maintenance, and inspection of power boilers. It also includes the necessary guidelines for the operation of auxiliary equipment and appliances that are directly responsible for the safe and reliable operation of power boilers.

Boilers which come under the purview of Section VII are Stationary, Portable, and Traction type boilers, but not Locomotive and High-temperature water boilers, Heating boilers (Section VI), and Nuclear power plant boilers (Section XI).

Section VIII - It provides detailed guidelines for the design, fabrication, testing. inspection, and certification of pressure vessels (both fired and unfired). Section VIII includes three divisions viz Division I, Division II, and Division III

Division 1 - Division provides guidelines for design, fabrication, inspection, testing, and certification of pressure vessels operating at either internal or external pressures exceeding 15 psi (100 Kpa).

Division 2 - It provides requirements for the materials, design, and Non-destructive examination for pressure vessels. Division 2 standards are more rigorous than division

1 However, it allows for higher stress intensity values.These rules may also be applied to human occupancy pressure vessels such as those used in the diving industry.

Division 3 - It provides guidelines for pressure vessels operating at or more than 10,000 psi (in general) either internally or externally. The maximum pressure limit is nowhere mentioned in the code even in divisions 1 and 2 too.

Section IX - This Section covers necessary guidelines and requirements pertaining to welding and brazing procedures (as per the requirements of other BPVC standards). It also contains guidelines for qualification and requalification of welders, welding operators and brazing operators. It also contains all the essential, non-essential and supplementary essential variables required for welding and brazing.

Section IX is further divided into four parts, Namely

1 Part QG - Contains General Requirements for all““(viz. Welding, Brazing, and Plastic Fusing)

2 Part QW - Contains requirements for Welding

3 Part QB - Contains requirements for Brazing

4 Part QF - Contains requirements for Plastic Fusing.

Note - Detailed summary for Section IX including preparation of welding procedure specification (WPS), steps followed for Procedure Qualification Record (PQR), Welder performance qualification test, range, and limits, etc. has been explained separately.

To learn the steps involved in writing a welding procedure specification,To understand welder performance qualification,To understand the thickness limit for performance and procedure qualification.

Section XII - It provides guidelines for construction and continued service of pressure vessels used for transportation of dangerous goods at pressures from full vacuum to 3000 psi and volume greater than 120 gallons.

List of some of the most widely used ASME Standards

CSD -1 - Controls and Safety Devices for Automatically-fired Boilers.

B1.1 - Unified Inch Screw Threads (UN and UNR Thread Form).

B1.20.1 - Pipe Threads, General Purpose (Inch).

B16.1 - Cast-iron Pipe Flanges and Flanged Fittings.

B16.3 - Malleable Iron Threaded Fittings, Classes 150 and 300

B16.4 - Gray Iron Threaded Fittings, Class 125 and 250.

B16.5 - Pipe Flanges and Flanged Fittings

B16.9 - Factory-made Wrought Steel Buttwelding Fittings

B16.11 - Forged Fittings, Socket-Welding and Threaded

B16.15 - Cast-bronze Threaded Fittings, Classes 125 and 250

B16.20 - Ring-joint Gaskets and Grooves for Steel Pipe Flanges

B16.24 - Cast Copper Alloy Pipe Flanges and Flanged Fittings

B16.25 - Buttwelding Ends

B16.28 - Wrought Steel Buttwelding Short Radius Elbows and Returns

B16.34 - Valves Flanged, Threaded, and Welding End

B16.42 - Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300

B16.47 - Large Diameter Steel Flanges, NPS 26 Through NPS 60

B18.2.2 - Square and Hex Nuts (Inch Series)

B31.1 - Power Piping

B31.2 - Fuel Gas Piping

B31.3 - Process Piping

B31.4 - Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids

B31.5 - Refrigeration Piping and Heat Transfer Components

B31.8 - Gas Transmission and Distribution Piping

B31.9 - Building Services Piping

B31.11 - Slurry Transportation Piping

B36 .10M- Welded and Seamless Wrought Steel Pipe

QAI-1 - Qualifications for Authorized Inspection

PVHO-1 - Safety Standard for Pressure Vessels for Human

Asme Performance Test Code Ptc 25 - Pressure Relief Devices

List of important ASNT Standards

ACCP - Central Certification Program

CP-189 - The standard for Qualification and Certification of Nondestructive Testing Personnel

SNT-TC-1A - Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

List of some of the most widely used ASTM standards

A 126 - Standard Specification for Gray Iron Castings for Valves,Flanges and Pipe Fittings.

B 139 - Standard Specification for Phosphor-Bronze Rod, Bar and Shapes.

D 56 - Standard Test Methods for Flash Point by Tag Closed Tester.

D 93 - Standard Test Methods for Flash Point by Pensky-Martens Closer tester.

E8 - Standard Test Methods of tension Testing of metallic materials.

E83 - Methods of Verification and Classification of Extensometers.

E125 - Reference Photographs for Magnetic Particle Indication on Ferrous Castings.

E 140 - Hardness Conversion Tables for Metals.

E 186 - Standard Reference Radiographs for Heavy-walled (2 to 4- 1/2 inch) Steel Castings.

E 208 - Method of Conducting Drop Weight Test to Determine Nil ductility Transition Temperature of Ferritic Steel.

E 280 - Standard Reference Radiographs for Heavy-walled (4-1/2 to 12-inch) Steel Castings

E 446 - Standard Reference Radiographs for Steel Castings up to 2 Inches in Thickness

Important ASME Designators

ASME Code designators and the associated sections of the ASME Boiler and Pressure Vessel Code are listed for user's convenience.

Section I - A, E, M, PP, S, V

Section II - None

Section III - N,NA,NPT,NV

Section IV - H,HLW,HV

Section VIII - Division 1: U,UM,UV

Division 2 - U2,UV

Division 3 - U3,UV3

Section XII - T,TD,TV.

Writing Procedure for WPS and PQR

Objectives: At the end of this lesson you shall be able to
- **explain boiler and pressure vessel codes.**

A welding procedure specification (WPS) is a written document providing direction to the welder (or welding operator). It contains all the necessary parameters viz joints, base metals, filler metals, positions, preheat, PWHT, gas etc. (Including ranges, if any) under which the welding process must be performed. These parameters are known as variables (as per ASME Section IX) Three types of variables are mentioned in the code these are,

1 Essential Variable

2 Non essential Variable

3 Supplementary Essential variable

Essential Variables (For WPS QG-105.1 & QW-251.2)

A change in essential - variable is considered to affect the mechanical properties (other than toughness) of the welded joint. Hence the WPS must be requalified, if the essential variable is changed.

Supplementary Essential Variables (QG-105.3 & QW-401.1)

A change in the supplementary essential variable will affect the toughness properties of the joint, heat-affected zone, or base material. Hence supplementary essential variables become additional essential variables in situations where procedure qualification requires toughness testing. When procedure qualification does not require the addition of toughness testing, supplementary essential variables are not applicable.

Nonessential Variables (QG-105.4 & QW-251.3)

Nonessential variables are those in which a change can be made without requalification of the existing WPS, since it is not considered to affect the mechanical properties of the joint. Though a change in the nonessential variable doesn't require requalification of the WPS but still it should be properly addressed in the welding procedure specification (WPS).

Some basic facts about WPS

A welding procedure specification shall contain, as a minimum, the specific essential and nonessential variables that are applicable to the welding process. When the referencing Code, standard, or specification requires toughness qualification of the welded joint, then applicable supplementary essential variables shall also be provided in the WPS.

These variables are listed in tables from QW-252 to QW-257. Please note that for““each welding process, there is a separate table containing the list of all variables. For example, list of variables (essential, nonessential and supplementary essential) for Shielded Metal Arc Welding (SMAW) is given in table QW-253. Please see the below table (Table-1) for a complete list of welding processes and their corresponding tables for variables (as per ASME Section IX)

Table-1

S.No	Welding Process	Table
1	Oxyfuel Gas Welding (OFW)	Qw-252 & Qw-2521
2	Shielded Metal Arc Welding (SMAW)	OW-253 & 0W-253.1
3	Submerged Arc Welding (SAW)	QW-254 & QW-254.1
4	Gas Metal - Arc Welding (GMAW and FCAW)	QW-255 & QW-255.1
5	Gas Tungsten - Arc Welding (GTAW)	QW-256 & QW-256.1
6	Plasma - Arc Welding (PAW)	OW-257 & QW-257.1
7	Electroslag Welding (ESW)	OW-258 & QW-258.1
8	Electrogas Welding (EGW)	QW-259
9	Electron Beam Welding (EBW)	QW-260
10	Stud Welding	OW -261
11	Inertia and Continuous Drive Friction Welding	OW -262
12	Resistance Welding	OW 263
13	Laser Beam Welding (LBW)	OW-264 & OW-264.1

S.No	Welding Process	Table
14	Low-Power Density Laser Beam Welding (LLBW)	QW-264.2
15	Flash Welding	QW-265
16	Diffusion Welding (DFW)	QW-266
17	Friction Stir Welding (FSW)	QW-267

Steps to be followed for preparation of WPS

First of all we need to identify the welding process which is to be used for example weather it's a SMAW or GMAW or GTAW or any other welding process or it's a of two or more welding processes. Once the welding process is decided then we need to see the corresponding table (QW-252 to QW-257) for the complete list of variables. With the help of the table we can list out all the necessary variables to be used in our WPS.

Once the minimum variables (essential, nonessential and supplementary variable, if any) are decided a preliminary WPS (or proposed WPS also known as pWPS) is prepared.

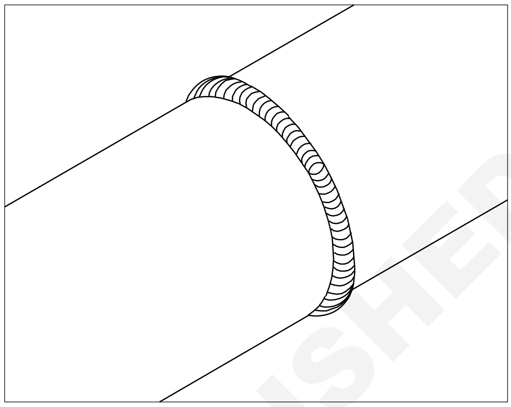
Based on the proposed WPS, Test coupon (or coupons) is prepared, and the coupon is welded as per the values (or range) provided in the pWPS. All the real time data (observed during the welding of test coupon) are recorded.After successful welding, test coupon (or coupons) is subjected to destructive test, and if the test coupon (or coupons) meets the minimum code requirement then the same pWPS is finalized and approved for further job. In case of any change same procedure is repeated till the test coupon doesn't meet the minimum code requirement.

All the real time data during welding of test coupon and destructive test report datais compiled into one document known as Procedure qualification record (PQR).After successful preparation of PQR, final WPS is prepared and produced to the authorized welding inspector for final approval.

What is Welding Procedure Qualification Record (PQR)?

This article talks about procedure qualification record (PQR) based on requirements of ASME Code Section IX. The purpose of qualifying a WPS is that to indicate joining process proposed for production welding has required mechanical property The WPS is written by knowledgeable person but needs to be tested to ensure the produced weld based on WPS has required mechanical property. When the WPS provided, then a test sample must be prepared and welded. All welding variable must be recorded during the welding Please note in WPS you have the range but you will not have a range in the PQR, and you need to record a single value for each specified variable.(Fig 1)

Fig 1



For example, your WPS indicates preheat temperature as 100 to 160 degree Fahrenheit. You are starting the preheat process on your test specimen and measuring base metal temperature with a pyrometer and after few minutes you record the joint temperature as 140 degree Fahrenheit, and then you stop preheating and asking your welder to start welding Your preheat temperature in the PQR form will be 140 degree Fahrenheit This applies to all other variables such as joint design, filler wire diameter, PWHT condition, material thickness, material grade and type, voltage, amperage, inert gas flow rate and type, etc. You should indicate a single value for each field, and the range will not be acceptable. Welding Procedure Qualification Records in ASME Code Section IX““The test specimen size and dimension must be based on identified values in ASME Code Section IX. After completion of welding and heat treatment (if needed), you need to send the test specimen to the metallurgical lab for mechanical testing. For any POR, normally two tension tests, two root face bend test and two face bend test is required.The acceptance criteria have been provided in the ASME Code Section IX. The QW- 451 table provides you the information about number and type of tests. For example, if your test specimen is greater than the % inch you cannot perform root and face bend test and instead you need to run 4 side bend tests.The acceptance criteria for tension test have been provided in QW-153.1. The test specimen should not be broken below the minimum specified tensile strength of base metal, but if it breaks in out of weld area or out of weld interface then would be acceptable if it is not more than 5% below the minimum specified tensile strength For instance if you material is SA 516 Gr 70, and it breaks out of weld area on 67 ksi then the test would be acceptable The acceptance criteria for bend test have been provided in QW-163 Normally after bend test there should be any crack more than 1/8 inch on the side that was placed on the stress.The PQR documents what occurred during welding of the test coupon and the result of the test coupon. The PQR gives suitability of weld for required mechanical properties eg strength and ductility The tension test indicates the strength and the bend tests indicate ductility.Please note the procedure qualification record cannot be revised otherwise the case for revising being typing error or misspelling. The PQR must include all essential variable (such as P number F number A number PWHT) and supplementary essential variables (such as Group Number).The nonessential variables are not code requirements for PQR When construction code like ASME Code Section VIII Div I requires impact testing. the impact testing must be included in Welding Procedure Qualification Record technical testing. Normally you need to conduct two set of impact testing, one set in weld metal and one set in heat affected zone.The ASME Section IX Training Course is 2 days video training course and available online and the student that successfully pass the exam. receive 141 academy certificate with 16 hours training credit.