WELDER
(GMAW & GTAW)

NSQF LEVEL - 3

TRADE THEORY

SECTOR : CAPITAL GOODS AND MANUFACTURING

(As per revised syllabus July 2022 - 1200 Hrs)

Directorate General of Training

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

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

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

Sector : Capital Goods and Manufacturing

Duration : 1 Year

Trades : Welder (GMAW & GTAW) - Trade Theory - NSQF Level - 3 (Revised 2022)

Developed & Published by

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

First Edition : February 2023 Copies : 1000

Rs.240/-

FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, 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 (GMAW & GTAW) - Trade Theory** in **CG & M Sector** under **Yearly Pattern.** The NSQF Level - 3 (Revised 2022) Trade Practical will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 3 (Revised 2022) trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 3 (Revised 2022) the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these Instructional Media Packages IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

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

Jai Hind

Director General (Training)
Ministry of Skill Development & Entrepreneurship,
Government of India.

New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under 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 for the trade of **Welder (GMAW & GTAW) - Trade Theory - NSQF Level - 3 (Revised 2022)** under the **CG & M** Sector for ITIs.

MEDIA DEVELOPMENT COMMITTEE MEMBERS

Shri. K. Rajasekaran	-	Assistant Training Officer, Govt. ITI, Chennai - 81.
Smt. G. Sangareeswari	_	Junioir Training Officer, Govt - ITI - Guindy.
Shri. V. Janarthanan	-	Assistant Professor, Rtd., MDC Member, NIMI, Chennai - 32.

NIMI CO-ORDINATORS

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

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 intended to be used in practical workshop. It consists of a series of practical exercises to be completed by the trainees during the course. These exercises are designed to ensure that all the skills in compliance with NSQF Level - 3 (Revised 2022) syllabus are covered.

The manual is divided into Six modules.

Module 1	-	**Induction Training & Welding Process**
Module 2	-	**Welding Techniques**
Module 3	-	**Weldability of Steel**
Module 4	-	**Gas Metal Arc Welding**
Module 5	-	**Gas Tungsten Arc Welding**
Module 6	-	**Pipe Joints & Inspection**

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

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

TRADE THEORY

The manual of trade theory consists of theoretical information for the Course of the **Welder (GMAW & GTAW)** - Trade Theory - NSQF Level - 3 (Revised 2022) in **CG & M**. The contents are sequenced according to the practical exercise contained in NSQF Level - 3 (Revised 2022) syllabus on Trade Theory attempt has been made to relate the theoretical aspects with the skill covered in each exercise to the extent possible. This correlation is maintained to help the trainees to develop the perceptional capabilities for performing the skills.

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

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

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

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

S.No.	Learning Outcome	Ref. Ex.No.
1	**Perform joining of MS sheet by Gas welding in different positions following safety precautions. (NOS: CSC/N0204)**	**1.1.01 - 1.1.06**
2	**Join MS plates by SMAW in different positions. (Mapped NOS: CSC/N0204)**	**1.1.07 - 1.1.09**
3	**Perform straight, bevel & circular cutting on MS plate by Oxy-acetylene cutting process. (Mapped NOS: CSC/N0201)**	**1.2.10 - 1.2.32**
4	**Perform different types of MS pipe joints by Gas welding (OAW). (NOS: CSC/N0204)**	**1.3.33 - 1.3.38**
5	**Weld different types of MS pipe joints by SMAW. (Mapped NOS: CSC/N0204)**	**1.3.39 - 1.3.46**
6	**Setup GMAW / GTAW plant and weld M.S, S.S and Aluminium sheets in all positions. (Mapped NOS: CSC/N0212)**	**1.3.47 - 1.3.49**
7	**Perform Arc gauging on MS plate. (NOS: CSC/N0204)**	**1.3.50 - 1.3.52**
8	**Join MS/ Aluminium /SS sheets/plates by GMAW in various positions using different modes of metal transfer. (Mapped NOS: CSC/N0209)**	**1.3.53 - 1.3.54**
9	**Using of mixed shielding gas for GMAW welding. (NOS: CSC/N0204)**	**1.4.55 - 1.4.66**
10	**Welding of metals by FCAW process. (Mapped NOS: CSC/N0205)**	**1.4.67 - 1.4.70**
11	**Join Aluminum & Stainless-Steel sheets by GTAW in different position. (Mapped NOS: CSC/N0212)**	**1.5.71- 1.5.90**
12	**Weld pipe joints by GTAW. (Mapped NOS: CSC/N0212)**	**1.6.91 - 1.6.94**
13	**Cut ferrous and nonferrous metal using plasma Arc cutting. (Mapped NOS: CSC/N0207)**	**1.6.95 - 1.6.97**
14	**Test welded joint by visual inspection Dye penetrant & Magnetic particle testing methods. (Mapped NOS: CSC/N0204)**	**1.6.98 - 1.6.99**

SYLLABUS

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
Professional Skill 43Hrs; Professional Knowledge 08 Hrs	Perform joining of MS sheet by Gas welding in different positions following safety precautions. (NOS: CSC/N0204)	**Induction training:** 1. Familiarization with the Institute. 2. Importance of trade Training. 3. Machinery used in the trade. Introduction to safety equipment and their use etc. 4. Hack sawing, filing square to dimensions. Markin	- 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.
		5. Setting up of Arc welding machine & accessories and striking an arc. 6. Setting of oxy-acetylene welding equipment, Lighting and setting of flame.	- 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 23Hrs; Professional Knowledge 04 Hrs	Join MS plates by SMAW in different positions. (Mapped NOS: CSC/N0204)	7. Fusion run without and with filler rod on M.S. sheet 2 mm thick in flat position. 8. Edge joint on MS sheet 2 mm thick in flat position without filler rod. 9. Marking and straight line cutting of MS plate. 10 mm thick by gas.	- Different process of metal joining methods: Bolting, riveting, soldering, brazing, seaming etc. - Types of welding joints and its applications. Edge preparation and fit up for different thickness. - Surface Cleaning
Professional Skill 164Hrs; Professional Knowledge 32 Hrs	Perform straight, bevel & circular cutting on MS plate by Oxy-acetylene cutting process.(Mapped NOS: CSC/N0201)	10. Straight line beads on M.S. plate 10 mm thick in flat position. 11. Weaved bead on M. S plate 10mm thick in flat position.	- Basic electricity applicable to arc welding and related electrical terms & definitions. - Heat and temperature and its terms related to welding - Principle of arc welding. And characteristics of arc.
		12. Square butt joint on M.S. sheet 2 mm thick in flat Position. 13. Fillet "T" joint on M. S. Plate 10 mm thick in flat position.	- 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.
		14. Beveling of MS plates 10 mm thick. By gas cutting. 15. Open corner joint on MS sheet 2 mm thick in flat Position. 16. Fillet lap joint on M.S. plate 10 mm thick in flat position.	- Arc welding power sources: Transformer, Rectifier and Inverter type welding machines and its care & maintenance. - Advantages and disadvantages of A.C. and D.C. welding machines.
		17. Chair fabrication without hand rest, with square pipe of 25mm width 1 mm (GMAW/GTAW welding machine)	- Welding positions as per EN & ASME: flat, horizontal, vertical and over head position. - Weld slope and rotation. - Welding symbols as per BIS & AWS.

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
		18. Fillet "T" joint on M S she et 2 mm thick in flat position. 19. Open Corner joint on MS plate 10 mm thick in flat position. 20. Fillet Lap joint on MS sheet 2 mm thick in flat position. 21. 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.
		22. Square Butt joint on M.S. sheet. 2 mm thick in Horizontal position. 23. Straight line beads and multi layer practice on M.S. Plate 10 mm thick in Horizontal position. 24. Fillet "T" 10 mm thick in Horizontal position.	- Calcium carbide uses and hazards. - Acetylene gas properties. - Acetylene gas Flash back arrestor
		25. Fillet Lap joint on M.S. sheet 2 mm thick in horizontal position. 26. 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.
		27. Fusion run with filler rod in vertical position on 2mm thick M.S. sheet. 28. Square Butt joint on M.S. sheet. 2 mm thick in vertical position. 29. Single Vee Butt joint on M.S. plate 12 mm thick in horizontal position (2G).	- Oxy acetylene gas welding Systems (Low pressure and High pressure). Difference between gas welding blow pipe(LP & HP) and gas cutting blow pipe - Gas welding techniques. Rightward and Leftward techniques.
		30. Small tool fabrication with 25mm square pipe of Width iMM& dimension 12*9*9 inch. (G M A W / GTAW process). 31. Fillet "T" joint on M.S sheet 2 mm thick in vertical position. 32. Fillet "T" 10 mm thick invertical 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 54Hrs; Professional Knowledge 12 Hrs	Perform different types of MS pipe joints by Gas welding (OAW). (NOS: CSC/N0204)	33. Structural pipe welding butt joint on MS pipe 0 50 and 3mm WT in 1G position. 34. Fillet Lap joint on M.S. Plate 10 mm in vertical position.	- Specification of pipes, various types of pipe joints, pipe welding positions, and procedure. - Difference between pipe welding and plate welding.
		35. Open Corner joint on MS plate 10 mm thick in vertical position. 36. Pipe welding - Elbow joint on MS pipe 0-50 and 3mm WT. 37. Pipe welding "T" joint on MS pipe 0 - 50 and 3mm WT. 38. Single "V" Butt joint on M S plate 12 mm thick in vertical position (3G).	- Pipe development for Elbow joint, "T" joint, Y joint and branch joint - Uses of Manifold system - Gas welding filler rods, specifications and sizes. - Gas welding fluxes - types and functions. - Gas Brazing &Soldering : principles, types fluxes & uses

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
			- Gas welding defects, causes and remedies.
Professional Skill 61Hrs; Professional Knowledge 11 Hrs	Weld different types of MS pipe joints by SMAW. (Mapped NOS: CSC/N0204)	39. Pipe welding 45 ° angle joint on MS pipe 0 - 50 and 3mm WT. 40. Straight line beads on M.S. plate 10mm thick in over head position.	- Electrode : types, functions of flux, coating factor, sizes of electrode. - Effects of moisture pick up. - Storage and baking of electrodes.
		41. Pipe Flange joint on M.S plate with MS pipe 0 - 50 mm X 3mm WT. 42. Fillet "T" 10 mm thick in over head position. 43. Pipe welding butt joint on MS pipe 0 - 50 and 5 mm WT. in 1G position. 44. Fillet Lap joint on M.S. plate 10 mm thick in over head position.	- Weldability of metals, importance of pre heating, post heating and maintenance of inter pass temperature. - Welding of low, medium and high carbon steel and alloy steels.
		45. Single "V" Butt joint on MS plate 10mm thick in over head position(4G). 46. Pipe butt joint on M. S. pipe 0 - 50mm WT 6mm (1G Rolled).	- Effectsof alloying elements on steel - Stainless steel: types- weld decay and weldability.
Professional Skill 25 Hrs; Professional Knowledge 05 Hrs	Setup GMAW / GTAW plant and weld M.S, S.S and Aluminium sheets in all positions. (Mapped NOS: CSC/N0212)	47. Square Butt joint on S.S. sheet. 2 mm thick in flat position. 48. Square Butt joint on S.S. Sheet 2 mm thick in flat position. 49. Square Butt joint on Brass sheet 2 mm thick in flat position.	- Brass - types - properties and welding methods. - Copper - types - properties and welding methods.
Professional Skill 23Hrs; Professional Knowledge 04 Hrs	Perform Arc gauging on MS plate. (NOS: CSC/ N0204)	50. Square Butt & Lap joint on M.S. sheet 2 mm thick by brazing. 51. Single "V" butt joint C.I. plate 6mm thick in flat position. 52. Arc gouging on MS plate 10 mm thick.	- Aluminium, properties and weldability, Welding methods - Arc cutting & gouging,
Professional Skill 20Hrs; Professional Knowledge 04 Hrs	Join MS/ Aluminium /SS sheets/plates by GMAW in various positions using different modes of metal transfer. (Mapped NOS: CSC/ N0209)	53. Square Butt joint on Aluminium sheet. 3 mm thick in flat position. 54. Bronze welding of cast iron (Single "V" butt joint) 6mm thick plate.	- Cast iron and its properties types. - Welding methods of cast iron.
Professional Skill 107Hrs; Professional Knowledge 22 Hrs	Using of mixed shielding gas for GMAW welding. (NOS: CSC/N0204)	55. Familiarization with the machinery used in the trade. 56. Introduction to safety equipment and their use etc. 57. Setting up of GMAW/GTAW welding machine & accessories.	- Outline of the subjects to be covered. - Safety precautions pertaining to GTAW & GMAW.
		58. Straight line beads on MS plate by GMAW welding. 59. Lap joint on MS plate by GMAW welding in down hand position.	- Introduction to GMAW - equipment - accessories. - Various names of the process.(MIG-MAG/ CO2 WELDING, FCAW). - Advantages & Limitations.

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
		60. Open corner joint on MS plate in down hand position. 61. "T" joint on MS sheet in flat position.	- Power source & accessories Wire Feed unit. - Types of shielding gases &advantages.
		62. "T" joint on MS sheet in horizontal position. 63. "T" joint on MS sheet in vertical position. 64. "T" joint on MS sheet in overhead position.	- Welding Gun & its parts. - Modes of metal transfer - Dip, Globular, spray &pulsed transfer and its significance.
		65. Single "V' butt joint by C02 welding in down hand position. 66. Single "V' butt joint by Argo shield welding in flat position (Gas: Argon and CO_2 mixture).	- Flux cored arc welding. - Welding wire types and specification.
Professional Skill 41Hrs; Professional Knowledge 09 Hrs	Welding of metals by FCAW process. (Mapped NOS: CSC/ N0205)	67. Straight line beads on MS plate by Flux cored Arc welding (FCAW). 68. Single "V' joint by Flux cored Arc welding.	- Trouble shooting in MIG welding. - Data and Tables related to CO2 welding.
		69. Straight line beads on S.S plate by GMAW welding. 70. Lap & Square butt and T joint on S.S. sheet.	- Reading of Welding procedure specifications (WPS). - Reading of Procedure qualification Record (PQR)
Professional Skill 171Hrs; Professional Knowledge 31 Hrs	Join Aluminum & Stainless-Steel sheets by GTAW in different position. (Mapped NOS: CSC/N0212)	71. Straight line beads on Aluminum plate by GMAW welding. 72. Single "V' and fillet joint on Aluminum plate. 73. Setting up GTAW welding plant and establishing the arc. 74. Beading practice on MS sheet by GTAW. 75. Square butt joint on MS in down hand position.	- Types of weld defects, causes and remedy in GMAW process. - Introduction to GTAW welding - Equipment& accessories. - Advantages & Limitations.
		76. Open corner joint on MS sheet in down hand position. 77. Lap joint on MS sheet in down hand position.)	- Power source - Types, polarity and application -
		78. Tee joint on MS sheet in down hand position.) 79. Lap joint on MS sheet in Horizontal position.	- Tungsten electrode, Types, sizes, and uses. - Type of shielding gases- Types & properties.
		80. Square butt joint on MS sheet in Horizontal position. 81. Square butt joint on MS sheet in Vertical position.	- GTAW Welding consumables - Types & Specifications as per BIS & AWS
		82. Lap & Tee joint on MS sheet in Vertical position. 83. Square butt joint on MS sheet in overhead position.	- Tables & data relating to TIG welding. - Different type of weld joints- plates & pipes.

Duration	Reference Learning Outcome	Professional Skills (Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
		84. Beading practice on SS sheet. 85. Square butt joint on SS sheet by TIG in flat position. 86. Open corner joint on SS sheet by TIG in flat position.	- Edge preparation of plates & pipes. - Fitting of joint plates for TIG Welding.
		87. Square butt joint on SS sheet in Vertical position. 88. Lap joint on SS sheet in vertical position.	- Advantages of root pass welding of pipes by TIG welding
		89. Tee joint on SS sheet in Vertical position. 90. Square butt joint welding of SS sheet with back purging Technique.	- Types of weld defects, causes and remedy in GTAW process.
Professional Skill 64Hrs; Professional Knowledge 12 Hrs	Weld pipe joints by GTAW. (Mapped NOS: CSC/N0212)	91. Beading practice on Aluminium sheet by GTAW. 92. Square butt joint on Aluminium sheet by GTAW in flat position.Open corner joint on Aluminium sheet in flat position.	- Purging: Importance, Method of giving.
		93. Square butt joint on Aluminium sheet in Vertical position.Single V butt joint on Aluminum sheet by TIG.	- Weldability of metals.
		94. Square butt joint on Tube welding practice on M.S. & S.S tube metals in rolled position.Square butt joint on Tube welding practice on Aluminium in rolled position.	- Preheating and Post heating - Distortion and methods of control. - Submerged Arc welding - Principles, application- Types of fluxes, welding head, power source and Parameter setting.
Professional Skill 23Hrs; Professional Knowledge 04 Hrs	Cut ferrous and nonferrous metal using plasma Arc cutting. (Mapped NOS: CSC/N0207)	95. Plasma cutting of SS sheets & Aluminum plates.Dimensional inspection of weldments. 96. Weld test specimen preparation. 97. Visual inspection of weldments.	- Plasma welding principles, Equipment, power source, parameter settings, Advantages & limitations - Plasma cutting principles and advantages.
Professional Skill 21Hrs; Professional Knowledge 04 Hrs	Test welded joint by visual inspection Dye penetrant & Magnetic particle testing methods. (Mapped NOS: CSC/N0204)	98. Dye penetrant. 99. Magnetic particle testing.	- Inspection & testing of weldments - Visual inspection methods - Inspection kits - universal gauge, Fillet gauge, etc. - Non-destructive Testing methods, PT, MPT, UT & RT - Destructive testing - Bend test & tensile test.

General discipline in the Institute

Objectives: At the end of this lesson you shall be able to
- **state the general discipline in 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
- **first aid treatment to be given for**
- **describe the first aid for different incident.**

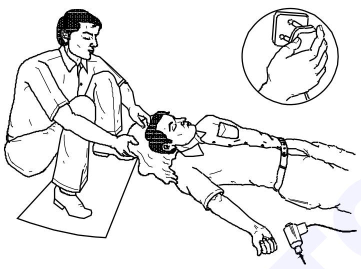
Electrical shock and breathing problems: The severity of an electric shock will depend on the level of the current which passes through the body and the length of time of contact, Do not delay to disconnect the contact.

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

WG20N110211

Fig 2



WG20N110212

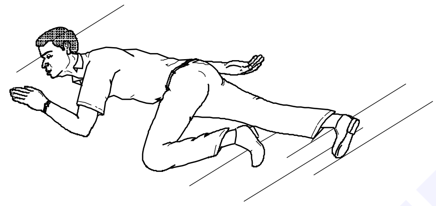
If you remain un-insulated, do not touch the victim with your bare hands until the circuit is made dead or he is moved away from the equipment.

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



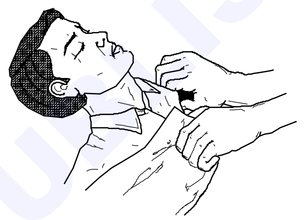
WG20N110213

Keep a constant check on the breathing and pulse rate.

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

Send for help.

Fig 4



WG20N110214

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.

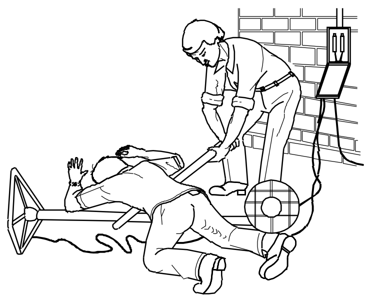
Treatment for electric shock:

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



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

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

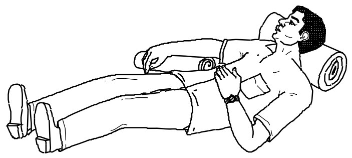
Burns and scalds: Burns are very painful. If a large area of the body is burnt, give no treatment, except to exclude the air. eg, by covering with water, clean paper, or a clean shirt. This relieves the pain.

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

Immediate action: Always in cases of severe bleeding:

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

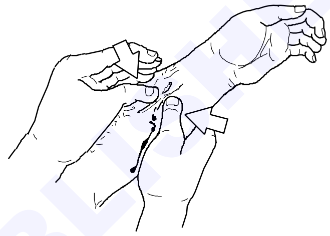
Fig 6



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

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

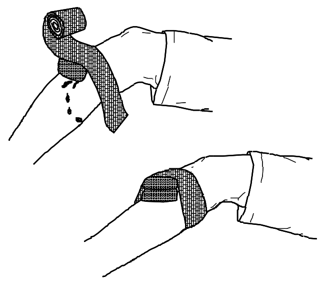
Fig 7



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

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

Fig 8



Follow the right methods of artificial respiration.

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

Importance of welding in Industry

Objectives: At the end of this lesson you shall be able to
- **state the importance of welding in industry**
- **state the advantages of welding 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.

Safety precaution SMAW and oxy-acetylene welding and cutting

Objectives: At the end of this lesson you shall be able to
- **SMAW safety precautions**
- **OAW safety precautions**
- **OAGC safety precautions.**

Arc welding operations should be performed in a covered place avoiding the ultraviolet light to be exposed to people passing by. The welding power source should be kept away from sun, water, grease, and oil. The welding machine should not be a bridge, using the wrong power source for the right machine. All switches should be in order and be performing fine.

Welding Safety Rules

- Conduct in a designated safe location. ...
- Protect yourself from fire hazards. ...
- Consider the risks. ...
- Maintain your equipment. ...
- Protect yourself with the correct PPE. ...
- Check for ventilation. ...
- Protect yourself from fumes and gases. ...
- Protect other workers

Safety precautions OAW

General gas welding safety tips

- Inspect equipment for leaks at all connections using approved leak-test solution.
- Inspect hoses for leaks and worn places.
- Replace bad hoses.
- Protect hoses and cylinders from sparks, flames, and hot metal.
- Use a flint lighter to ignite the flame.

Safety precaution

The following precautions will help prevent fire:

- Move the workpiece to a safe location for carrying out hot work;
- Remove nearby combustible materials (such as flammable liquids, wood, paper, textiles, packaging or plastics);
- Protect nearby combustible materials that cannot be moved. Use suitable guards or covers such as metal sheeting, mineral fibre boards or fire-retardant blankets;
- Check that there are no combustible materials hidden behind walls or in partitions, particularly if the welding or cutting will go on for some time. Some wall panels contain flammable insulation materials, eg polystyrene;
- Use flame-resistant sheets or covers to prevent hot particles passing through openings in floors and wall (doorways windows, cable runs, etc);
- If the consequences of a fire are severe, eg work inside ships, you may need to appoint a fire watch during and after the work finishes. It is normal to maintain fire watch for 30 minutes after hot work finishes;
- Prevent flame, heat, sparks or hot spatter from landing on the hoses;
- Keep fire extinguishers nearby.

Introduction and definition of welding, Arc and Gas Welding Equipments, tools and accessories

Objectives: At the end of this lesson you shall be able to
- **state the invention of welding**
- **describe the different ways to weld**
- **name the different types of arc welding machine**
- **name the equipments tools and accessories of arc & gas**
- **explain the functions of each accessories welding.**

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).

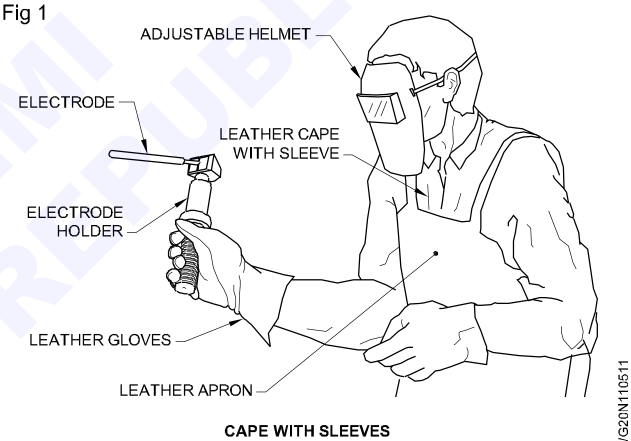
GMAW involves a wire fed "gun" that feeds wire at an adjustable speed and sprays a shielding gas (generally pure Argon or a mix of Argon and Co_2) over the weld puddle to protect it from the effect of atmosphere.

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.

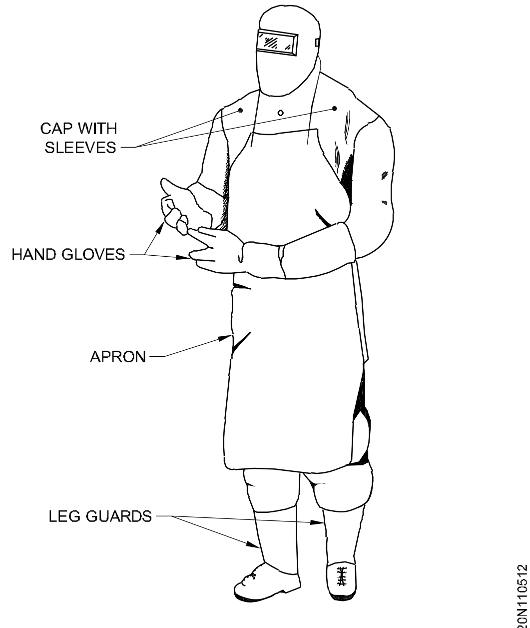
Many different sources of energy can be used for welding, including a gas flame, an electrical arc, a laser, an Electron Beam (EB), Friction, and ultrasound. While often an industrial process, welding may be performed in many different environments, including in open air, under water, and on outer space,. 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.

Fig 1



CAPE WITH SLEEVES

Fig 2



LEG GUARDS

All the above safety apparels should not be loose while wearing them and suitable size has to be selected by the welder. (Fig 1&2)

The industrial safety boot 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.

Major parts of a hammer

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

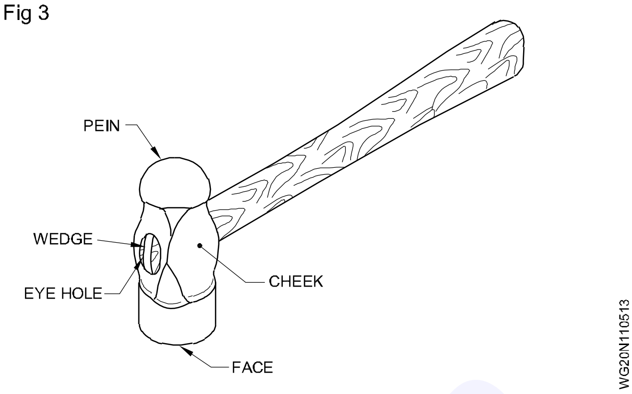
The head is made of drop-forged carbon steel, while the wooden handle must be capable of absorbing shock.

The parts of a hammer-head are the

- face
- pein
- cheek
- eye hole.

(See Fig 3)

Fig 3



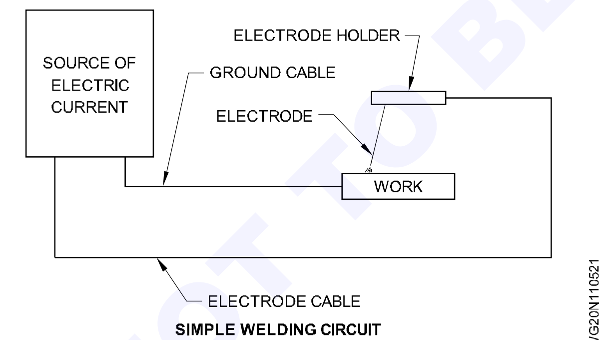
Arc welding machines

Objectives : At the end of this lesson you shall be able to
- **arc welding machine**
- **different types of arc welding machine**
- **gas welding equipments**
- **tools and accessories.**

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

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

Fig 1



SIMPLE WELDING CIRCUIT

Necessity

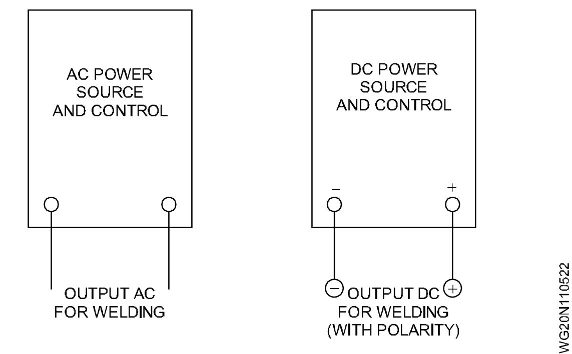
- The equipment is used to
- Provide Ac or DC welding supply for arc welding
- Provide higher voltage (OCV) for striking the arc and lower voltage (AV) for maintaining the arc
- Change the high voltage of the main supply (AC) to low voltage and heavy current supply (AC or DC) suitable for arc welding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

Type (Fig 2): Basically power sources are:

- Alternating current welding machine
- Direct current welding machine.

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

Fig 2



DC machines

- Motor generator set
- Engine generator set
- Rectifier set

AC machines

- Transformer sets

> **AC means alternating current. It changes or reverses its direction of flow of current 50 times per second, if it is 50 cycles/sec. (Fig 3)**
>
> **DC means direct current. it flows steadily and constantly in one direction. (Fig 4)**

Fig 3

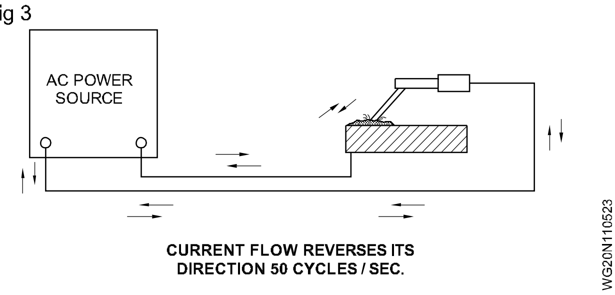
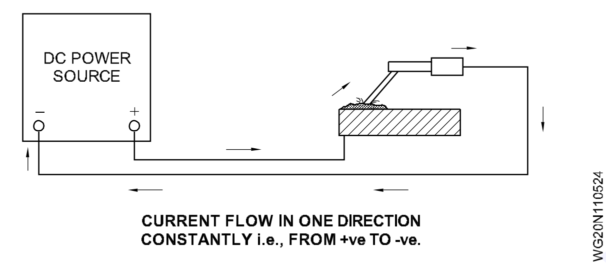


Fig 4



Care and maintenance of arc welding machines and accessories

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

Arc welding machines: Do not keep the machine in open air. In a 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.

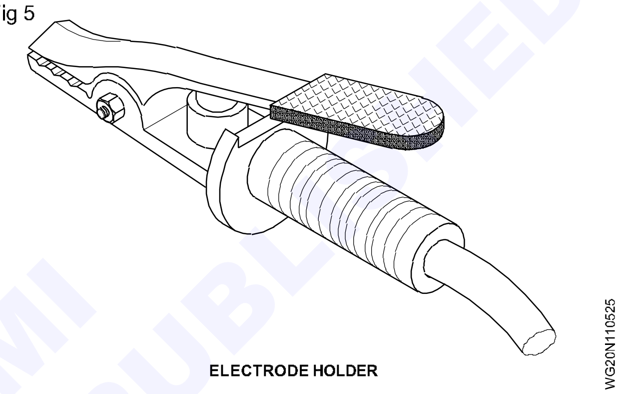
Avoid loose connections at the main fuses, starting switch.etc.

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

Electrode-holder (Fig 5): It is a clamping device used to grip and manipulate the electrode during arc welding. It is made of copper/copper alloy for better electrical conductivity.

Fig 5



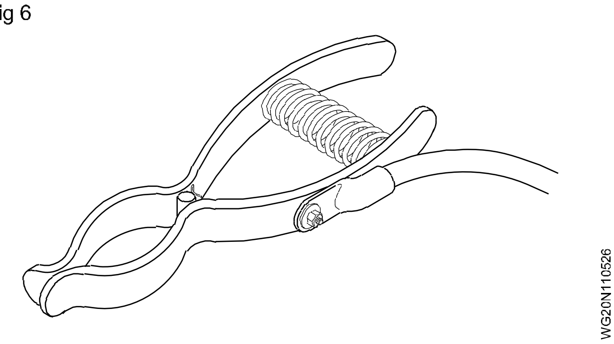
ELECTRODE HOLDER

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

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

Earth clamp (Fig 6): It is used to connect the earth cable firmly to the job on welding table. It is also made of copper/copper alloys.

Fig 6



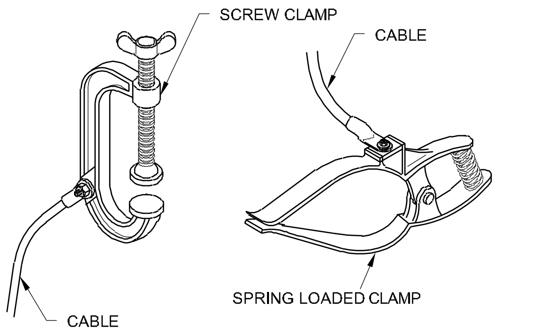
Screw or spring-loaded earth clamps are made in various sizes i.e. 200 - 300 - 500 amps. (Fig 7)

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.

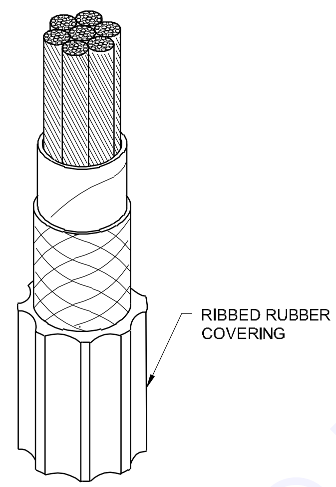
Fig 7



WORK CABLE ATTACHMENTS

Cables are made of super flexible rubber insulation, having fine copper wires and woven fabric reinforcing layers. (Fig 8)

Fig 8



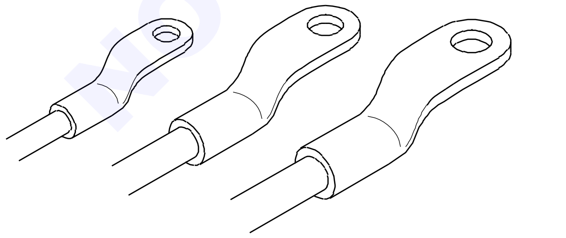
WELDING CABLE WITH HEAVY RIBBED OUTER RUBBER COVERING

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 9)**

Fig 9



LUGS FOR WELDING LEADS

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

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

Table 1

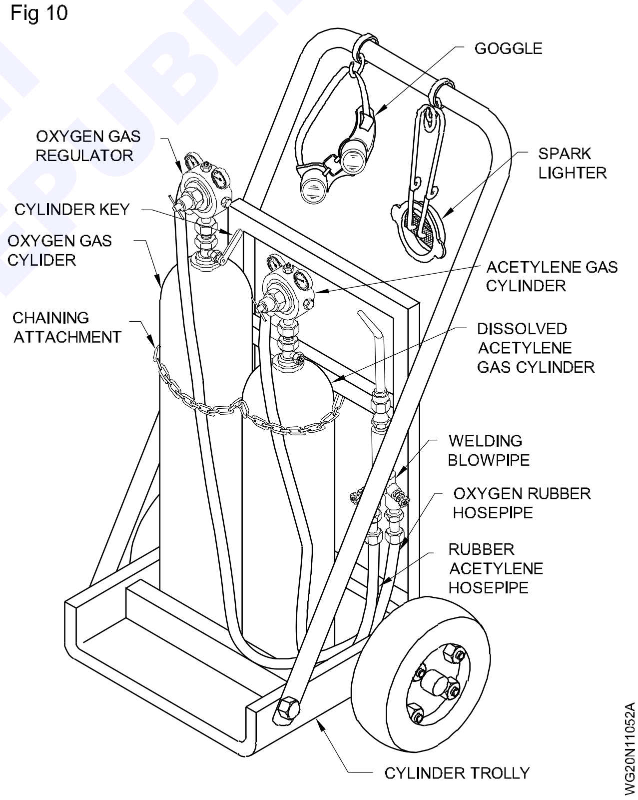
Recommendations of copper cable for arc welding

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

High pressure oxy-acetylene welding equipment and accessories

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 10)

Fig 10

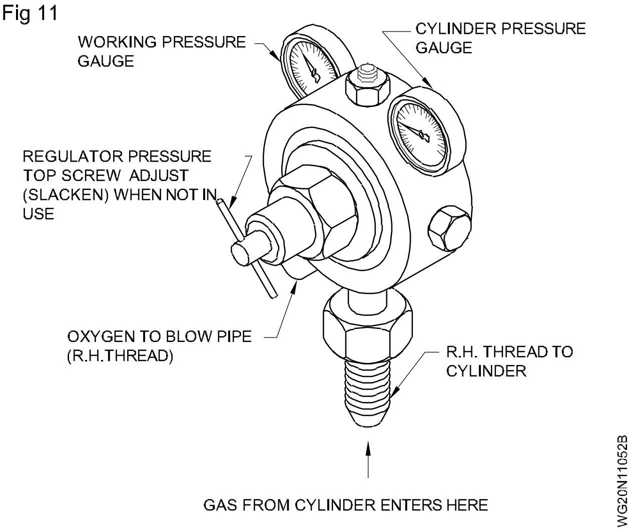


Oxygen gas cylinders: The oxygen required for gas welding is stored in bottle-shaped cylinders. These cylinders are painted in black colour. Oxygen cylinders can store gas to a capacity of 7 m^3 with the pressure ranging between 120 to 150 kg/cm^2. Oxygen gas cylinder valves are right hand threaded.

Dissolved acetylene cylinders: The acetylene gas used 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.

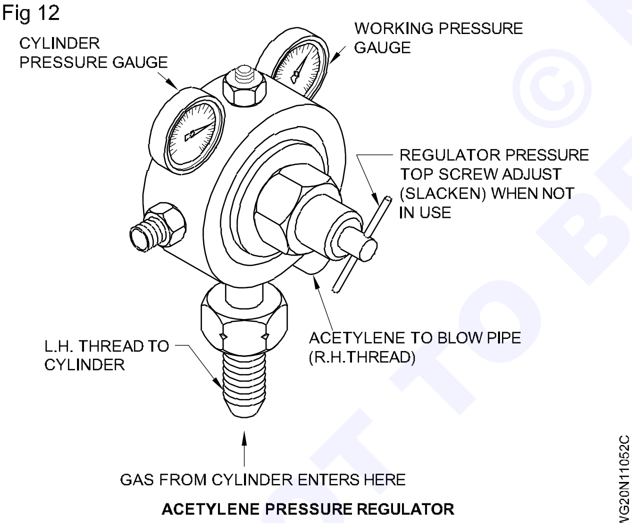
Oxygen pressure regulator: This is used to reduce the oxygen cylinder gas pressure according to the required working pressure and to control the flow of oxygen at a constant rate to the blowpipe. The threaded connections are right hand threaded. (Fig 11)

Fig 11



Acetylene regulator: As with the case of oxygen regulator this also is used to reduce the cylinder gas pressure to the required working pressure and to control the flow of acetylene gas at a constant rate to the blowpipe. The threaded connections are left handed, for quickly identifying the acetylene regulator, a groove is cut at the corners of the but. (Fig 12)

Fig 12



ACETYLENE PRESSURE REGULATOR

Rubber hose-pipes and connections: These are used to carry gas from the regulator to the blowpipe. These are made of strong canvas rubber having good flexibility. Hosepipes which carry oxygen are black in colour and the acetylene hoses are of maroon colour (Fig 13)

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 14)

At the blowpipe end of the rubber hoses-protectors are fitted. The hose protectors are in the shape of a connecting union and have a non-return disc fitted inside to protect from flashback and backfire during welding. (Fig 15)

Fig 13

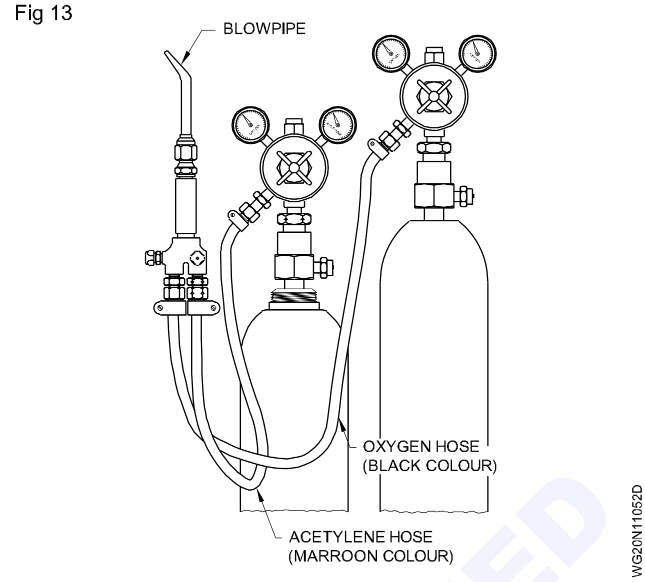


Fig 14

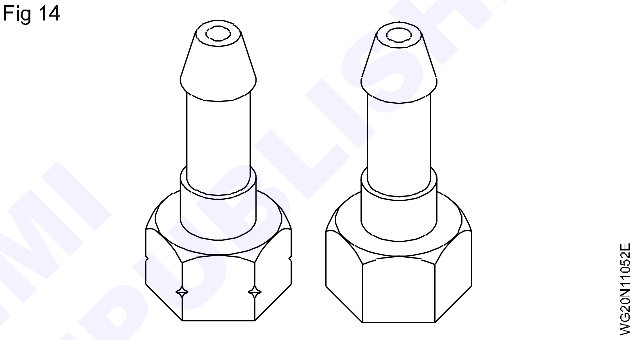
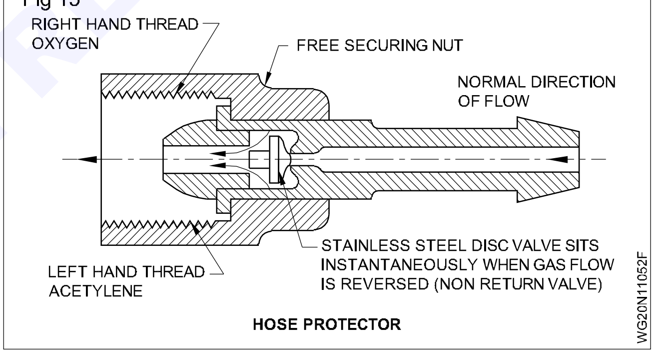


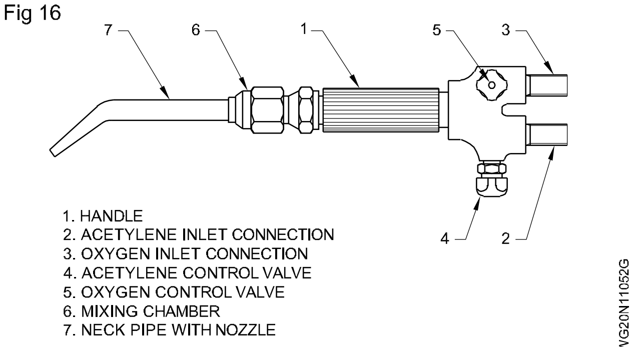
Fig 15



HOSE PROTECTOR

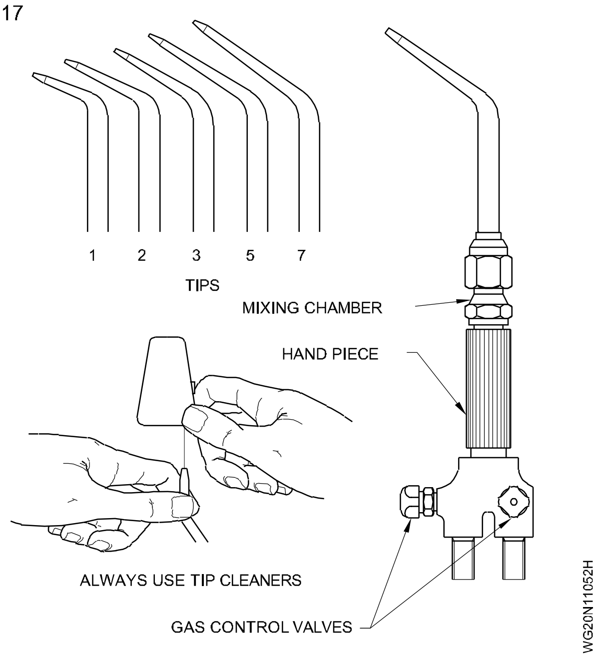
Blowpipe and nozzle: Blowpipe are used to control and mix the oxygen and acetylene gases to the required proportion. (Fig 16)

Fig 16



A set of interchangeable nozzles/tips of different sizes is available to produce smaller bigger flames. (Fig 17)

Fig 17



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

Table 1

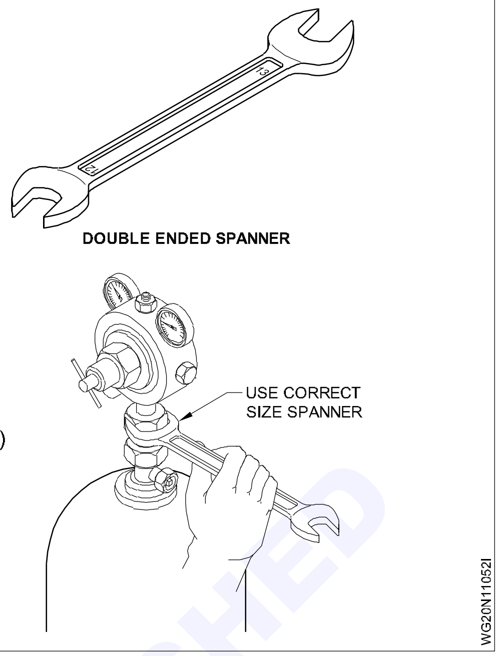
plate thickness	Nozzle size
mm	Number
0.8	1
1.2	2
1.6	3
2.4	5
3.0	7
4.0	10
5.0	13
6.0	18
8.0	25
10.0	35
12.0	45
19.0	55
25.0	70
Over 25 .0	90

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

Double ended spanner: A double ended spanner is shown in Fig 18a and 18a. It is made of forged chrome vanadium steel. It is used to loosen or tighten nuts, bolts with hexagonal or square heads. The size of the spanner is marked on it as shown in Fig 1. In welding practice the spanners are used to fix the regulator onto the gas cylinder valves, hose connector and protector to the regulator and blow pipe, fix the cable lugs to the arc welding machine output terminals, etc.

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

Fig 18



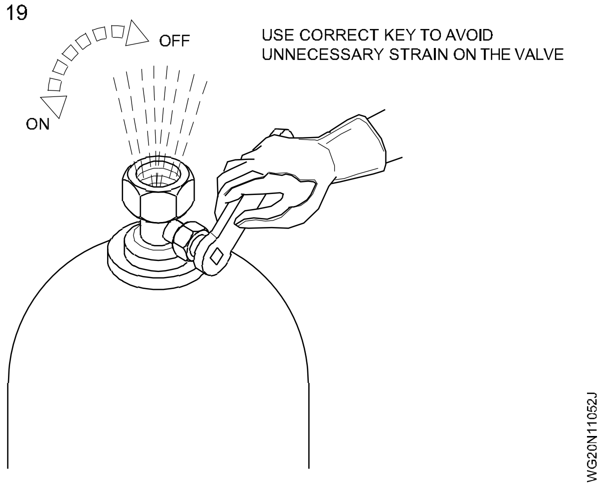
Cylinder Key: A cylinder key is shown in Fig 19. It is used to open or close the gas cylinder valve socket to permit or stop the gas flow from the cylinder to the regulator.

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

Nozzle or tip cleaner

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

Fig 19

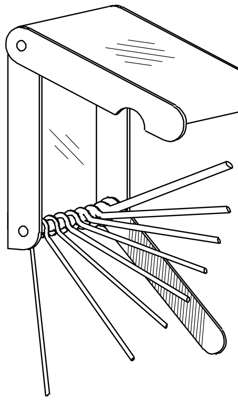


Tip cleaner: A Special tip cleaner is supplied with the torch container. For each tip there is a kind of drill and a smooth file Fig 20.

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

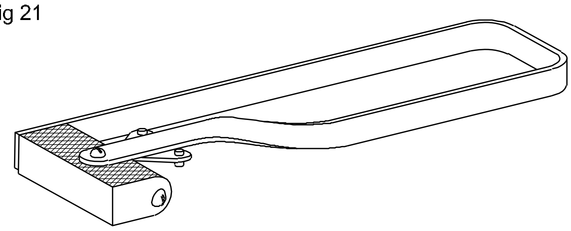
The smooth file is then used to clean the surface of the tip. While cleaning, leave the oxygen valve partly open to blow out the dust.

Fig 20



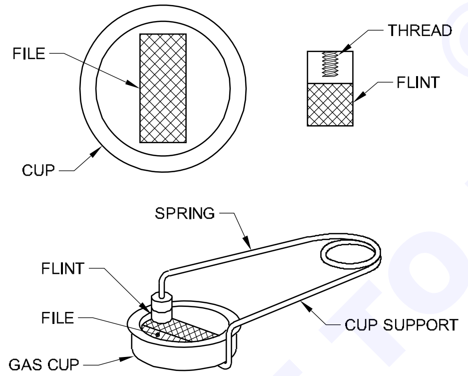
Spark lighter: The spark lighter, as illustrated in Fig 21&22 is used for igniting the torch. While welding, form the habit of always employing a spark lighter to light a torch. Never use matches. The use of matches for this purpose is very dangerous because the puff of the flame produced by the ignition of the acetylene flowing from the tip is likely to burn your hand.

Fig 21



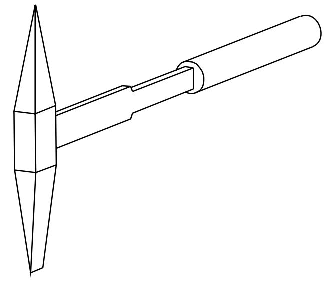
ALWAYS USE A SPARKLIGHTER TO LIGHT A TORCH

Fig 22



Chipping hammer: The chipping hammer (Fig 23) Is used to remove the slag which covers the deposited weld bead. It is made of medium carbon steel with a mild steel handle. It is provided with a chisel edge on one end and a point on the other end for chipping off slag in any position.

Fig 23



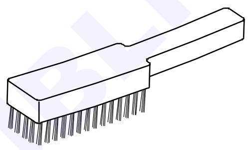
CHIPPING HAMMER

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

Carbon steel wire brush: A carbon steel wire brush is shown in Fig 24. It is used for

- Cleaning the work surface from rust, oxide and other dirt etc. prior to welding.
- Cleaning the inter bead weld deposits after chipping off the slag
- General cleaning of the weldment.

Fig 24



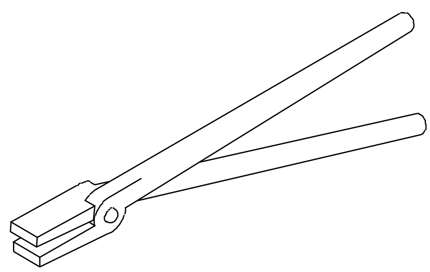
WIRE BRUSH

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

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

Tongs: Fig 25 show a pair of tongs used to hold hot work pieces and to hold the job in position.

Fig 25



TONGS

Various welding processes and their application arc and gas welding terms and definition

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

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

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

Electric welding processes can be classified as:-

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

Electric arc welding can be further classified as:

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

Electric resistance welding can be further classified as:

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

Gas welding processes can be classified as:

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

The other welding processes are:

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

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

SCAW	Shielded Carbon Arc
SW	Stud Arc
TW	Thermit
UW	Ultrasonic

Applications of Various welding processes

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Welding arc, gas terms & Its Definition

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

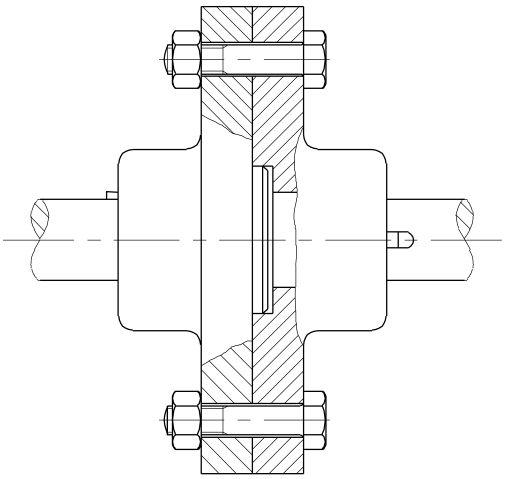
25 **Electrode** (Flux coated) A metal stick which is coated with flux and having parts indicated as stub end, tip, bare/core wire and flux coating. The size of this is determined by size of bare/core wire diameter. (This is used in shielded Metal Arc welding as consumable material).

Different process of metal joining methods: Bolting, Riveting - soldering, Brazing seaming etc

Objectives: At the end of this lesson you shall be able to
- **name the different metal joinery process**
- **identify different types of bolts riverts**
- **describe the uses of metal joining process.**

Bolts and nuts (Fig 1)

Fig 1



WG20N110711

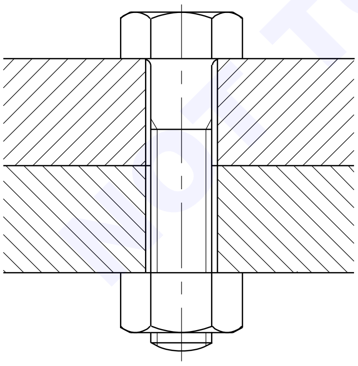
These are generally used to clamp two parts together.

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

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

Bolts with clearance hole (Fig 2)

Fig 2



WG20N110712

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

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

Rivet joints

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

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

Specification of rivets

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

Rivets

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

The materials used for rivets are mild steel, copper yellow

brass, aluminium and heir alloys.

The length of the rivets 'L' is indicated by the shank length. (Fig 3)

Rivet joints (Fig 4&5)

Rivet joints are classified as lap joints and butt joints.

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

Soldering

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

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

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

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

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

Fig 3

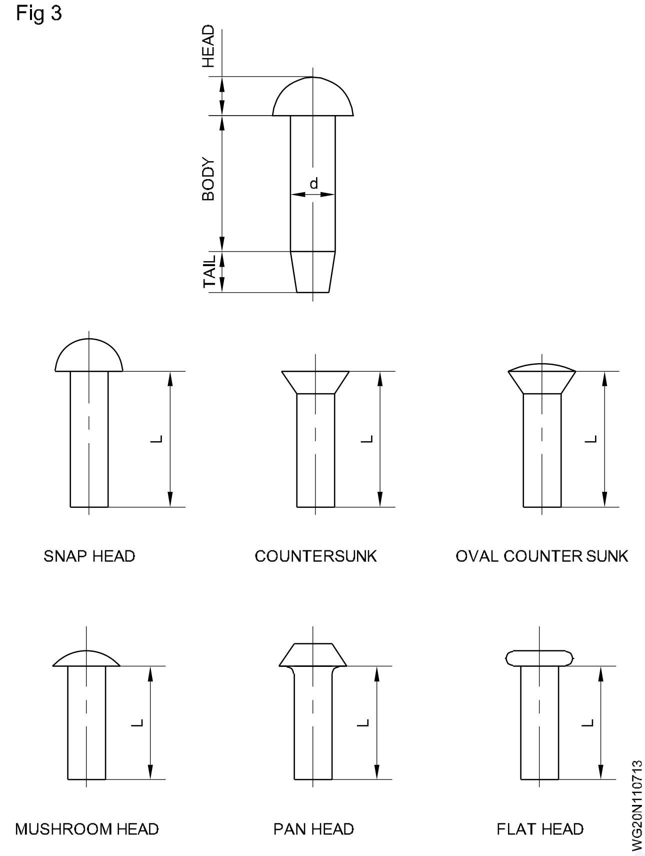
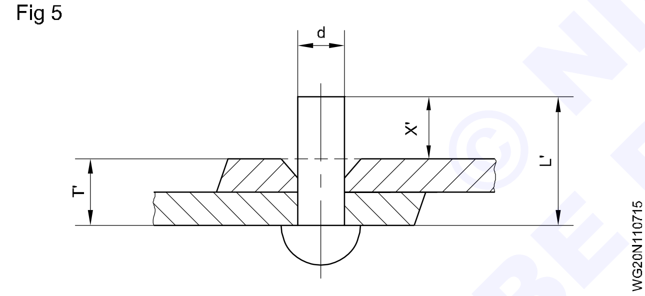


Fig 5



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)

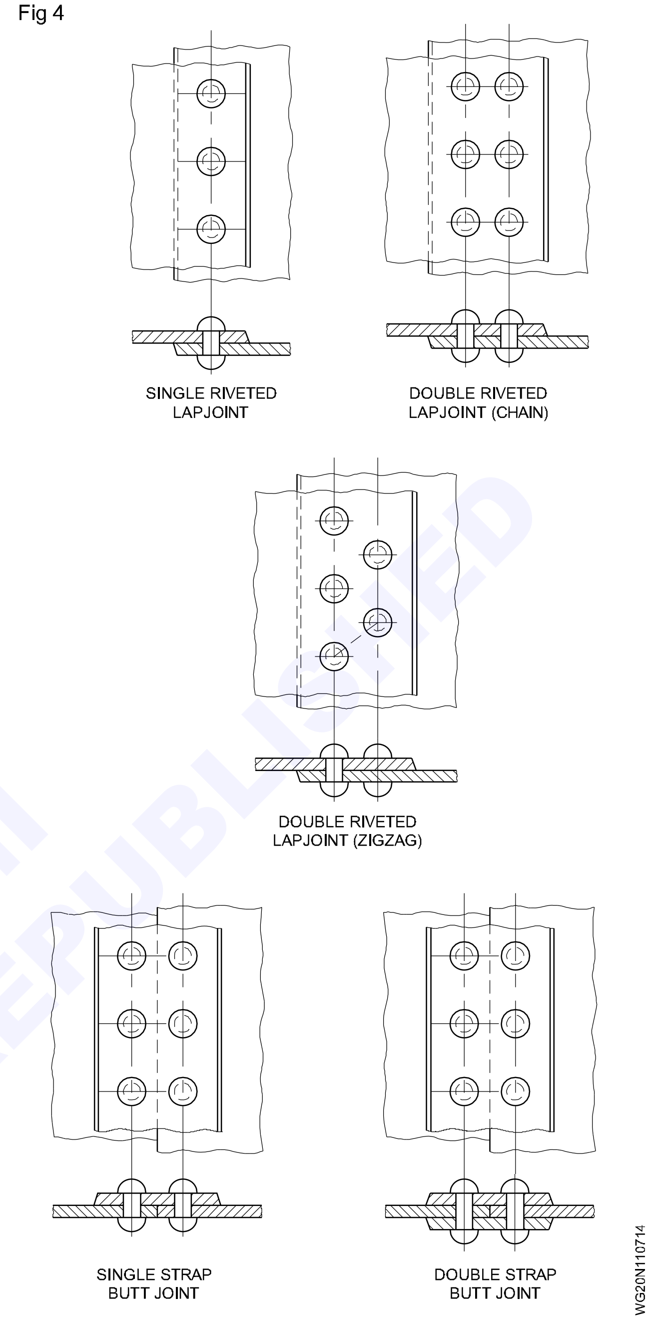
Soldering iron: The soldering iron is used to melt the solder and heat metal that are joined together.

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

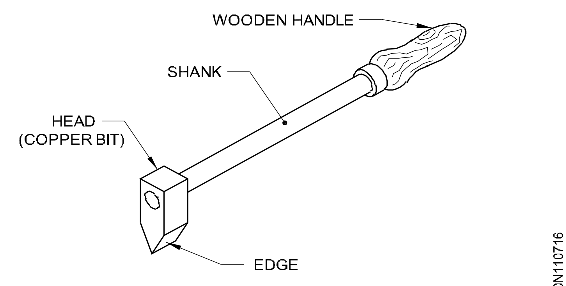
Fig 4



- 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 6)

Fig 6



SOLDERING IRON (HATCHET TYPE)

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

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. (Fig 7)

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.

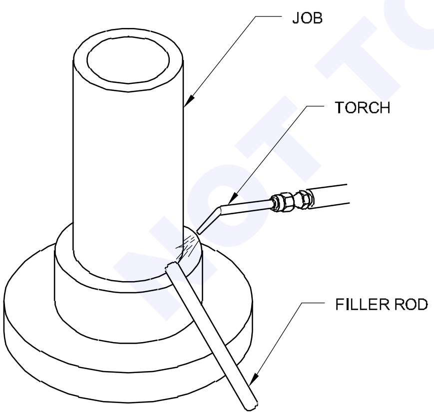
Brazing filler rods/ metals melt at temperature from 860°C to 950°C and are used to braze iron and its alloys.

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 7



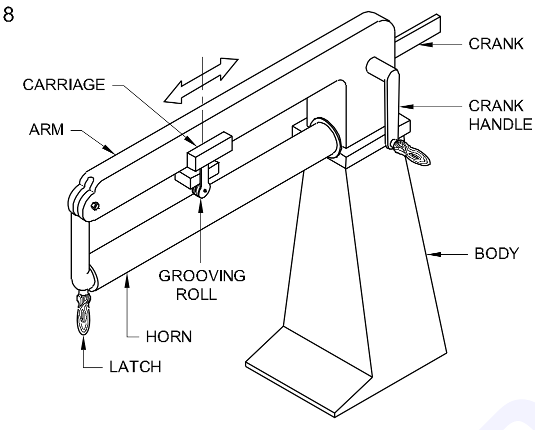
TORCH BRAZING

Seaming and Machine

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

Parts shown in Fig 8 are Body, Arm, Pressure roller, Carriage, Crank handle, Latch and Crank rack.

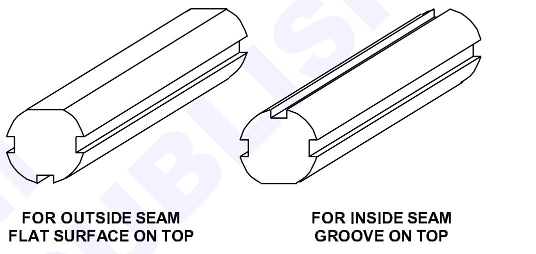
Fig 8



GROOVING MACHINE

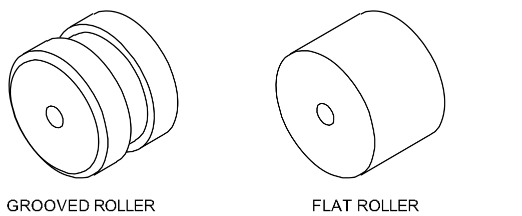
Horn: It contains grooves of various widths on throughout the length as shown in Fig 9.

Fig 9



Pressure roller: Two types of pressure rollers are available along with the machine. One is flat roller and the other is grooved one, Grooved roller is having grooves of 3 mm, 4 mm, 5 mm and 6 mm widths as shown in Fig 10.

Fig 10

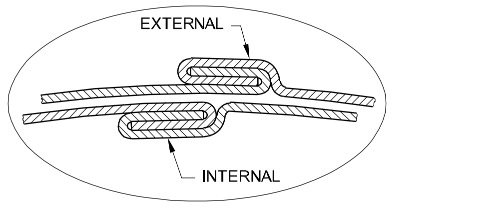


PRESSURE ROLLERS

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

Internal and External locks (Fig 11) can be made by adjusting the horn and changing the pressure rollers on the seam closing machine.

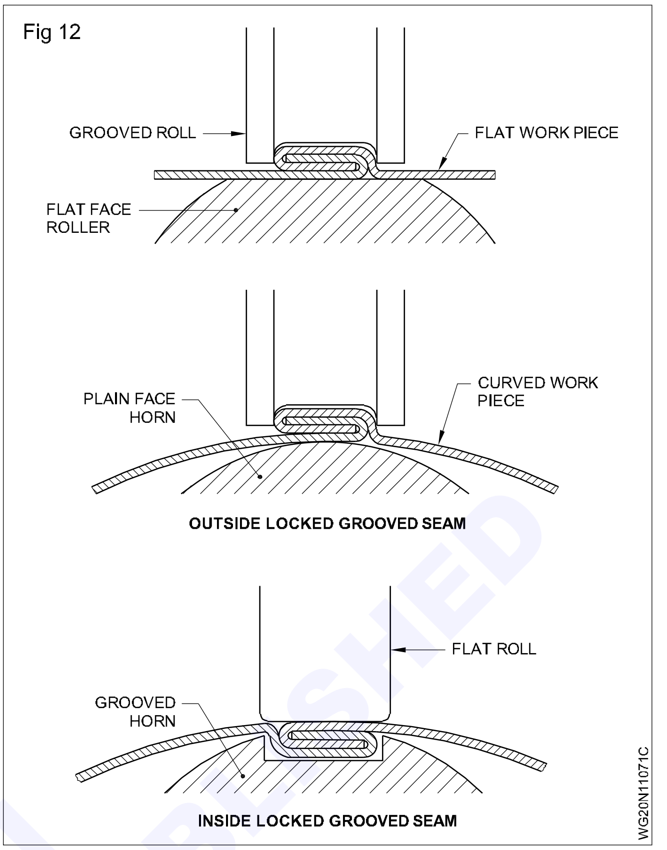
Fig 11



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.

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 12.

Fig 12



Types of welding joints and its applications. Edge preparation and fit up necessity of edge preparation

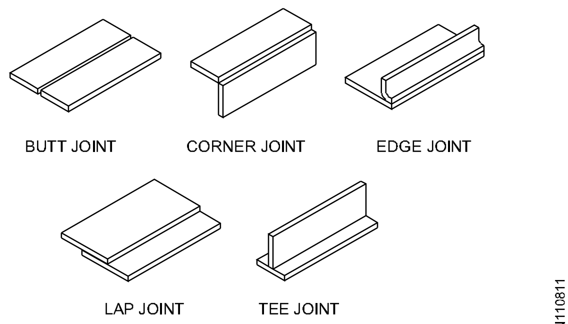
Objectives: At the end of this lesson you shall be able to
- **name the basic welding joints and its application**
- **describe the edge preparation & surface cleaning.**

Basic welding joints (Fig 1)

The various basic welding joints are shown in Fig 1.

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

Fig 1

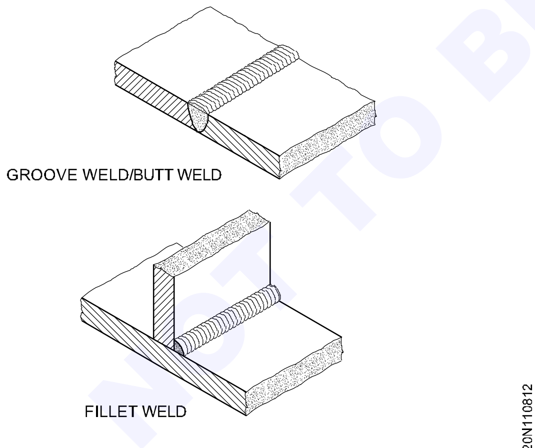


FUNDAMENTAL TYPE OF JOINTS

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

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

Fig 2



TYPE OF WELD

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

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

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

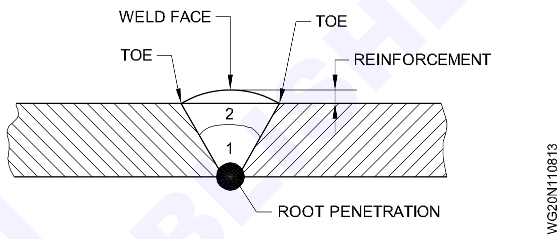
Leg length: The distance between the junction of the metals and the point where the weld metal touches the base metal 'toe' (Fig 5)

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

Fusion penetration: The depth of fusion Zone in the parent metal.

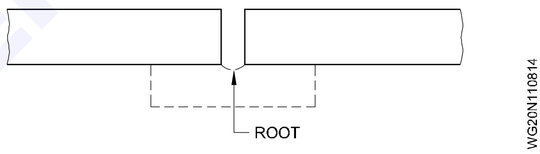
Reinforcement: Metal deposited on the surface of the parent metal of the excess metal over the line joining the two toes. (Fig 3)

Fig 3



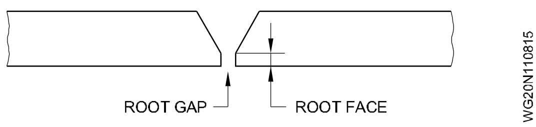
Root: The parts to be joined that are nearest together. (Fig 4)

Fig 4



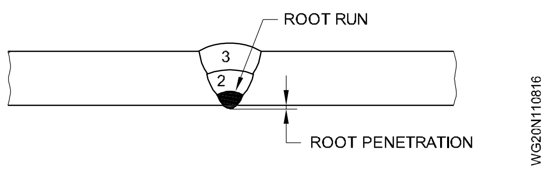
Root face: The surface formed by squaring off the root edge of the fusion face to avoid a sharp edge at the root. (Fig 5)

Fig 5



Root run: The first run deposited in the root of a joint (Fig 6)

Fig 6



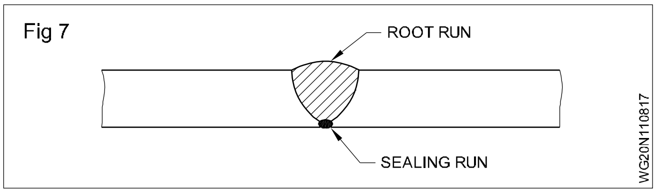
Root penetration: It is the projection of the root run at the bottom of the joint.

Run: The metal deposited during one pass.

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

Sealing run: A small weld deposited on the root side of a butt or corner joint (after completion of the weld joint). (Fig 7)

Fig 7



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

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

Toe of weld: The point where the weld face joins the parent metal.

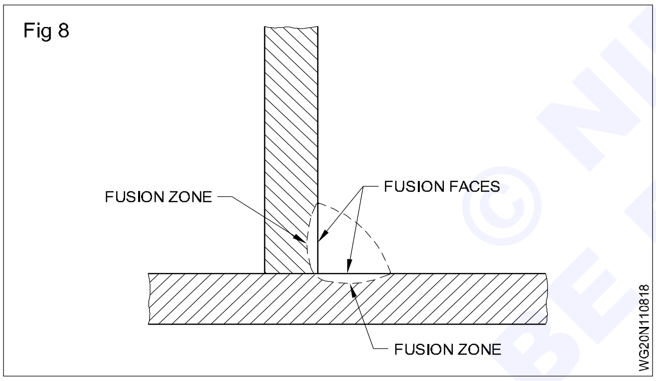
Weld face: The surface of a weld seen from the side from which the weld was made.

Weld Junction: The boundary between the fusion zone and the heat affected zone.

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

Fusion zone: The depth to which the parent metal has been fused. (Fig 8)

Fig 8



Edge preparation

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.

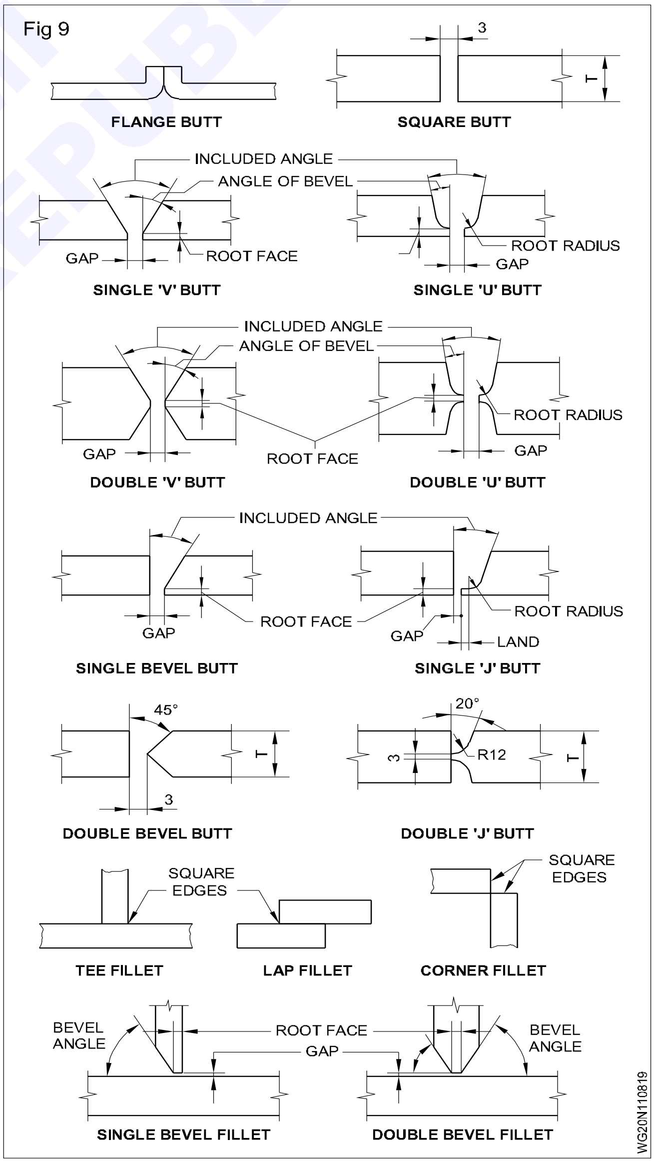
Method of edge preparation: The joining edges may be prepared for welding by any one of the methods mentioned below.

- 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 9 below.

Fig 9

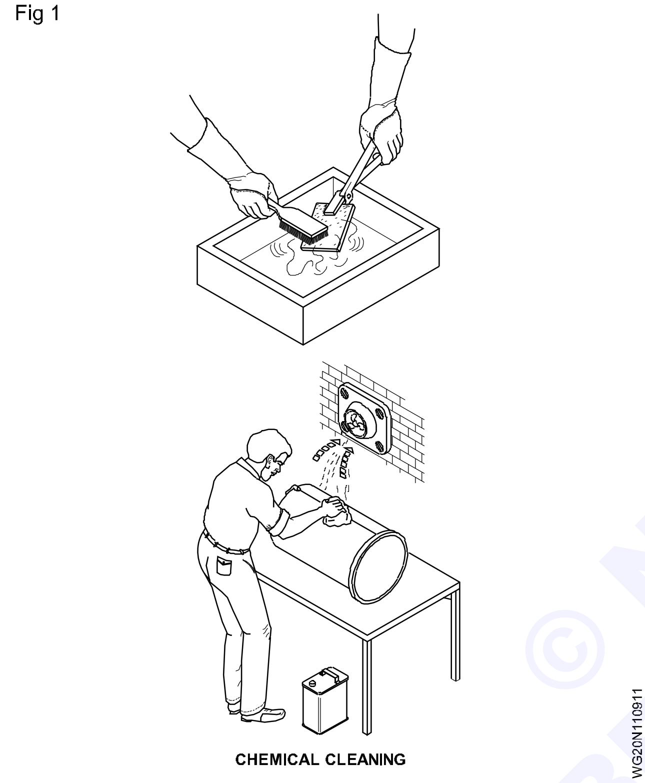


Surface cleaning

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

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

Fig 1



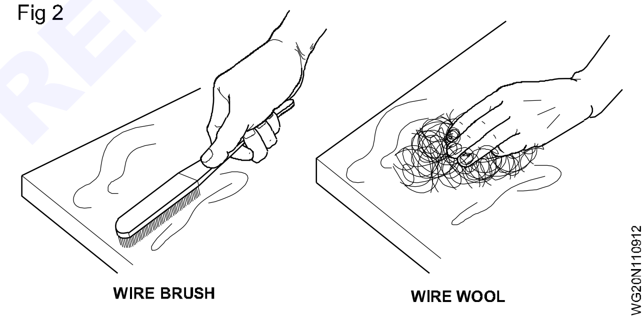
Importance of cleaning: The basic requirement of any welding process is to clean the joining edges before welding. The joining edges of surface may have oil, paint, grease, rust, moisture, scale or any other foreign matter. If these contaminants are not removed the weld will become porous, brittle and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

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

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

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

Fig 2



Basic electricity applicable to arc welding and related electrical terms & definitions, Heat and temperature and its terms related 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)

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

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

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

Fig 1

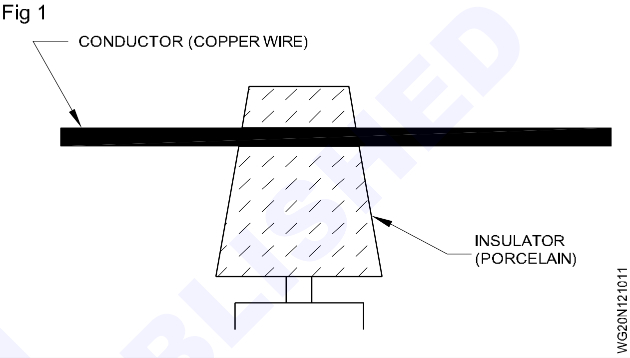
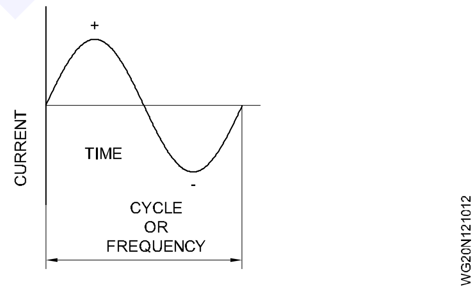


Fig 2



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.

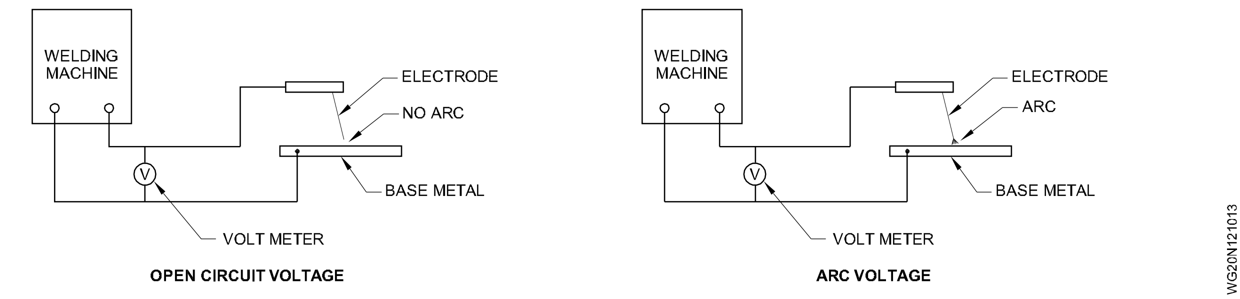
Series circuit: The resistances of a circuit are connected in a series end-to-end making only one path in which the current flows.

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)

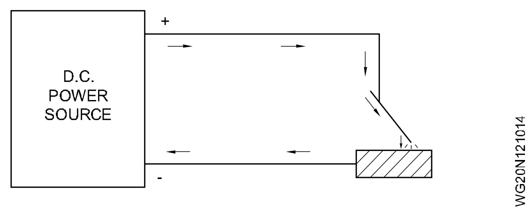
Direct current (DC): Electric current which always flows in a particular direction is known as direct current. (i.e) Negative to positive (electronic direction). Positive to negative (conventional direction).

Fig 3



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

Fig 4



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

The law states:

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

V=IR

Where V = Voltage

I = Current

R = Resistance

Current decreases when resistance increases.

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

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

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

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

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

Open circuit voltage and arc voltage: 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". (Fig 3)

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". (Fig 3)

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

- **explain the differrence between heat and temperature and its units.**

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.

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

Heat and temperature terms related to welding

Filler Metal - This is metal added to the weld pool. A weld can be made with or without filler metal. Thin gauge metal is sometimes welded by melting the two base metals together.

Flash Burn - This is a burn from the radiation produced from the ULTRA VIOLET rays from the welding arc. It can burn the skin similar to sunburn, and even blister the cornea. When it feels like someone is rubbing hot sand in your eyes.

Fillet Weld Toe - Is the end of the weld at the end of the leg. Again there will be one for each plate.

Fillet Weld Root - Where the weld begins at the intersection of the joined plates.

Heat Affected Zone - After it is heated, it cools at different rates depending on the temperature in the shop or field.

Pre Heating - Some steels will accept the weld better, and the weld will be more sound if the steel is heated before being welded on. This is especially true up north in the winter time. Adding hot filler metal to cold steel is NOT a good idea because it could cause the steel to become brittle and crack.

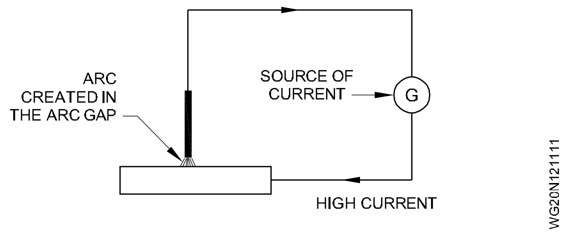
Post Heating - Post - heat is of course, exactly what is sez… heating it up after you have welded.

Principle of arc welding and characteristics of arc

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

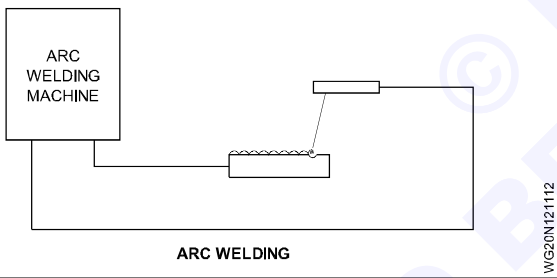
When high current passes through an air gap from one conductor to another, it produces very intense and concentrated heat in the form of a spark. The temperature of this spark (or arc) is app. 3600°C, which can melt and fuse the metal very quickly to produce a homogeneous weld. (Fig 1)

Fig 1



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

Fig 2



ARC WELDING

Characteristics of arc

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

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

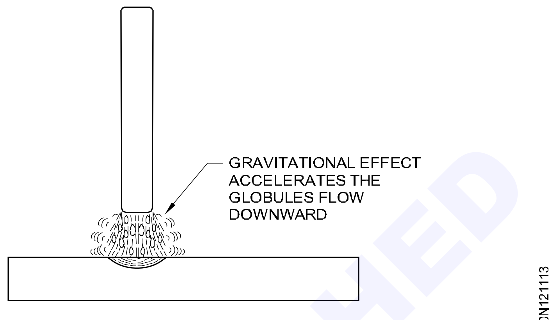
Gravity force (Fig 3): Molten globules formed at the arcing end of the electrode travel downwards towards the job in the molten pool.

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

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

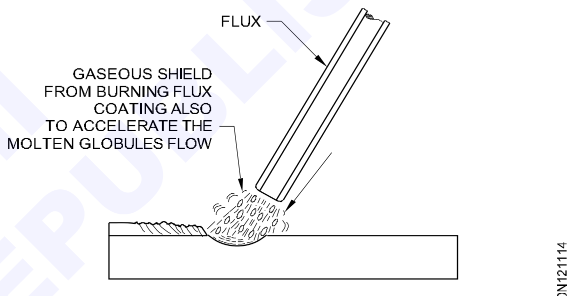
- Production of carbon monoxide and hydrogen mainly

Fig 3



GRAVITY FORCE

Fig 4



GAS EXPANSION EFFECT

- Formation of a sleeve of the flux at the arcing end due to a little higher melting point of the flux coating than the core wire.

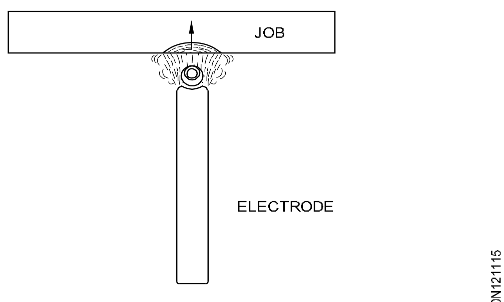
These gases expand and gain velocity. The flux sleeve direct these gases to flow in the direction of the molten metal. The gases flowing from the tip of the electrode have a pushing effect. Thus the metal globules are carried deep into the weld pool and influence penetration.

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

Surface tension (Fig 5): It is the characteristic (Force) of the base metal to attract and retain the molten metal in it. This effect is more useful in the case of positional welding.

The short arc promotes more surface tension effect.

Fig 5



SURFACE TENSION EFFECT

Common gases used for welding and cutting flame temperature and uses - types of ox-ace flames and uses

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

Objectives: At the end of this lesson you shall be able to
- **name different types of oxy-acetylene flames**
- **explain the charcteristics and used of oxy-acetylene flames.**

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

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

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

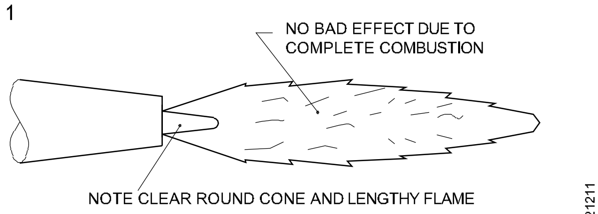
- Neutral flame
- Oxidising flame
- Carburising flame.
- Characteristics and uses

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

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.

Fig 1

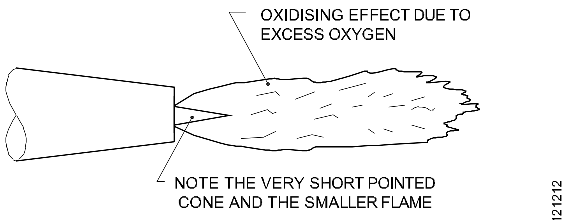


NEUTRAL FLAME
(EQUAL QUANTITIES OF OXYGEN AND ACETYLENE)

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)

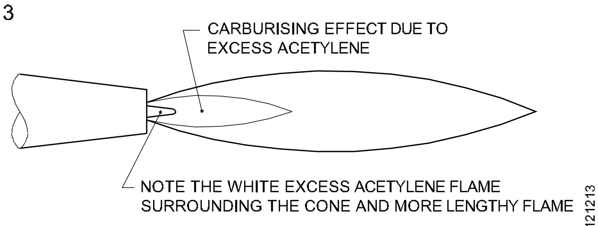
The flame has an oxidising effect on metals which prevents evaporation of zinc/tin in brass welding/brazing.

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.

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

Fig 3



CARBURISING FLAME
(EXCESS ACETYLENE)

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

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

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

Oxy-acetylene cutting equipment, principle, parameters and application

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

Principles 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 produce and cutting action takes place.

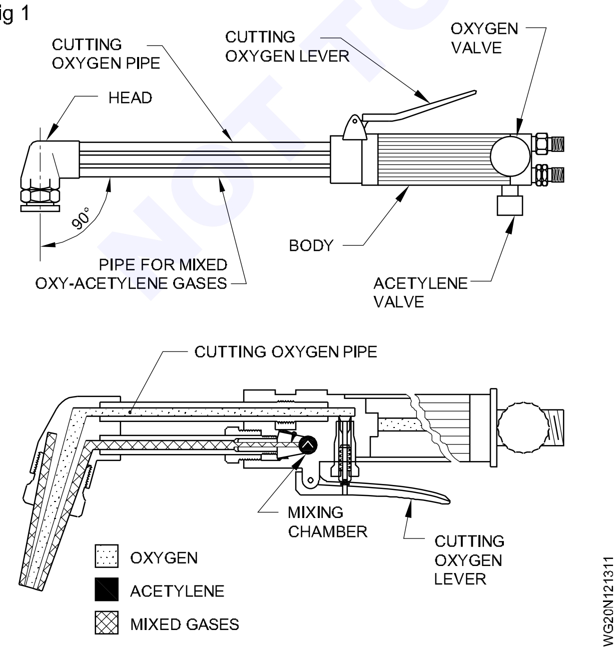
Cutting equipment: The oxy-acetylene cutting equipment is similar to the welding equipment, except that instead of using a welding blowpipe, a cutting blowpipe is used. The cutting equipment consists of the following.

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

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

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

Fig 1



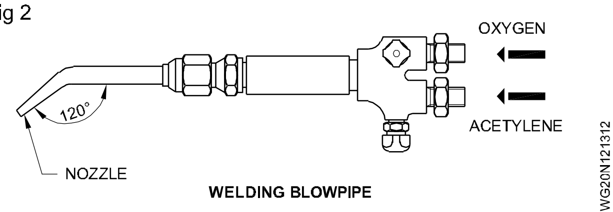
The cutting tip is made with an orifice in the centre surrounded by five smaller holes. The centre opening permits the flow of the cutting oxygen and the smaller holes are for the preheating flame. Usually different tip sizes are provided for cutting metals of different thicknesses.

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.

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).

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)

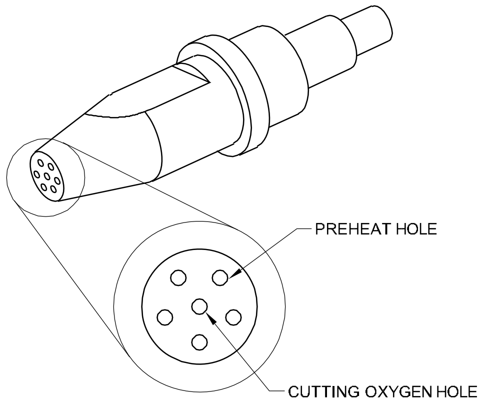
The nozzle of the welding blowpipe has only one hole in the center for the heating flame. (Fig 4)

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

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

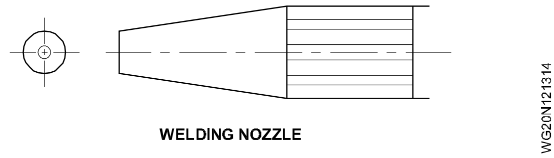
The cutting nozzle size is given by the diameter of the cutting oxygen orifice in mm.

Fig 3



CUTTING TIP

Fig 4



WELDING NOZZLE

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

Operating data for cutting mild steel

Parameters

Cutting nozzle size-mm	**Thickness of plate (mm)**	**Cutting oxygen Pressure kgf/cm²**
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 sources: Transformer, Rectifier and Inverter type welding machines and its care & maintenance

Objectives: At the end of this lesson you shall be able to
- **arc welding power source**
- **types of welding machine**
- **care and maintenance.**

Some General Terms to Understand

Insulation class- The temperature withstanding capability of the insulation materials.

Power factor- Ratio of active power used to the total power drawn from the system.

Efficiency- Power utility factor of the machine expressed as a % output to input. It accounts for losses in the system particularly transformer losses. In welding power sources 'no load' loss is a very important criteria because power source arc-on time is hardly 25% in a shop floor situation.

Ip classes define the degree of protection provided by the closure and is indicated by various 2-digit numbers such as 22,23,54 etc.

The first digit defines the degree of protection with respect to person and solid ingress.

The degrees range from, 0-6 where 0 means no protection & 6 means Dust proof.

The second digit defines the degree of protection with respect to harmful ingress of water. The degrees range from 0-8 where 0 means no special protection & 8 means protection against submersion (Hermetically sealed).

Power Source Selection Criteria General:

Copper or Aluminum conductors-A total non-issue class of insulation.

Input power - 3 phase or 2 line of 3 phase Duty cycle. pertaining, IP class, power factor, Efficiency.

Power source selection criteria SMAW:

Type of welding current-AC or DC or both amperage range determined by size & type of electrode.

Open circuit voltage (OCV) - high OCV desirable from the stand point of arc initiation & arc maintenance. But electrical hazard factors & high cost are to be considered. Welding positions - If vertical & overhead welding are planned, slope adjustment of the V-A curve is desirable.

Power source selection criteria MIG/MAG:

Maximum & minimum electrode wire diameter. Welding job thickness. welding position joining materials, Circularity of joints - Pulsed/non-pulsed, preciseness of parameter control-step-controlled or step less. Dip transfer/spray transfer, shielding Gas Inductance level required

Inverter its concept and application

Inverters: Mains voltage is rectified to DC. The inverter converts to the high frequency AC. The transformer changes the HF AC to suitable welding voltage. The AC is rectified. Various filters remove the disturbing frequencies and ripples in the DC current. The entire process is monitored by a control circuit. This gives the machine ideal static and dynamic characteristic. A CDC voltage is available for welding purpose through a microprocessor based real time adaptive process control.

Why inverters: Traditional power sources have the following disadvantages:

Higher weight due to low frequency of operation (50Hz) larger volume occupying more workspace. Features of, inverter power sources,

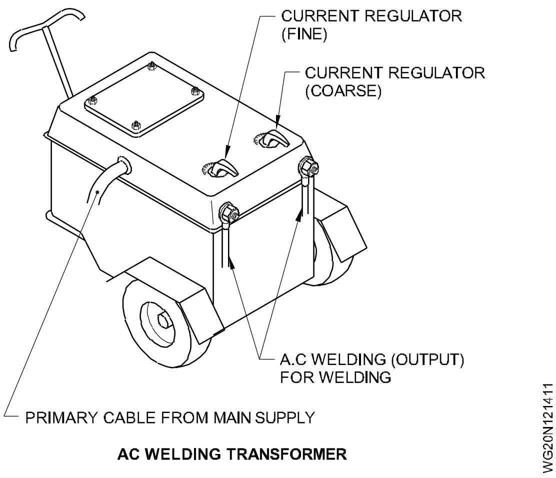
- Very light and compact-portable.
- Power consumption reduced by 40-50%
- Can quickly modify static, and dynamic output characteristics for multi-process capability.
- Excellent arc stability.
- TIG welding can be done at 1 ampere.
- Hot start and adjustable arc force for SMAW, GMAW-pulse and synergic MIG welding.
- Possible to achieve spray transfer at lower currents.
- High switching frequencies of 50,000 hertz facilitates microprocessor based real time adaptive process control.

A.C welding transformer, rectifier, inverter and its care & maintenance

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

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

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

> **This action is called the principle of mutual induction.**

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

Voltage at secondary coil =

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

Advantages

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

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

Disadvantages

Not suitable for:

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

> **AC cannot be used without special precautions of safety.**

Care and maintenance

Transformer body must be properly earthed.

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

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

Do not run the machine continuously on its maximum capacity.

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

Do not change the current when welding is going on.

Always keep and install the machine on dry floor.

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

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.

Prime mover: It is the driving source as motor or engine used to rotate the armature in the generator.

Check every week the contact of the carbon brushes with the commutator to ensure it is in good condition without sparking.

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.

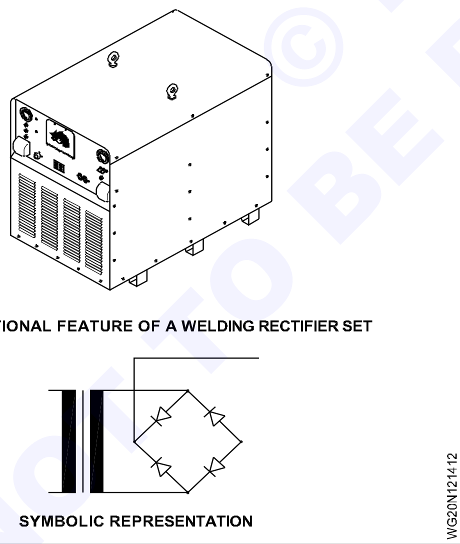
Ensure the electric motor is properly earthed.

AC/DC welding rectifier its construction

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 2) The rectifier cell consists of a supporting plate made of steel or aluminium (Fig 3) which is plated with a thin layer of nickel or 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



CONSTRUCTIONAL FEATURE OF A WELDING RECTIFIER SET

SYMBOLIC REPRESENTATION

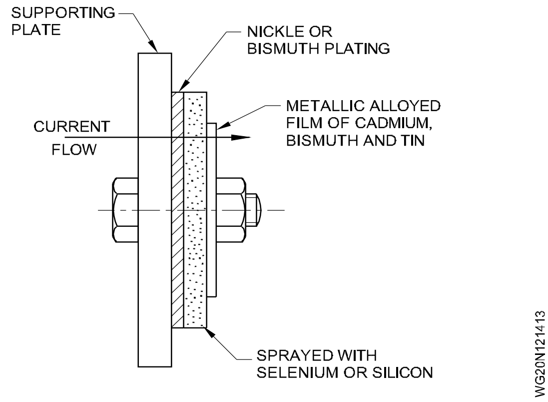
Working principle: The output of the step down transformer is connected to the rectifier unit, which converts AC to DC. The DC output is connected to positive and negative terminals, from where it is taken for welding purposes through welding cables. It can be designed to provide either AC or DC welding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

Fig 3



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

Keep the rectifier plates clean.

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

Keep the air ventilation system in good order.

Never run the machine without the fan.

Inverters

Basic principle inverter basically converts DC to AC

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

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

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

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

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

Working principle

1 Main voltage is rectified to DC

2 The inverter converts the DC to high frequency AC

3 The transformer changes the HF AC to suitable welding current.

4 The AC is rectified

5 Various filters remove the disturbing frequencies and ripples in the DC current. There is also a filter which protects against exterior high frequency disturbances.

6 The entire process is monitored by a control circuit. This gives the machine an ideal static and dynamic characteristics.

7 A DC voltage is available for welding purpose

Advantage

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

Disadvantage

- expensive, • difficult to repair
- sensitive to high currents

Advantages and disadvantages of AC and DC welding machine

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

Advantages of AC welding

A welding transformer has:

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

Disadvantages of AC welding

It is not suitable for bare and light coated electrodes.

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

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

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

Advantages of DC welding

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

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

Bare wires and light coated electrodes can be easily used.

Positional welding is easy due to polarity advantage.

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

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

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

It is easy to strike and maintain a stable arc.

Remote control of current adjustment is possible.

Disadvantages of DC welding

DC welding power source has:

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

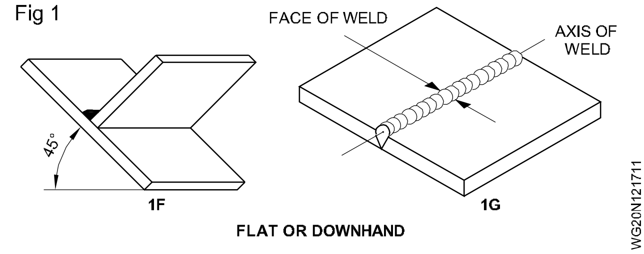
Welding positions as per EN & ASME: flat, horizontal, vertical and over head position

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

Basic welding positions

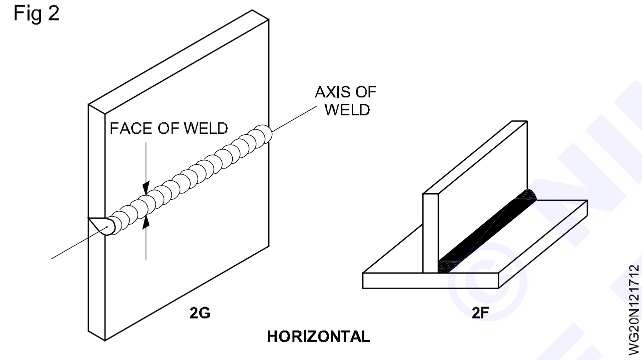
- Flat or down hand position (Fig 1)

Fig 1



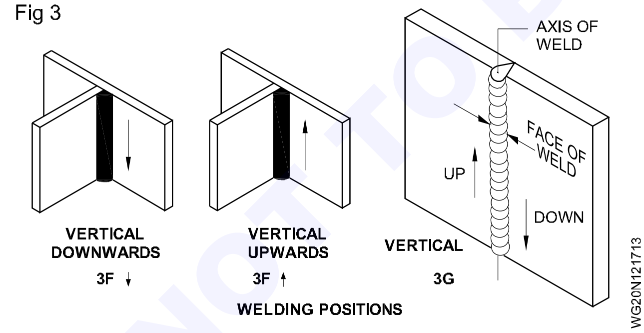
- Horizontal position (Fig 2)

Fig 2



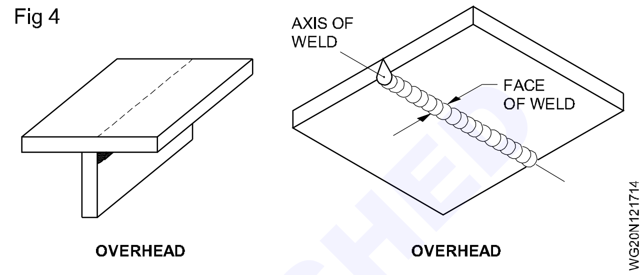
- Vertical position (Vertical up and down) (Fig 3)

Fig 3



- Overhead position (Fig 4)

Fig 4



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

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

All joints may be welded in all positions.

Plate welding position:

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

Pipe welding position:

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

Weld slope and rotation

Objectives : At the end of this lesson you shall be able to
- **weld slope and weld rotation with respect to butt and fillet joint**
- **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

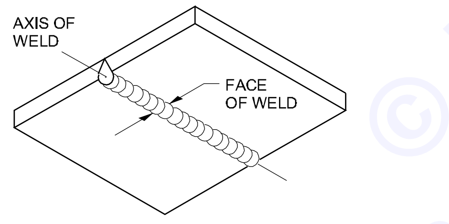
4 Overhead

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)

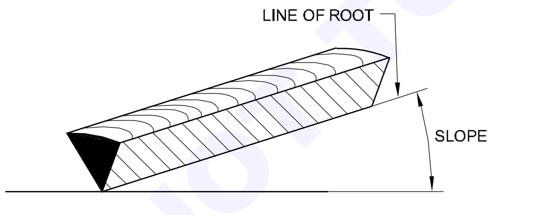
Fig 1



OVERHEAD

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

Fig 2



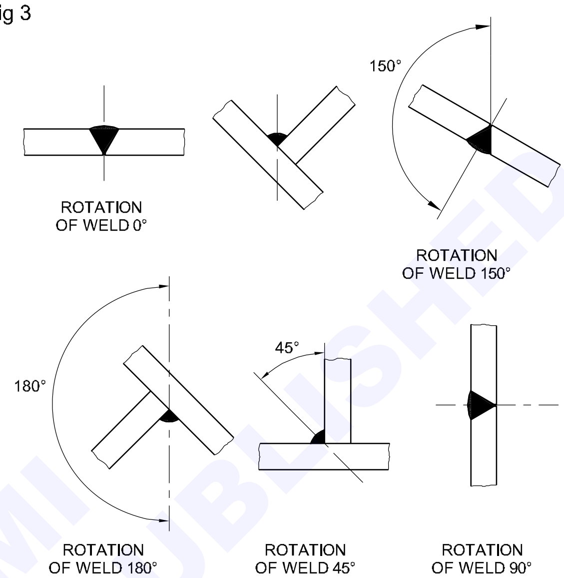
WELD SLOPE

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)

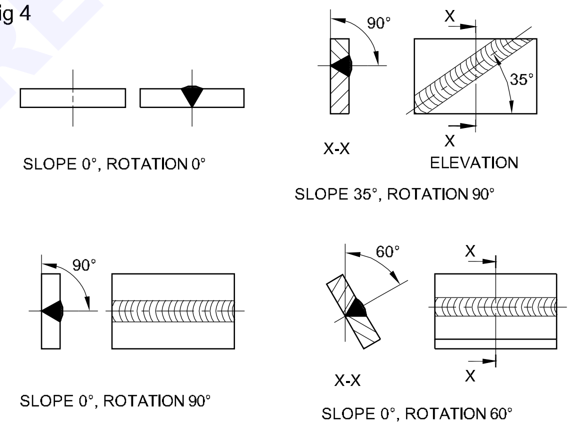
Weld in flat position. (Fig 5)

Fig 3



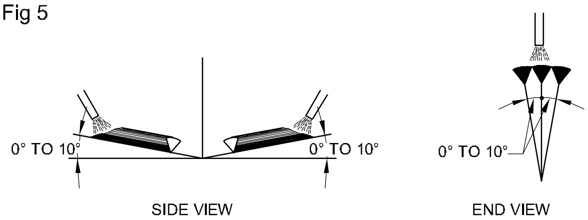
WELD ROTATION

Fig 4



SLOPE AND ROTATION

Fig 5



WELD IN FLAT POSITION

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

Fig 6

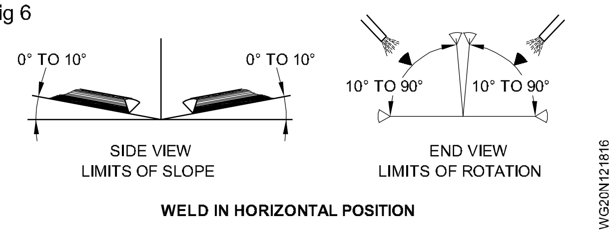
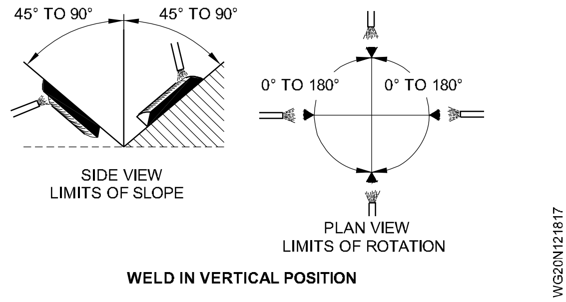
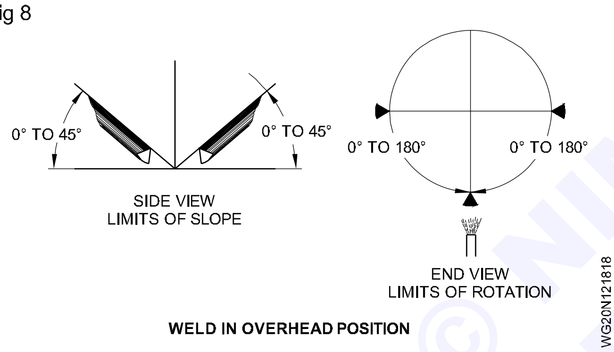


Fig 7



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 symbols as per BIS & AWS

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

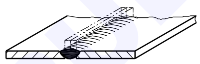
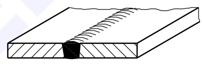
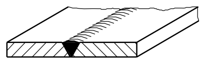
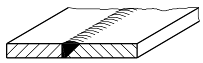
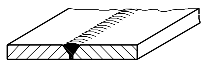
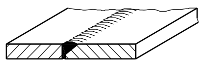
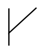
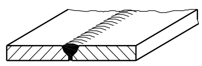
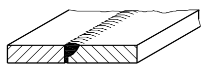
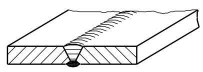
Necessity: For conveying the information required for welding for designers and welders, standard symbols are used. The symbols described below provide the means of placing on drawing the information concerning type, size, location of weldment.

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

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

TABLE 1

Elementary symbols

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

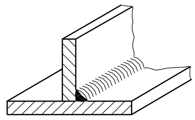
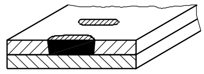
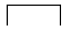
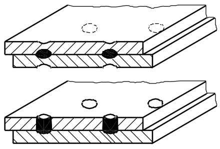
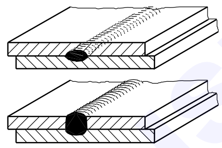
Sl. No.	Designation	Illustration	Symbol
10	Fillet weld		
11	Plug weld; Plug or slot weld/USA		
12	Spot weld		
13	Seam weld		

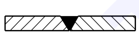
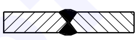
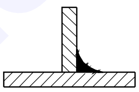
TABLE 2

Supplementary symbols

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

Table 3

Examples of application of supplementary symbols

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

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

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

1 Reference line

2 Arrow

3 Welding elementary symbols

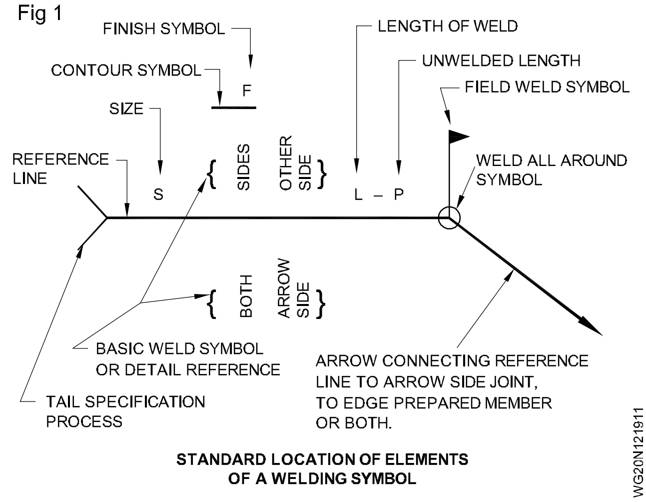
4 Dimensions and other details

5 Supplementary symbols

6 Finish symbols

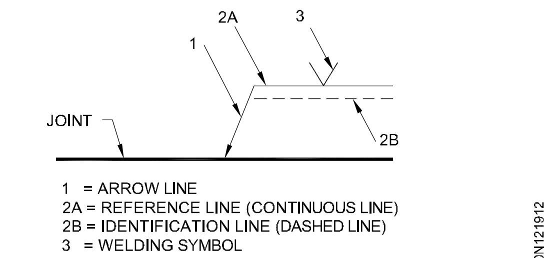
7 Tail (Specification, process)

Fig 1



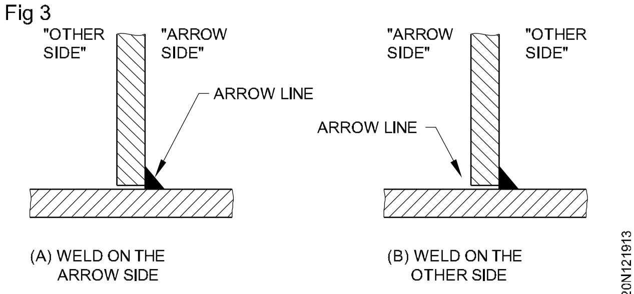
Methods of representation (Fig 2 and 3)

Fig 2



METHOD OF REPRESENTATION

Fig 3



T-JOINT WITH ONE FILLET WELD

The reference line, arrow-head and tail

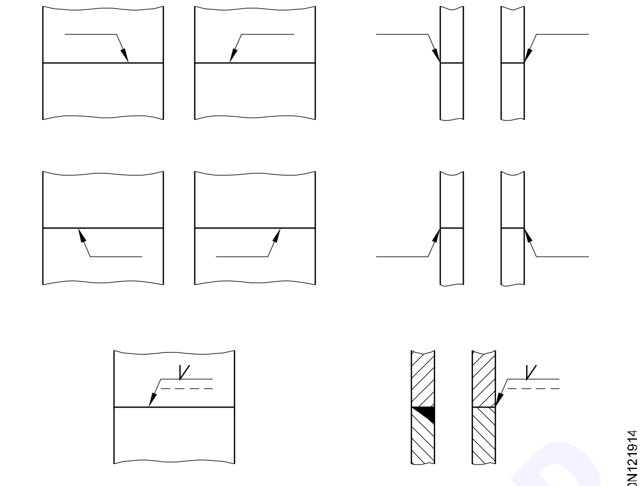
The reference line shown in Figs 1 and 5 is always drawn as horizontal line. It is placed on the drawing near the joint to be welded. All other information to be given on the welding symbols is shown above below the reference line.

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

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

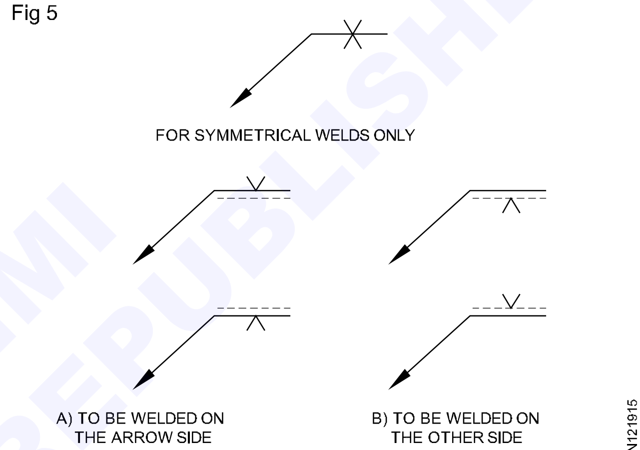
Tail: The tail is used only when necessary. If used it may give information on specification, the welding process used. or other details required which are not shown in the welding symbol.

Fig 4



POSITION OF THE ARROW LINE

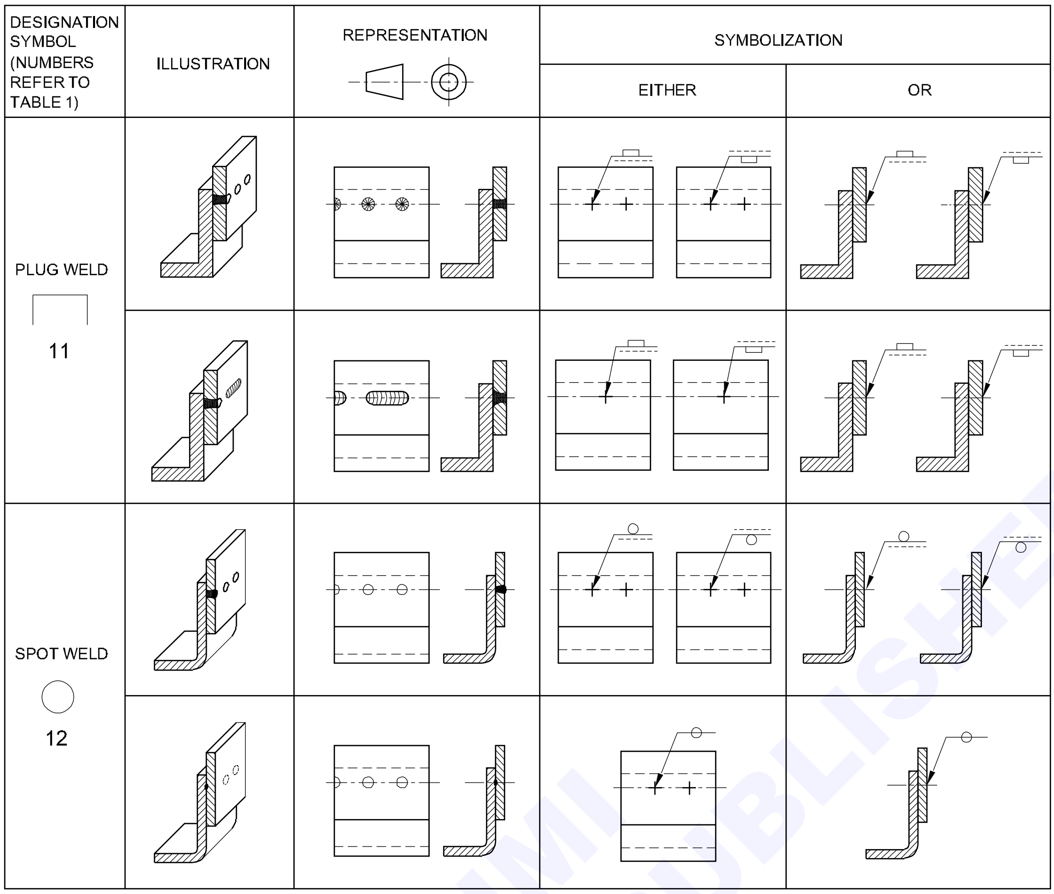
Fig 5



POSITION OF SYMBOLS ACCORDING TO THE REFERENCE LINE

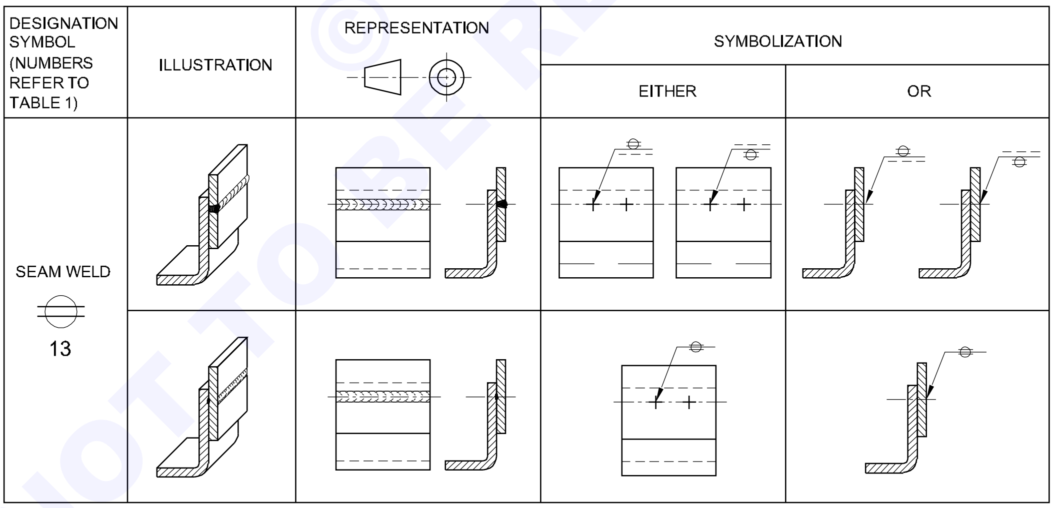
Welding/elementary symbol: Figs 6 and 7 illustrate how some of the various types of weld symbols are used in welding symbols.

Fig 6



EXAMPLES OF USE OF ELEMENTRY SYMBOLS

Fig 7

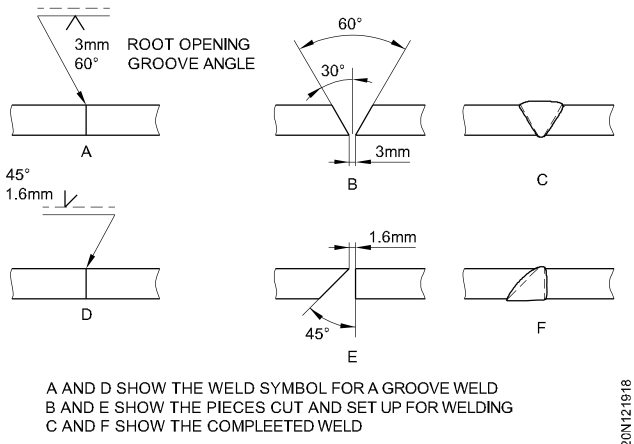


EXAMPLES OF USE OF ELEMENTRY SYMBILS

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

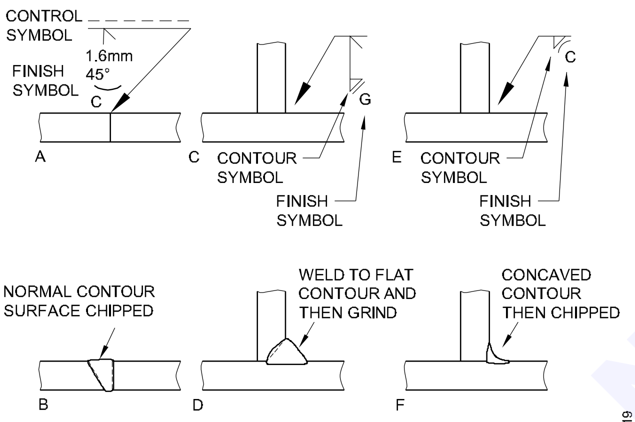
Contour and finish symbols: The shape or contour of the completed weld bead is shown on the welding symbol as a straight or curved line between the basic weld symbol and the finish symbol. The curved contour line indicates a normal convex or concave weld bead. (Fig 9)

Fig 8



ROOT OPENING AND GROOVE ANGLE

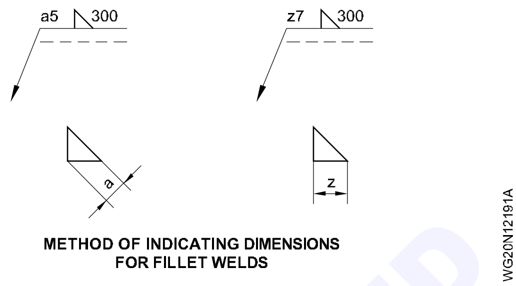
Fig 9



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

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

Fig 10



METHOD OF INDICATING DIMENSIONS FOR FILLET WELDS

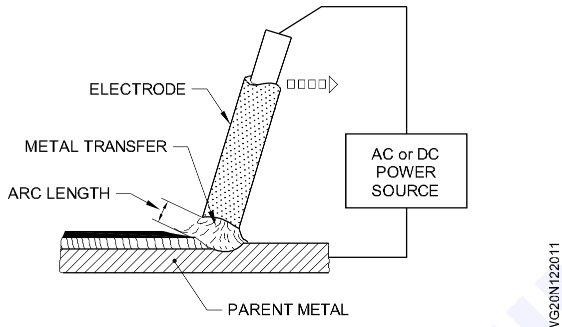
Arc length - types - effects of arc length

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

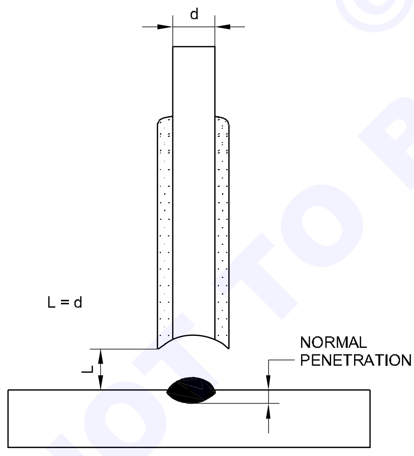
- Medium or normal
- Long
- Short

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

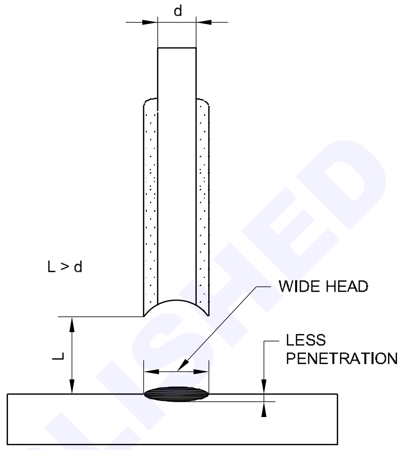
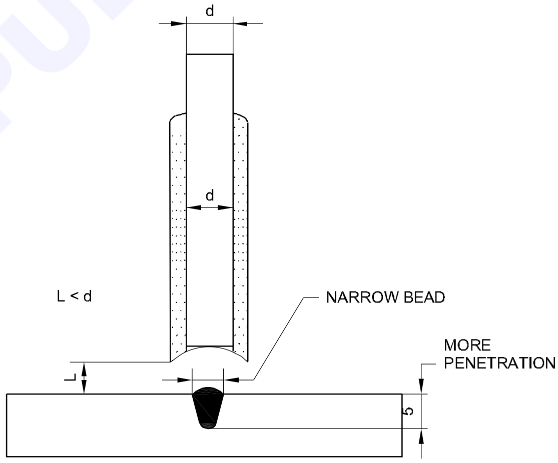


Fig 4



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.

Short arc: It makes a popping sound causing:

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

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

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

Uses of different arc lengths

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

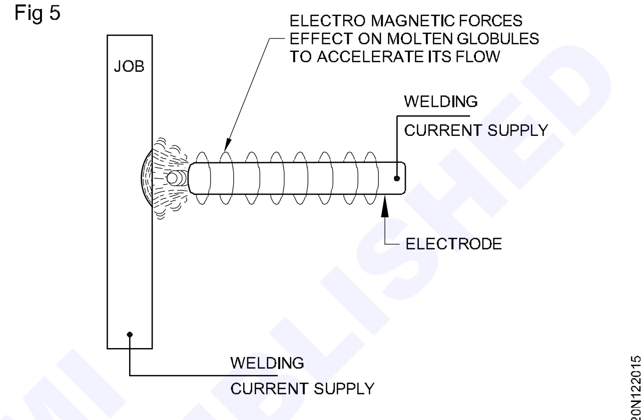
Long arc: It is used in plug and slot welding. for restarting the arc and while withdrawing the electrode at the end of a bead after filling the crater. Generally long arc is to be avoided as it will give a defective weld.

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

Electromagnetic force (Fig 5): 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 5



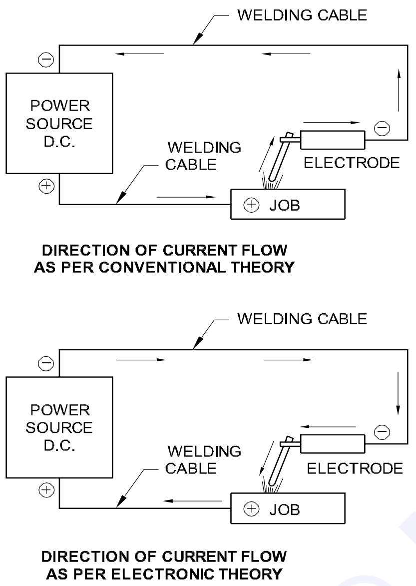
ELECTRO MAGNETIC EFFECT

Polarity: Types and applications

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

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

Fig 1



WG20N122111

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.

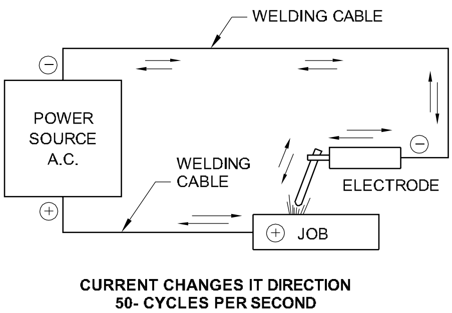
In older machines the electrode and earth cables are interchanged whenever the polarity has to be changed.

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



WG20N122112

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.

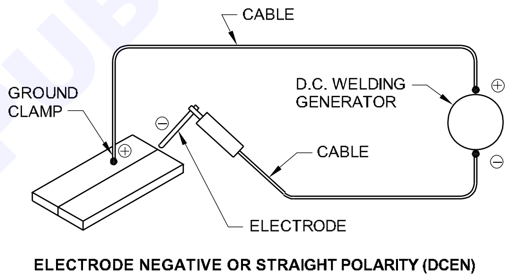
To have this advantage of unequal heat distribution in the electrode and base metal, the polarity is an important factor for successful welding.

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)

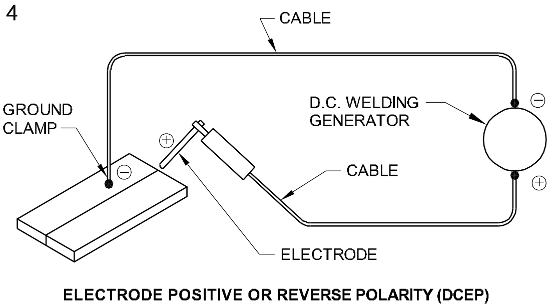
Fig 3



WG20N122113

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



WG20N122114

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.

Calcium carbide uses and hazards

Objectives : At the end of this lesson you shall be able to
- **ingredients and grades of calcium carbide**
- **the properties 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 $Ca\ C_2$

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.

Calcium carbide hazards

Calcium carbide can irritate the skin causing a rash, redness and burning feeling on contact. Permanent damage (corneal opacities) exposures may cause a build up a fluid in the lungs.

Acetylene gas - Properties

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

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

Composition of acetylene gas: Acetylene is composed of:

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

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

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

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

Acetylene gas Flash back arrestor

Objectives : At the end of this lesson you shall be able to
- **flash back arrestor**
- **function of flash back arrestor.**

Flash back arrester

When a flashback occurs, the flame burns rapidly 'upstream', generally causing a loud explosion. If unchecked it can continue through the torch into hoses, regulators and gas bottles/cylinders. (Fig 1)

Causes that can trigger a flashback include: Worn or improperly maintained equipment, operator error, improper monitoring of cylinder pressures, and many other causes!

The consequences of a flashback can vary from slight equipment damage through to a major gas cylinder explosion resulting in death, injury and/or extensive property damage.

There is no way of predicting just how severe the effects will be, which is why you need to protect yourself against a flashback.

A flashback arrestor is designed to contain a flashback, and prevent it from penetrating into "upstream equipment" (e.g. hoses, regulators and gas cylinders).

The main parts of a flashback arrestor and their functions are; (Fig 2)

1 Non-return valve: This stops the reverse flow (back surge) of gas.

2 Sintered flame filter: This blocks the flame.

3 Thermal activated cut-off valve: (Fitted a regulator mounted models only). In case of a sustained (continuous) flashback or backfire, this valve will close and stop the flow of gas in any direction.

Fig 1

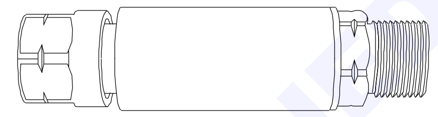
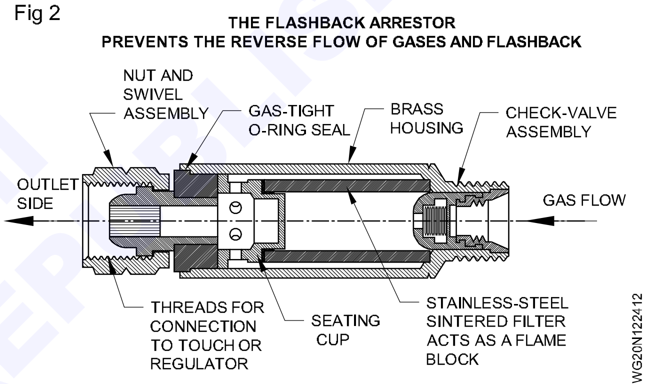


Fig 2



Oxygen gas and its properties, charging process of oxygen and acetylene gases

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

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

Properties of oxygen gas

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

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.

Oxygen and Dissolved Acetylene gas cylinders and Color coding for different gas cylinders uses of Single stage and double stage Gas regulators

Objectives : At the end of this lesson you shall be able to
- **different gas cylinders**
- **colour coding**
- **single stage & double stage regulator.**

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

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

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

Table 1

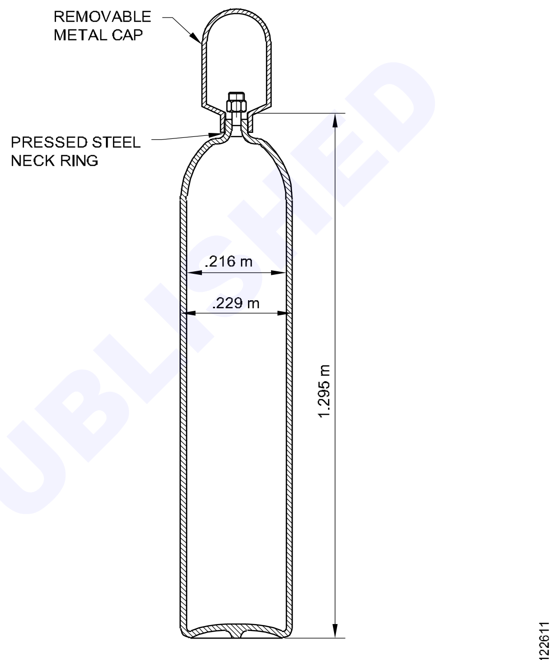
Identification of gas cylinders

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

Charging of gas in oxygen cylinder (Fig 1): 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.

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.

Fig 1



CONSTRUCTIONAL FEATURE OF OXYGEN GAS CYLINDER

The cylinders are filled with porous substances such as:

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

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

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

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

Uses of single and double stage and regulator

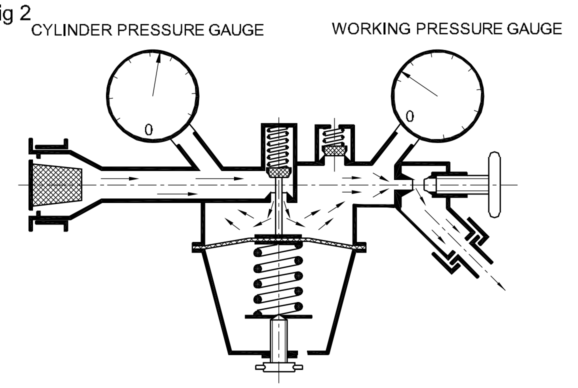
Types of regulators

- single stage regulator
- Double stage regulator

Welding regulator (Single stage)

Working principle: When the spindle of the cylinder is opened slowly, the high pressure gas from the cylinder enters into the regulator through the inlet valve. (Fig 2)

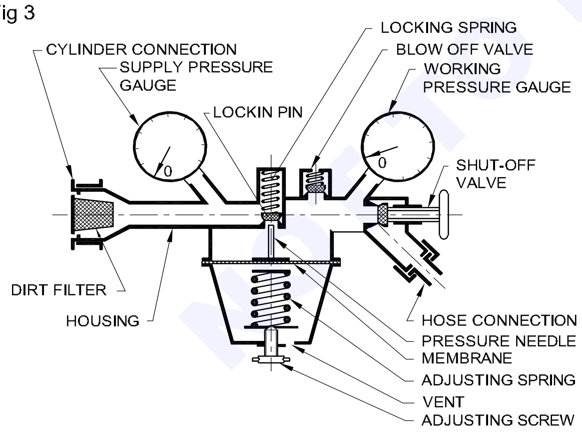
Fig 2



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 3)

Fig 3



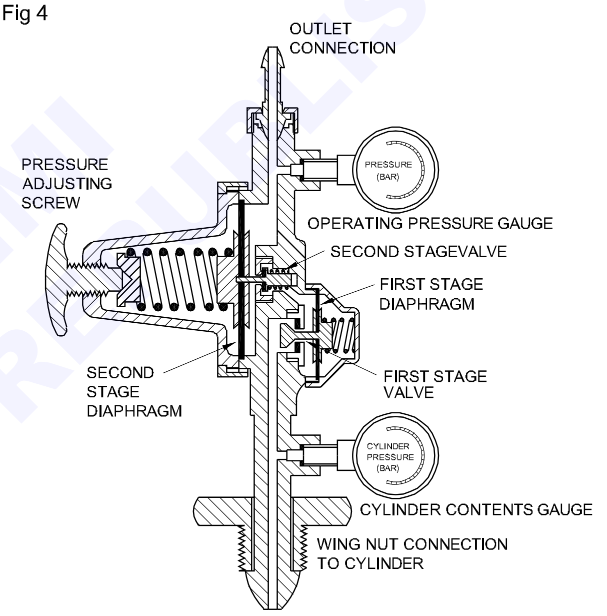
SINGLE STAGE REGULATOR

Welding regulator (double stage)

Working principle: The two-stage regulator (Fig 4) 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



TWO STAGE REGULATOR

Oxy acetylene gas welding Systems (Low pressure and High pressure)

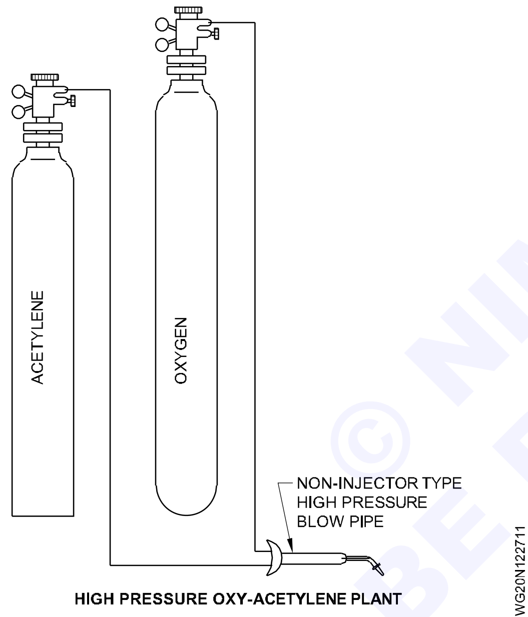
Objectives : At the end of this lesson you shall be able to
- **the low pressure and the high pressure systems of oxy-acetylene plants and systems**
- **low pressure and high pressure blowpipes**
- **the advantages and disadvantages of both systems.**

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)

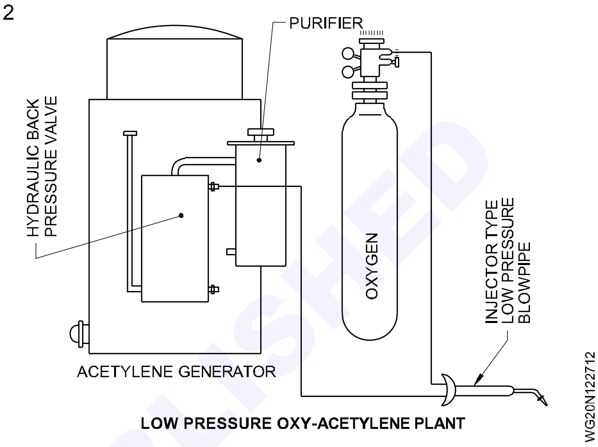
> **High pressure and low pressure plants utilize oxygen gas kept in compressed high pressure cylinders only at 120 to 150 kg/cm^2 pressure.**

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.

> **The terms low pressure and high pressure systems used in oxy-acetylene welding refer only to acetylene pressure, high or low.**

Fig 2



LOW PRESSURE OXY-ACETYLENE PLANT

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

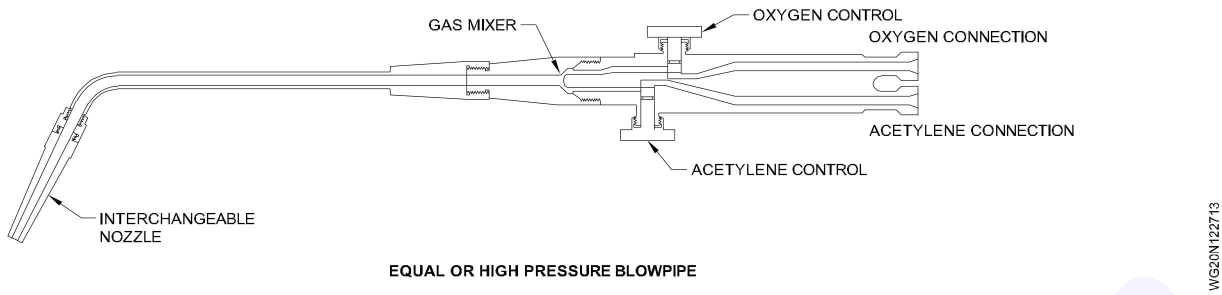
There are two types of blowpipes.

- 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 3): 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 3

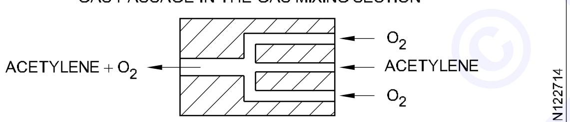


EQUAL OR HIGH PRESSURE BLOWPIPE

The equal pressure blow pipe 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 4). The mixed gases flow through a neck pipe to the nozzle and then get ignited at the tip of the nozzle. Since the pressure of the oxygen and acetylene gases are set at the same pressure of 0.15 kg/cm^2 they mix together at the mixing chamber and flows through the blow pipe to the nozzle tip on its own. This equal pressure blow pipe/torch is also called as high pressure blow pipe/torch because this is used in the high pressure system of gas welding.

Fig 4

GAS PASSAGE IN THE GAS MIXING SECTION



EQUAL PRESSURE TYPE TORCH

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

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

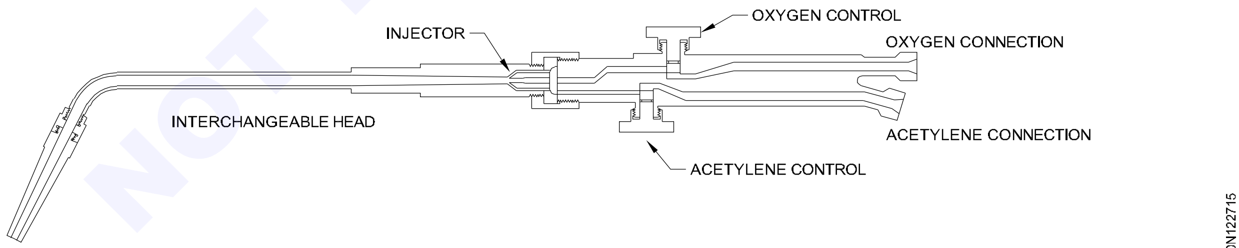
Low pressure blowpipe

This blowpipe has an injector (Fig 5) 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 6)

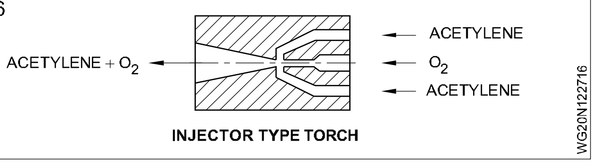
It is usual for the whole head to be interchangeable in this type, the head containing both the nozzle and injector. This is necessary, since there is a corresponding injector size for each nozzle.

Fig 5



LOW PRESSURE BLOWPIPE

Fig 6



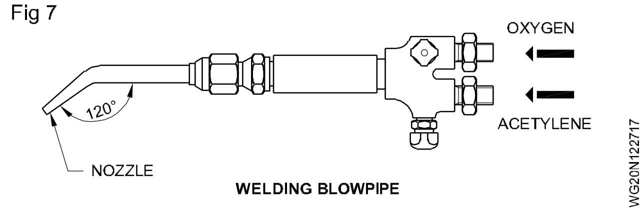
INJECTOR TYPE TORCH

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

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 7)

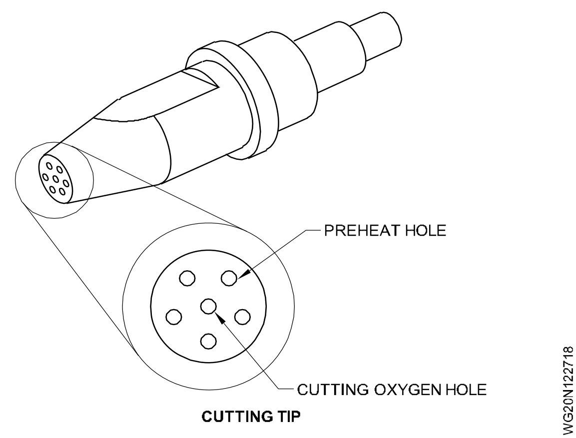
Fig 7



WELDING BLOWPIPE

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 8)

Fig 8



CUTTING TIP

Gas welding techniques. Rightward and Leftward techniques

Objectives: At the end of this lesson you shall be able to
- **the different gas welding techniques and explain the leftward welding techniques & rightward.**

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

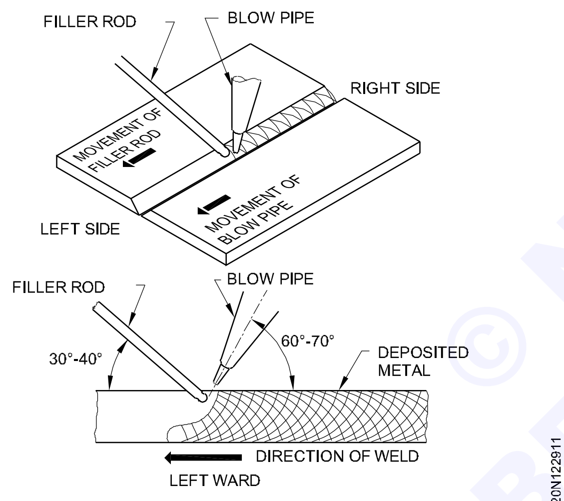
1 Leftward welding technique (Forehand technique)

2 Rightward welding technique (Backhand technique)

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

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

Fig 1



LEFT WARD WELDING TECHNIQUE

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

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

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

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

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

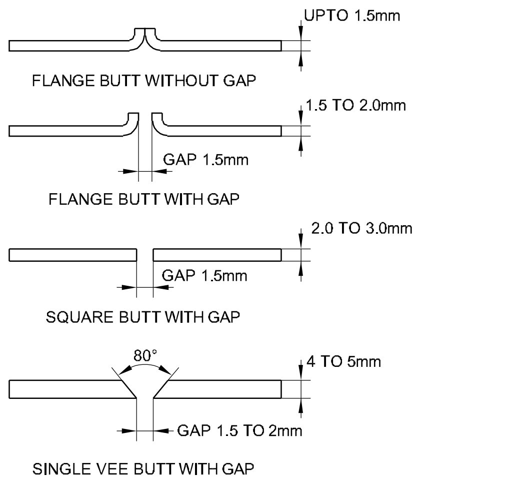
For butt joints the edges are prepared as shown in Fig 2. the table given below gives the details for welding mild steel by leftward technique for butt joints.

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	For gas welding of mild steel no flux is required to be used
1.6 to 2	1.6	3	Square	2	
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	

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

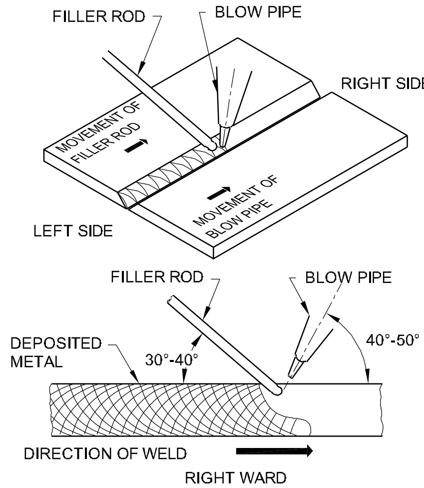
Rightward welding technique: It is an oxy-acetylene gas welding technique, in which the welding is begun at the left hand edge of the welding job and it proceeds towards the right.

This technique was developed to assist the production work on thick steel plates (Above 5mm) so as to produce economic welds of good quality.

It is also called backward or back hand technique.

the following are its features. (Fig 3)

Fig 3



FEATURE OF RIGHTWARD WELDING TECHNIQUE

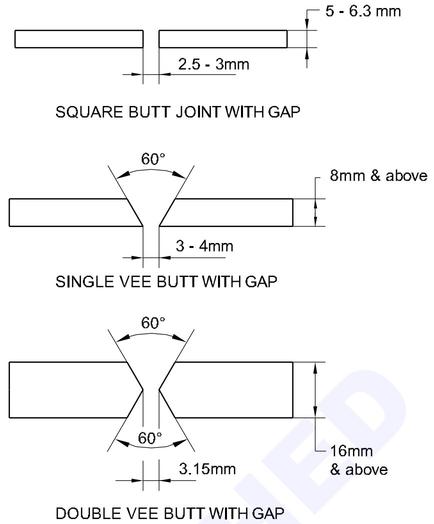
Welding is commenced at the left hand edge of the job and it proceeds to the right. The blowpipe is held at an angle of 40° - 50° with the welding line. The filler rod is held at an angle of 30° - 40° with the welding line. The filler rod follows the welding blowpipe. The welding flame is directed towards the deposited weld metal.

The filler rod is given a rotational or circular loop motion in the forward direction. The blowpipe moves back in a straight line steadily towards the right. This technique generates more heat for fusion, which makes it economical for thick steel plate welding.

Edge preparation for rightward technique (Fig 4)

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

Fig 4



EDGE PREPARATION FOR RIGHTWARD WELDING

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

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

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

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

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

Table 1 (For Butt joints)

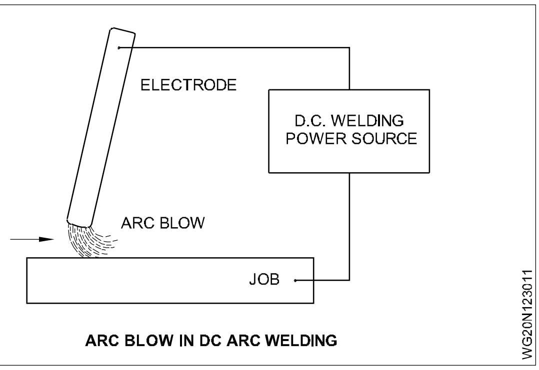
Metal thickness in mm	C.C.M.S filler rod diameter in mm	Blow pipe nozzle size	Edge preparation	Root gap in mm	Flux to be used
5	3.15	10	Square	2.5	For gas
6.3	4.0	13	Square	3.0	welding of mild
8	5.0	18	60° Vee	3.0	steel no flux
10 to 16	6.3	18	60° Vee	4.0	is required to
Above 16	6.3	25	60° double Vee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

Arc blow - causes and methods of controlling

Objectives : At the end of this lesson you shall be able to
- **the arc blow in DC welding**
- **the effects of arc blow on welds**
- **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)

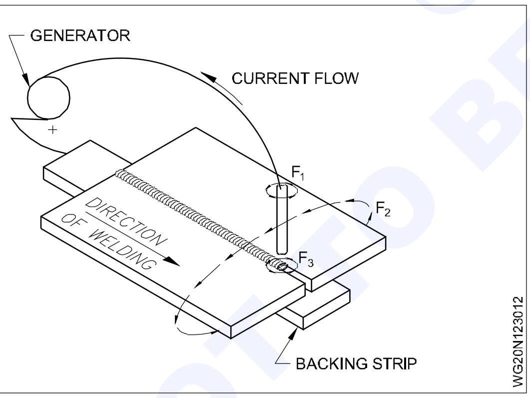
Fig 1



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)

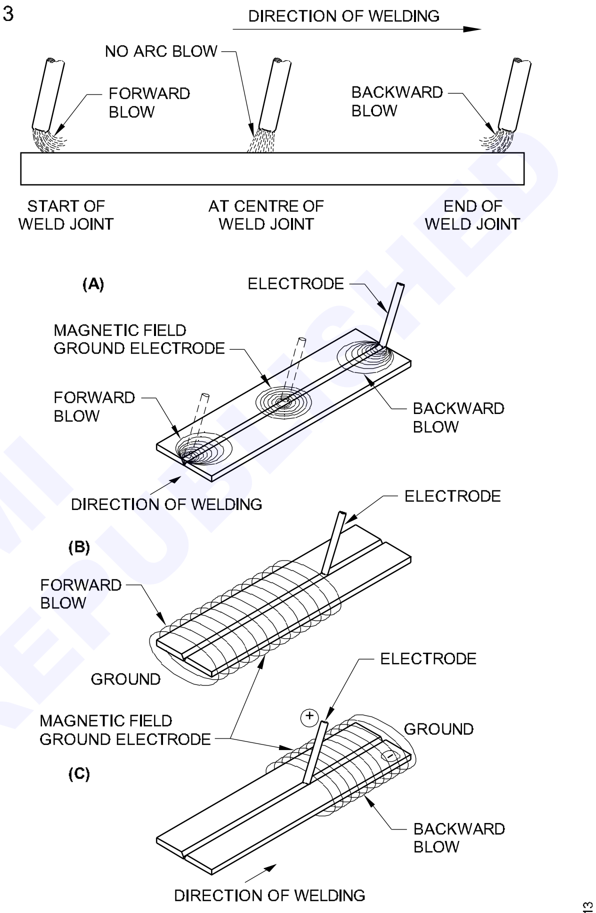
Fig 2



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



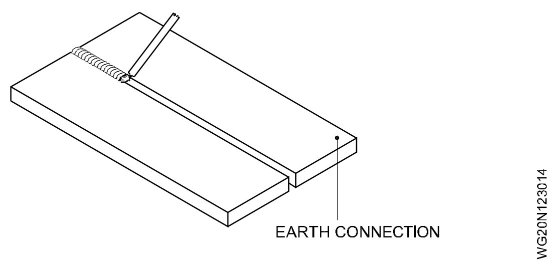
MAGNETIC FIELDS THAT RESULT IN FORWARD OR BACKWARD ARC BLOW (A) AROUND THE ELECTRODE/ARC (B) AND (C) AROUND THE WORK

Methods used to control the arc blow

The arc blow can be controlled by:

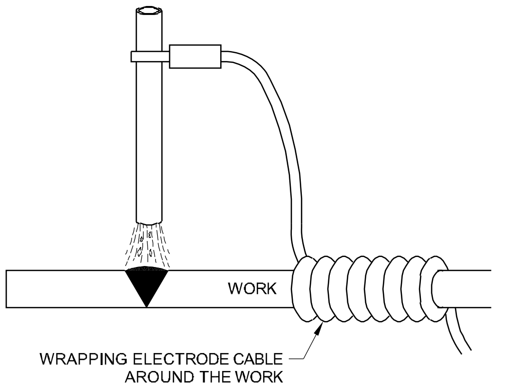
- Place the earth connection as far from the weld joint as possible. (Fig 4)

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)

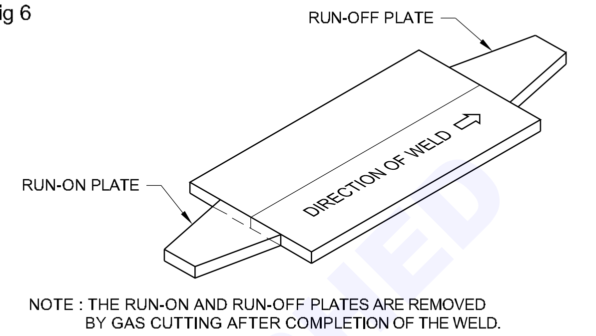
Fig 5



- welding towards a heavy welding tack or a weld already made.
- 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

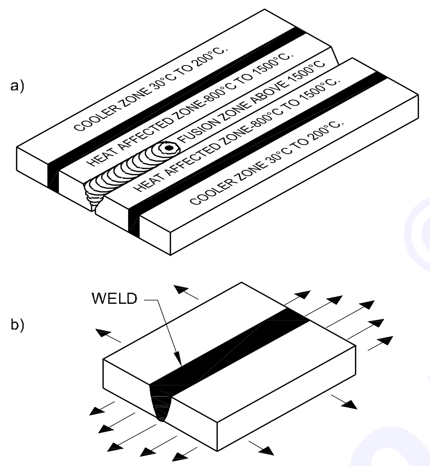


Distortion in arc & gas welding and methods employed to minimize distortion

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

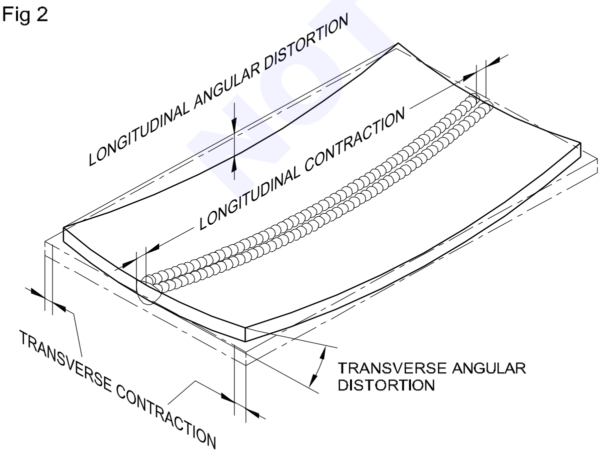
Causes of distortion: In arc welding, the temperature at different areas of the joint are different. (Fig 1a). The expansions in these areas are also different depending on the temperature (Fig 1b). In the same way after welding, different areas of the joint contract differently, But in a solid body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

Fig 1



EXPANSION OF A PLATE DURING WELDING (MILD STEEL)

Fig 2



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

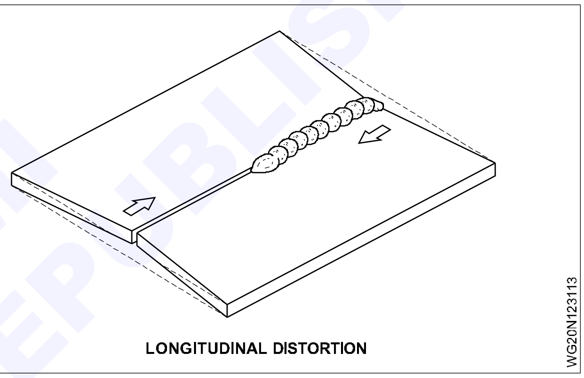
Types of distortion

The 3 types of distortion are:

- longitudinal distortion
- transverse distortion
- angular distortion.

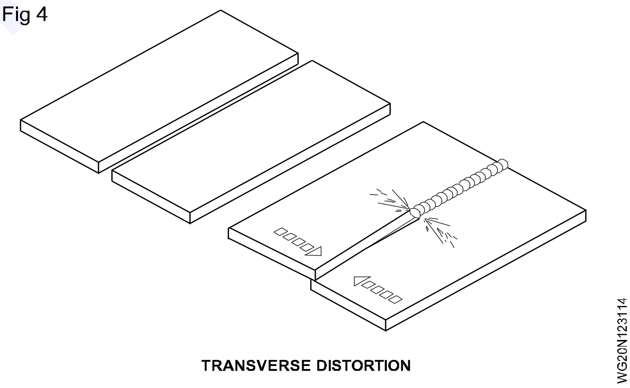
The figures (3,4,5) illustrate the different types of distortion.

Fig 3



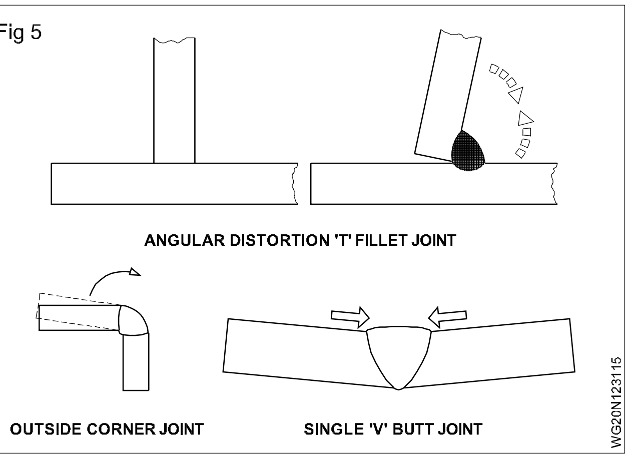
LONGITUDINAL DISTORTION

Fig 4



TRANSVERSE DISTORTION

Fig 5



Factors affecting distortion

Design

Parent metal

Joint preparation and set up

Assembly procedure

Welding process

Deposition technique

Welding sequence

Unbalanced heating about the neutral axis

Restraint imposed

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

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

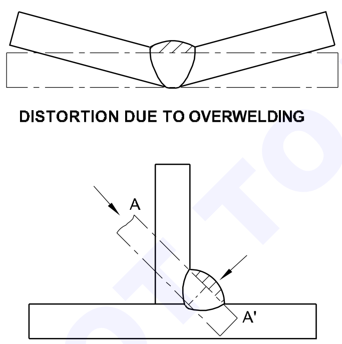
- Reducing the effective shrinkage force.
- Making the shrinkage forces to reduce distortion.
- Balancing the shrinkage force with another shrinkage force.

Methods of reducing the effective shrinkage forces

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

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

Fig 6



DISTORTION DUE TO OVERWELDING

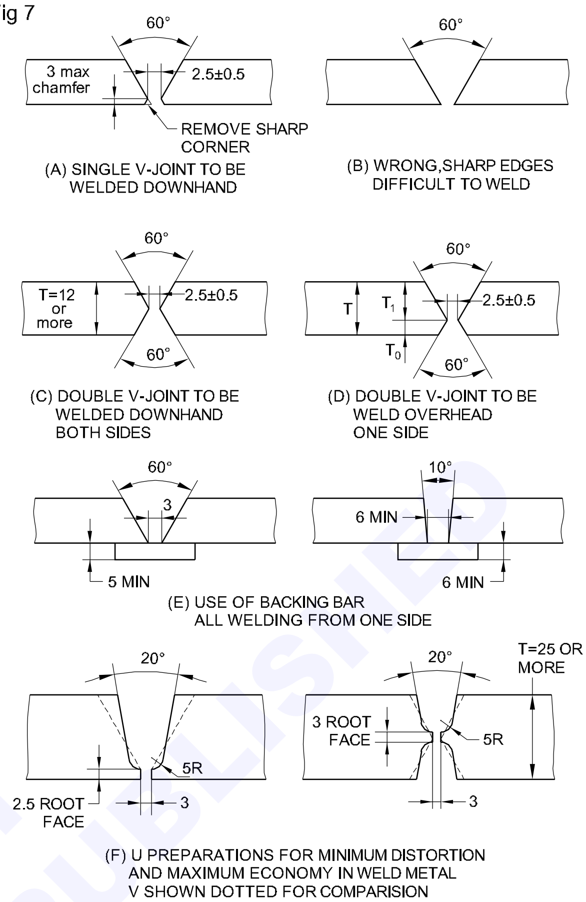
EXCESS WELD METAL ABOVE THE LINE A A' OF CONVENTIONAL FILLET WELD

WG20N123116

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. (Fig 8)

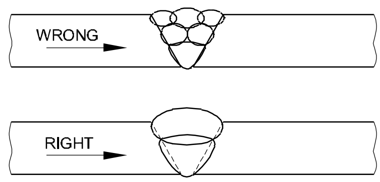
Fig 7



PREPARATION OF PLATES FOR BUTT WELDING

WG20N123117

Fig 8

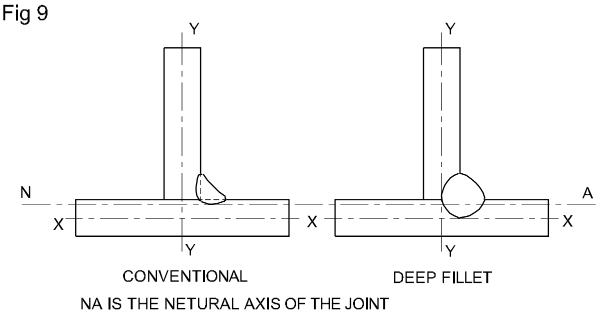


COMPARISION OF PASSES OF WELD

WG20N123118

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

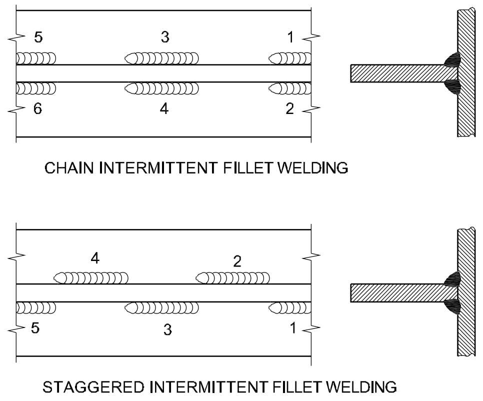


DEEP PENETRATION FILLET WELD

WG20N123119

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)

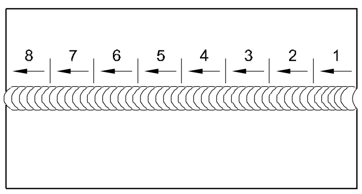
Fig 10



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

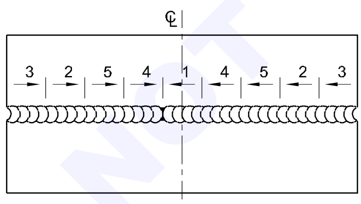


BACK STEP WELDING METHOD

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)

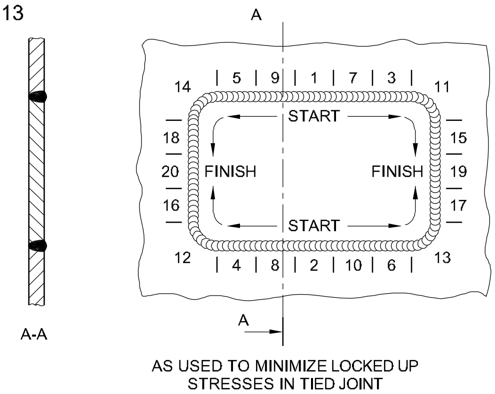
Fig 12



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

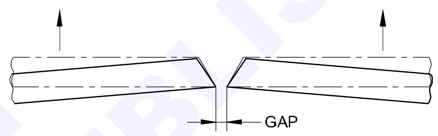


SKIP WELDING

Methods used for making the shrinkage forces work to reduce distortion

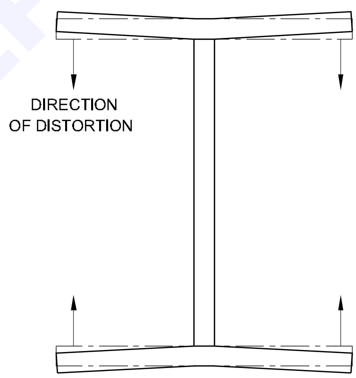
Locating parts out of position: Distortion may be allowed for by pre-setting the plates in the opposite way so that the weld pulls them to the desired shape. When the weld shrinks it will pull the plate to its correct position (Fig 14 & 15)

Fig 14



PRE-SETTING TO COMPENSATE FOR ANGULAR DISTORTION

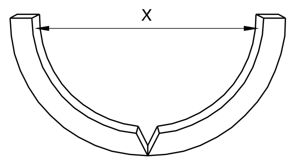
Fig 15



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)

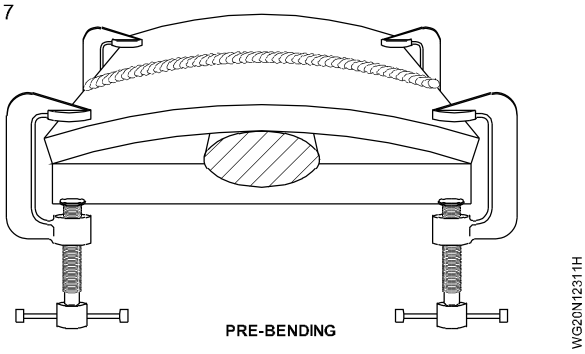
Fig 16



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

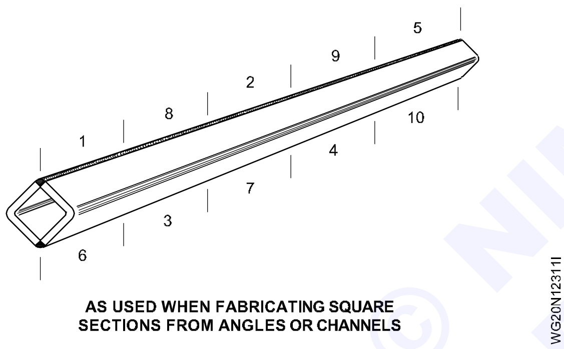


PRE-BENDING

Methods of balancing of one shrinkage force with another shrinkage force

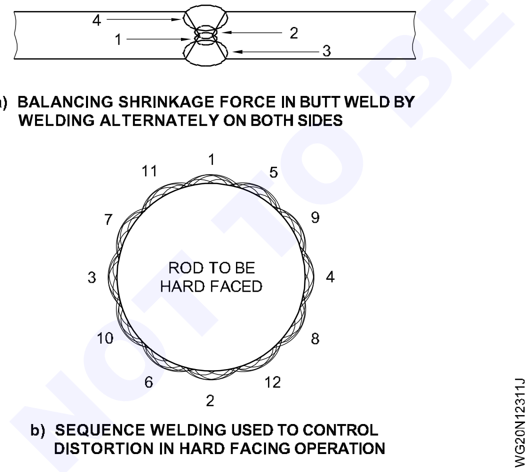
Use of proper welding sequence: This places the weld metal at different points about the structure. In this method, welds are made from each side alternately so that when a second run of weld metal shrinks it will counteract the shrinkage forces of the first weld. (Figs 18, 19 a and 19b)

Fig 18



AS USED WHEN FABRICATING SQUARE SECTIONS FROM ANGLES OR CHANNELS

Fig 19

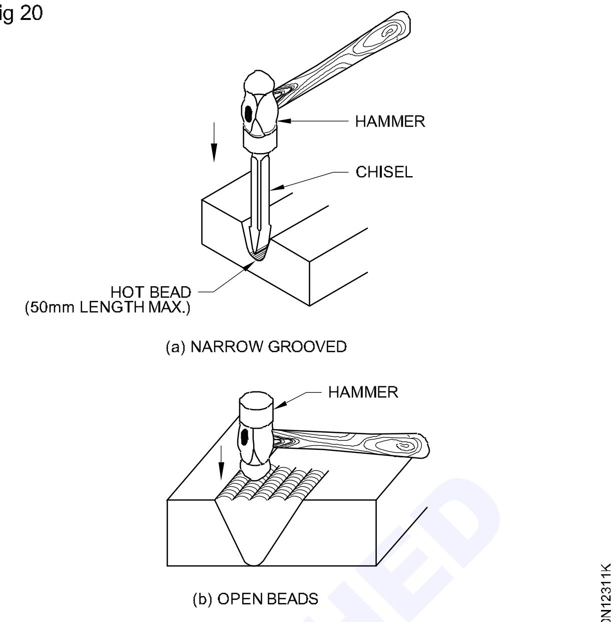


a) BALANCING SHRINKAGE FORCE IN BUTT WELD BY WELDING ALTERNATELY ON BOTH SIDES

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)

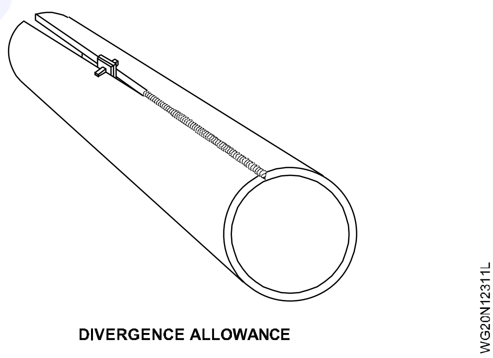
Fig 20



PEENING

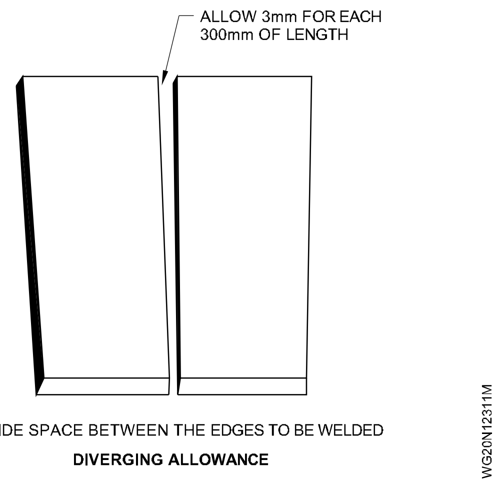
Divergence allowance: As there is a tendency of the plates to extend & converge along the seam during welding, this technique is used to diverge the plates from the point where welding commences by placing a wedge or an alignment clamp between the plates ahead of the weld. (Fig 21& 22)

Fig 21



DIVERGENCE ALLOWANCE

Fig 22



PROVIDE SPACE BETWEEN THE EDGES TO BE WELDED

DIVERGING ALLOWANCE

The spacing allowances are as follows.

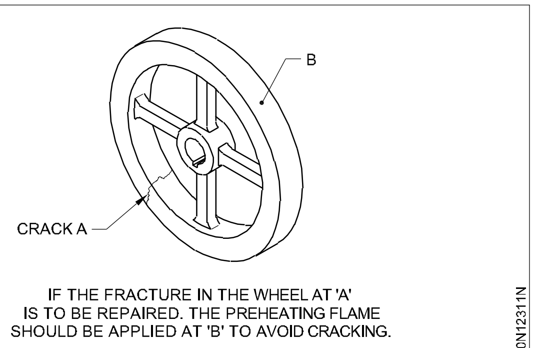
3mm/m for (mild steel) Ferrous metals

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)

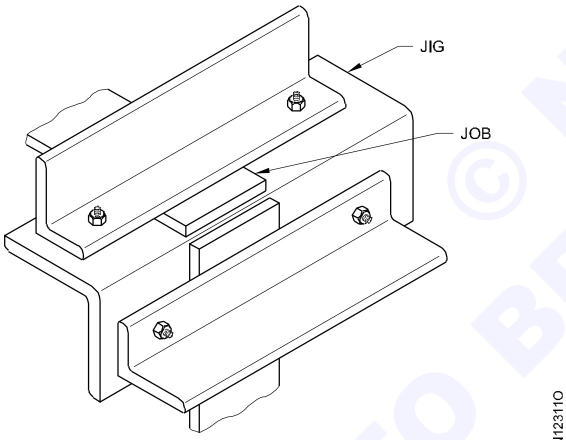
Fig 23



TECHNIQUE OF LOCAL PREHEATING

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

Fig 24



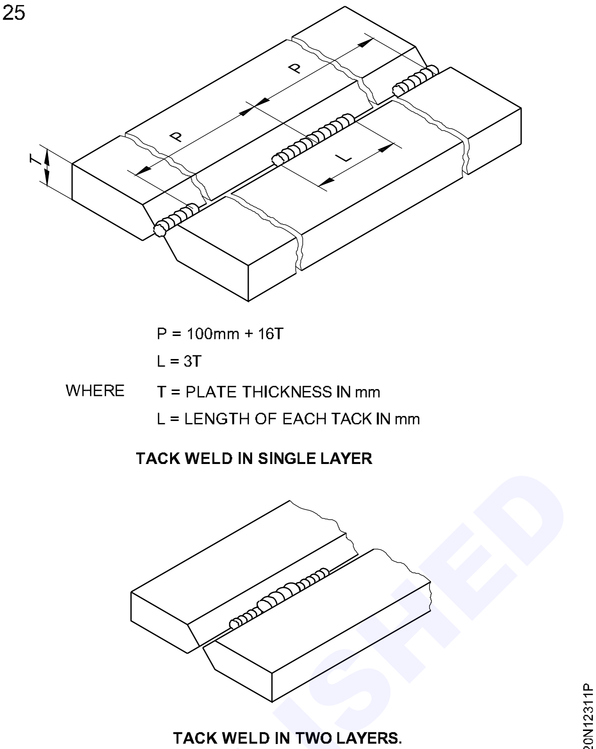
USE OF JIGS AND FIXTURES TO AVOID DISTORTION

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

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

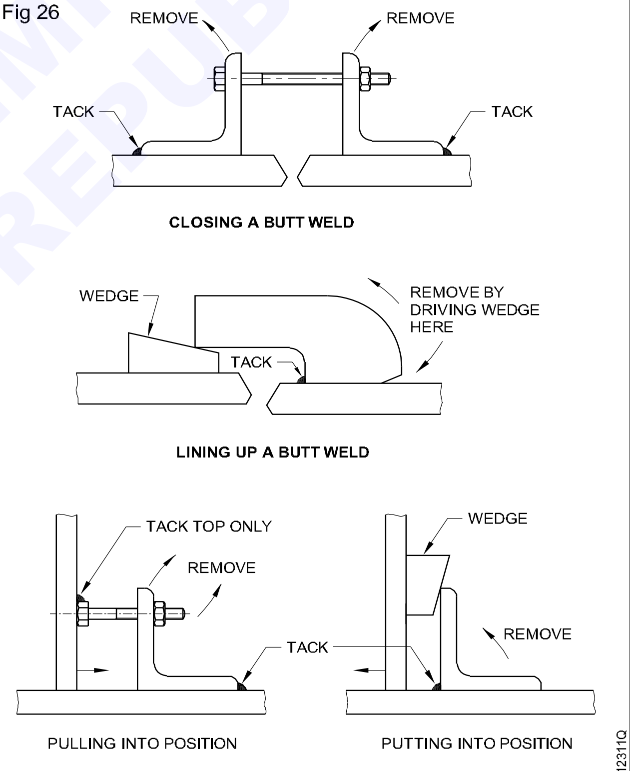
Mechanical methods: Small parts, deformed by angular distortion can be straightened by using a press. If the parts of the assembly are not restrained, they can be brought into alignment by hammering, drifting or jacking without giving excessive force (stress}.

Fig 25



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

Fig 26



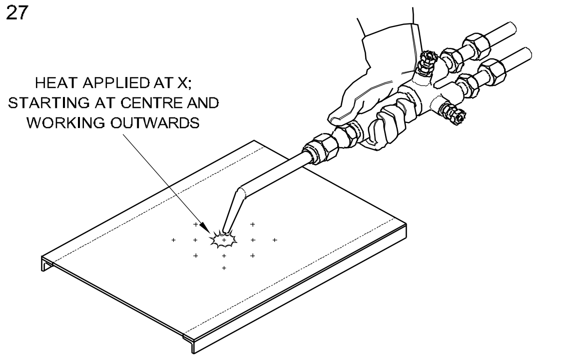
TACK WELDING ERECTION CLEATS
AND AIDS TO ASSEMBLY

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

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

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

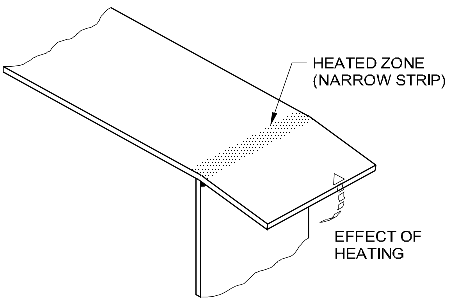
Fig 27



SPOT HEATING TO CORRECT BUCKING OF THIN SHEET

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

Fig 28



CORRECTION OF DISTORTION CAUSED BY FILLET WELD

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

The methods of flame straightening are shown in Fig 29.

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

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

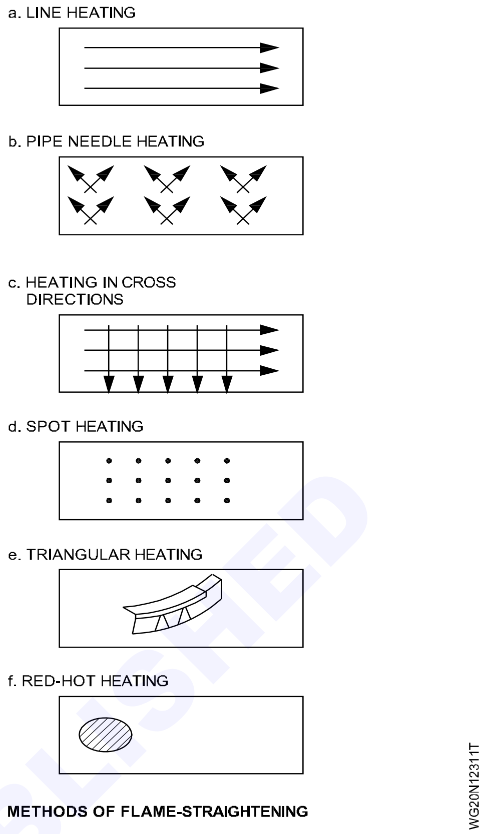
In checker board (cross-directions) heating, (Fig 29c) heat is applied along a pair of two lines crossing each other. This method is used to remove severe distortion.

In spot heating. (Fig 29d) 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 Remedies

Objectives : At the end of this lesson you shall be able to
- **weld defects in arc welded joints**
- **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

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.

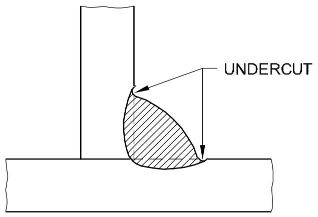
A remedy can be

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.

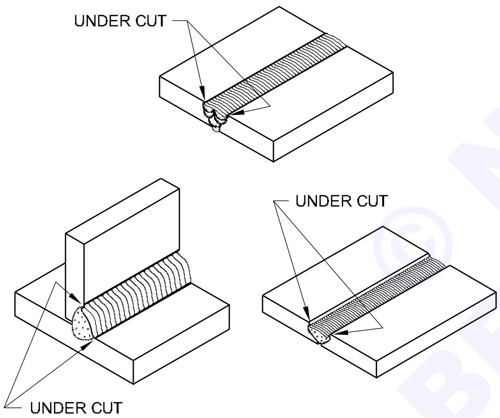
Undercut: A grooved or channel formed in the parent metal at the toe of the weld. (Figs 1, 2 & 3)

Fig 1



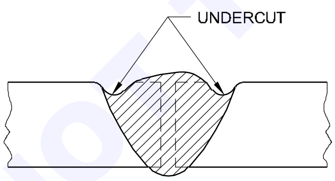
TEE-JOINT FILLET WELD

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

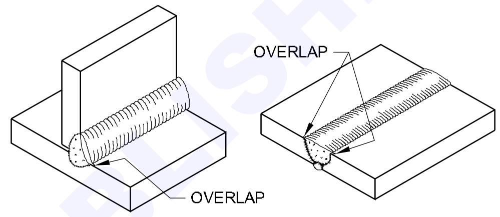
b Corrective action

- 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.

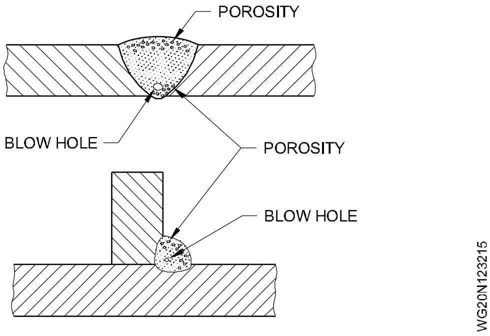
b Corrective actions

- Remove the overlap by grinding without an under-cut.

Blowhole and porosity

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

Fig 5



Causes

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

Remedies

a Preventive actions

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

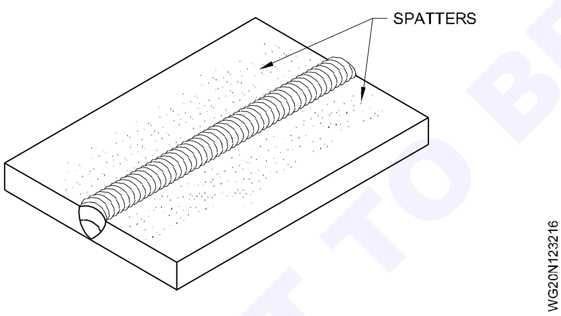
b Corrective action

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

Spatter

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

Fig 6



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

Remedies

a Preventive actions

- Use correct current.
- Use correct polarity (DC).
- Use correct arc length.
- Use good flux-coated electrode.

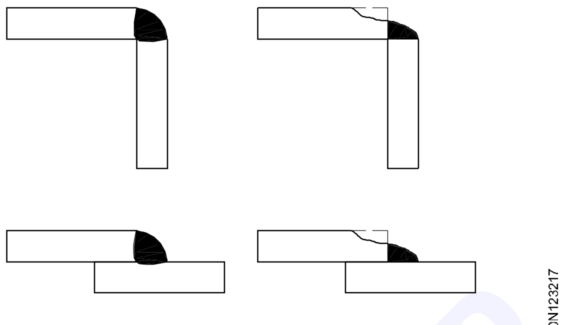
b Corrective actions

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

Edge of plate melted off

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

Fig 7



EDGE OF PLATE MELTED OFF

Causes

- Use of oversize electrode.
- Use of excessive current.
- Wrong manipulation of the electrode i.e. excessive weaving of electrode.

Remedies

a Preventive action

- Select correct size electrode.
- Set correct current.
- Ensure correct manipulation of electrode.

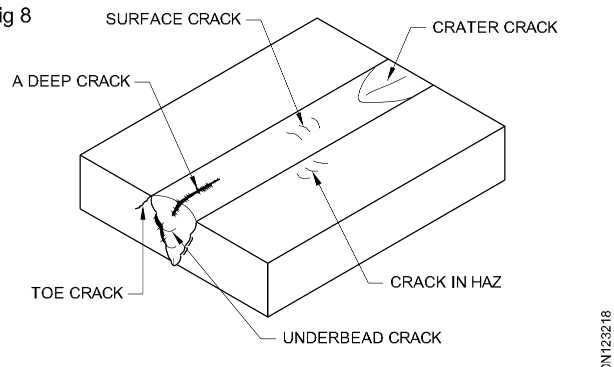
b Corrective action

- Deposit additional weld metal to increase throat thickness.

Crack

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

Fig 8



DIFFERENT TYPES OF CRACKS

Causes

- Wrong selection of electrode.
- Presence of localized stress.
- A restrained joint.
- Fast cooling.

– Improper welding techniques/sequence.
– Poor ductility.
– Absence of preheating and post-heating of the joint.
– Excessive sulphur in base metal.

Remedies

a Preventive actions

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

Cracks

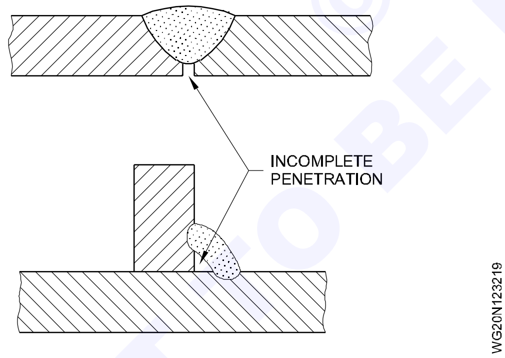
b Corrective actions

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

Incomplete penetration

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

Fig 9



Causes

– Edge preparation too narrow - less bevel angle.
– Welding speed too much.
– Key-hole not maintained during welding the root run of a grooved joint.
– Less current.
– Use of larger dia. electrode.
– Inadequate cleaning or gouging before depositing sealing run.
– Wrong angle of electrode.
– Insufficient root gap.

Remedies

a Preventive actions

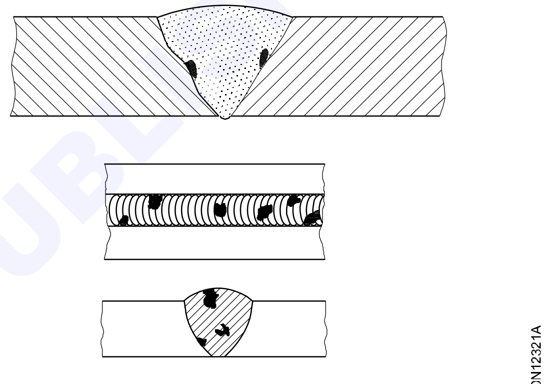
- Correct edge preparation is required.
- Ensure correct angle of bevel and required root gap.
- Use correct size of electrode.
- Correct welding speed is required.
- Maintain a keyhole throughout the root run.
- Correct current setting is required.

b Corrective actions

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

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

Fig 10



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.

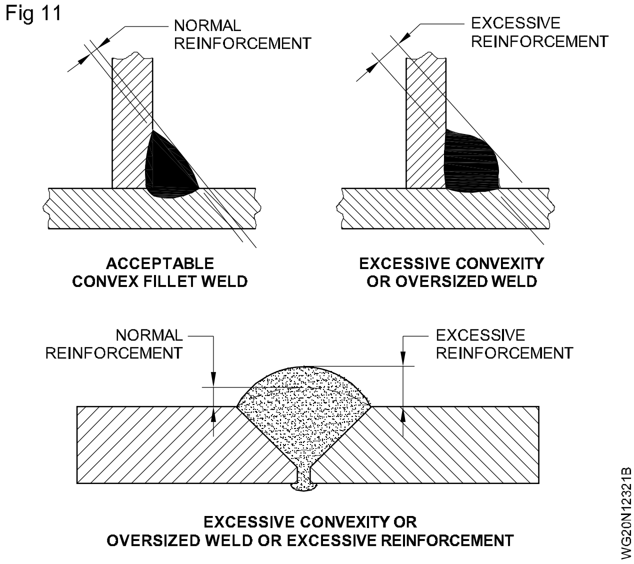
b Corrective actions

- 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.

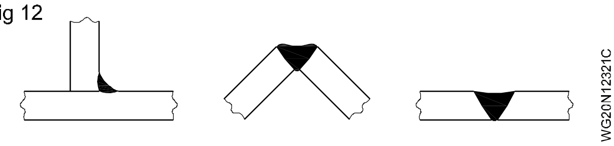
Fig 11



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)

Fig 12



Causes

- Incorrect bead profile due to improper weaving of electrode.
- Use of small dia. electrode.
- Excessive speed of welding.
- Wrong welding sequence when using stringer beads to fill the groove.
- Sagging of weld metal is not controlled in horizontal position.
- Electrode movement is not uniform.
- Improper electrode angle between the plate surfaces.

Remedies

- Lack of fusion.
- Mismatch.
- Uneven/irregular bead appearance.
- Excessive root penetration.

Specification of pipes, various types of pipe joints, pipe welding positions, and procedure

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

Standard Specification for Carbon Steel Pipe ASTM Code, ASTM Standards List, Gi Pipe ASTM

Code, ASTM Stainless Steel Pipe Standards Specification

A1010/A1010M	Standard Specification for Higher-Strength Martensitic Stainless Steel Plate, Sheet, and Strip
A1011/A1011M	Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength LowAlloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
A105/A105M	Standard Specification for Carbon Steel Forgings for Piping Applications
A1053/A1053M	Standard Specification for Welded Ferritic-Martensitic Stainless Steel Pipe
A106/A106M	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
A126	Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings
A134	Standard Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)
A135/A135M	Standard Specification for Electric-Resistance-Welded Steel Pipe
A139/A139M	Standard Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over
A167	Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
A179/A179M	Standard Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes
A181/A181M	Standard Specification for Carbon Steel Forgings, for General-Purpose Piping
A182/A182M	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A193/A193M	Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

Welded pipe joints

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

Advantages of welded pipe

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

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

Method of pipes welding

The following are the methods of pipe welding by arc.

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

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

Types of pipe joints

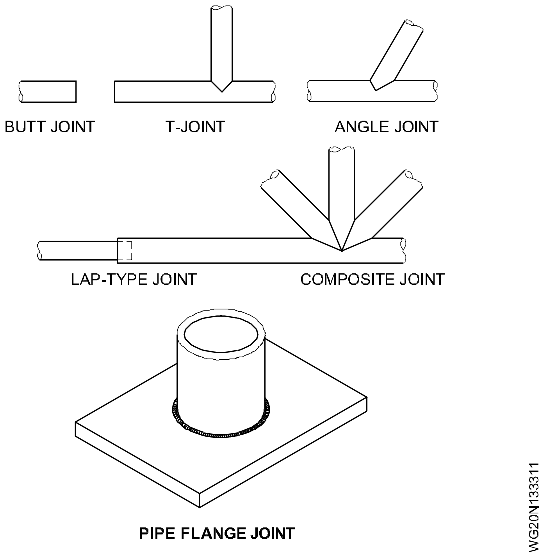
1 Butt joint

2 'T' joint

3 Lap joint (Fig 1)

4 Angle joint

Fig 1

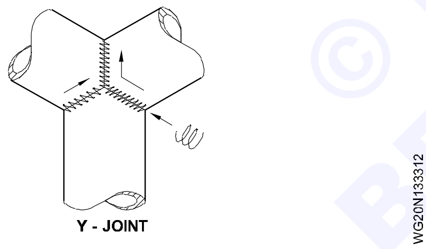


5 composite joint

6 Pipe flange joint

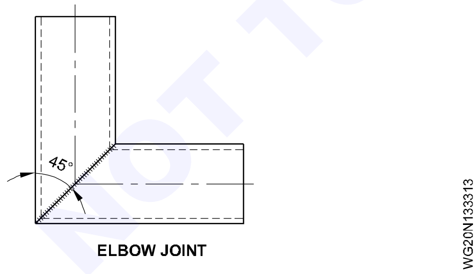
7 Y joint (Fig 2)

Fig 2



8 Elbow joint (Fig 3)

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

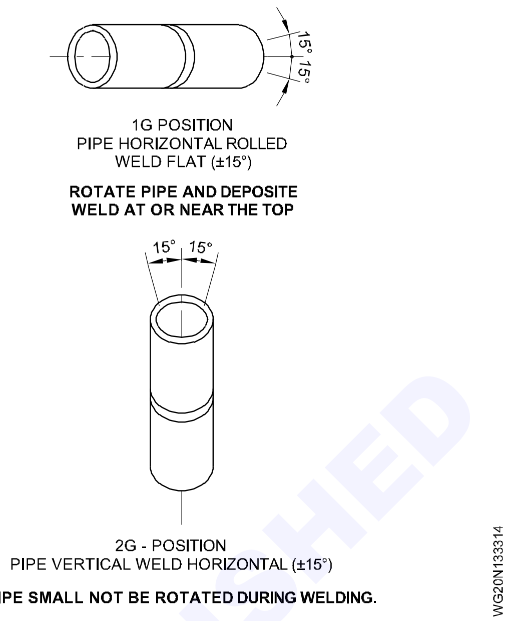
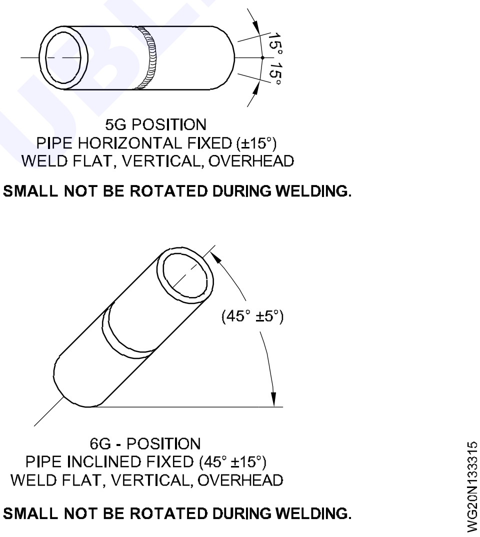


Fig 5



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

2 G - Pipe weld in horizontal position i.e. pipe axis is perpendicular to the ground.

5 G - Pipe weld in flat (fixed) position i.e. pipe axis is parallel to the ground.

6 G - Pipe weld in including (fixed) position i.e. pipe axis is including to both horizontal and vertical planes.

During the welding of butt joints the pipe may be

1 rolled or rotated (1G position)

2 fixed (2G, 5G and 6G position).

Welding of pipe butt joints by arc can be done in 1G position by a Continuous rotation method and

b Segmental method.

1a Pipe welding by arc (in 1G position) by continuous rotation method: Satisfactory welding of butt joints in pipes depends upon the correct preparation of pipe ends and careful assembly of the joint to be welded. Ensure that the bores and root faces are in correct alignment and that the gap is correct.

Clean the edges. Prepare an angle of bevel 35° by gas cutting and filing. A root face 1.5 to 2.5 mm is to be provided.

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

Select a 2.5 mm rutile electrode for 1st run and a 3.15 mm rutile electrode for 2nd run.

Set a current of 70-80A for 1st run and 100-110 for the 2nd run.

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

Fig 6

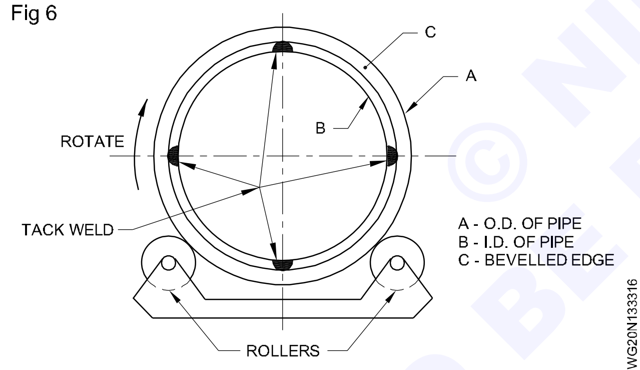
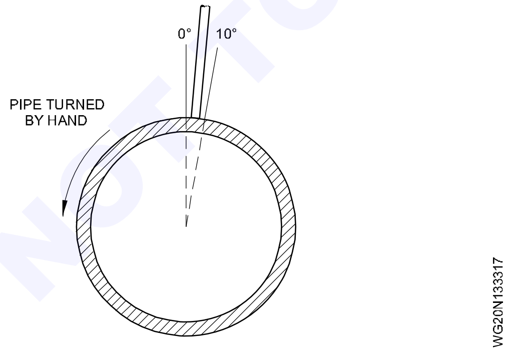


Fig 7



– Direct the electrode centrally at the root of the joint and in line with the radius of the pipe at the point of welding.

– Strike the arc near the top dead center and hold the arc length as short as possible. Continue to weld as the pipe is rotated manually at steady speed.

– Deposit first run by weaving the electrode very slightly from root face to root face.

– Adjust the speed of rotation to obtain full fusion of the root faces without excessive penetration.

– Chip out tack weld as they are approached. Do not weld over tacks otherwise loss of penetration at the tacking points may occur.

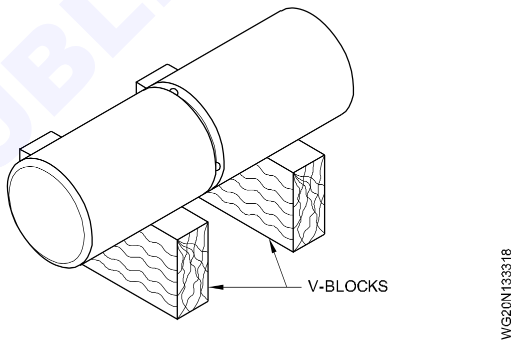
– Complete the weld with the second run. Adjust the speed of rotation to secure fusion to the outer edge of each fusion face. The amount of reinforcement should be even around the edge of the joint.

1b Welding of a pipe butt (IG position i.e. by rotation) by segmental welding.

– The edges of the pipe are beveled to 35 to 40° angle with a root gap of 2.5 mm.

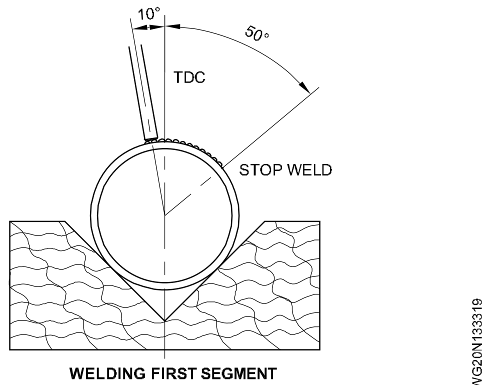
– Tack the pipe as before and support the assembly on two 'V' blocks. (Fig 8)

Fig 8



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

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)

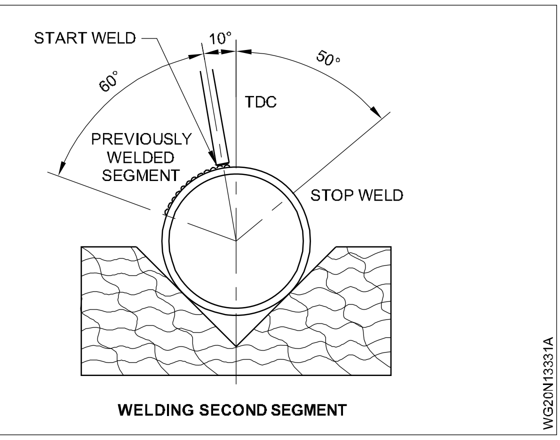
– Continue welding in segments until the root run has been completed.

– 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 10



WELDING SECOND SEGMENT

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.

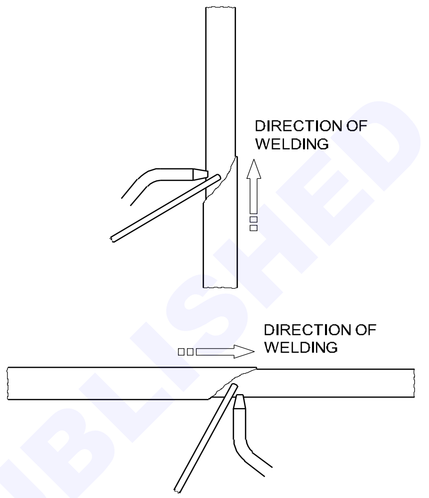
Pipe welding: When welding the circumference of a mild steel pipe, the angles of the rod and the blowpipe are given in relation to the tangent to the pipe at the point of welding.

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.

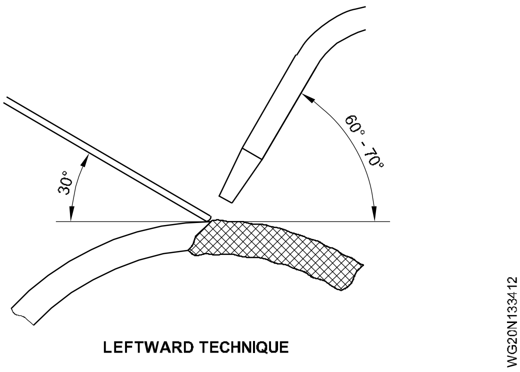
Position	Method
At the top of the pipe, flat position.	Leftward or rightward
At the flank of a set on branch when both pipe axes are in horizontal flat position.	Leftward or rightward
The weld is made along the vertical sides of the pipe.	Leftward or rightward or all-position rightward
The weld at the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

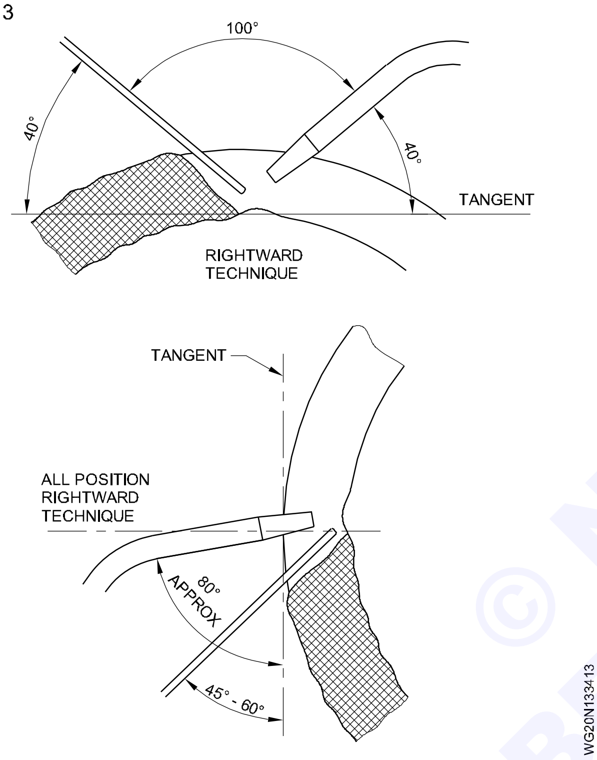
The leftward, rightward or all-position rightward techniques are used as appropriate on sections of 5 mm and above. (Fig 3)

Fig 2



LEFTWARD TECHNIQUE

Fig 3

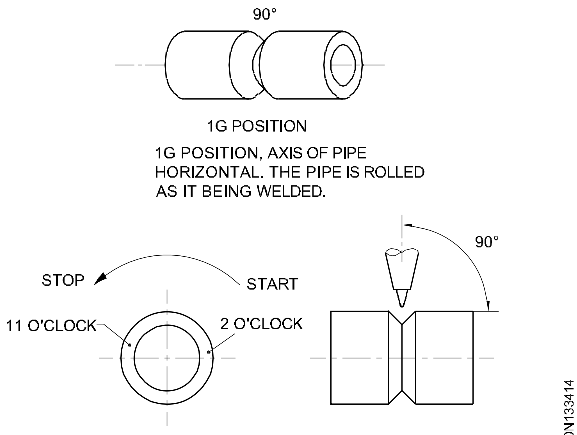


Differences between plate welding and pipe welding

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

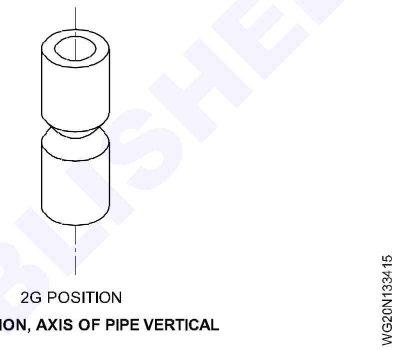
In plate welding, the line of weld is in only one position. In pipe welding, welding can be done in one position when it can be rotated. (Fig 4) Otherwise all-position welding can be done in the pipe when the pipe is in fixed position. (Fig 6) Sometimes the pipe may be in a fixed position and only one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

Fig 4



WELDING PIPE IN THE 1G POSITION

Fig 5



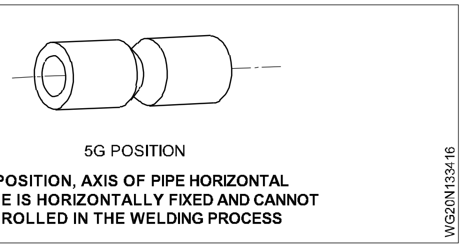
2G POSITION, AXIS OF PIPE VERTICAL

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

Possibility of distortion is higher in plate welding. Possibility of distortion is less in pipe welding.

Tip travel and hand travel will be equal in plate welding. Tip travel will be less and hand travel will be more in pipe welding.

Fig 6



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

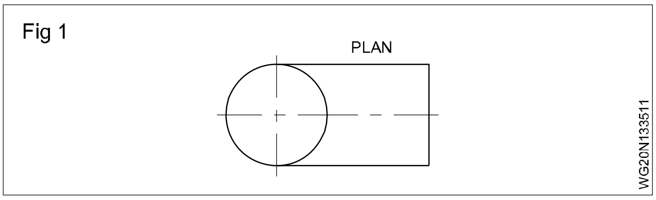
Pipe development for Elbow joint, TEE joint, “Y” joint, Branch joint

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

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

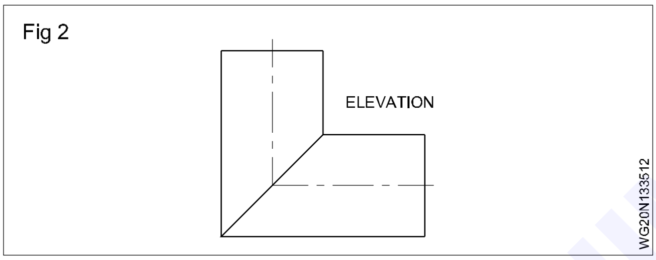
Draw plan as shown in Fig 1.

Fig 1



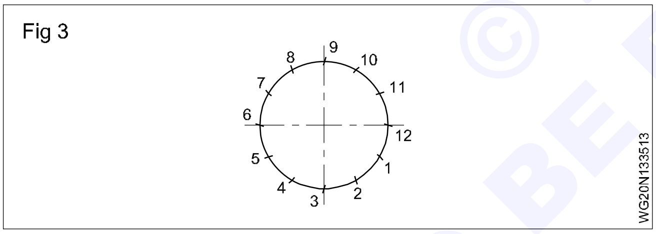
Below this, draw the front elevation as shown in Fig 2.

Fig 2



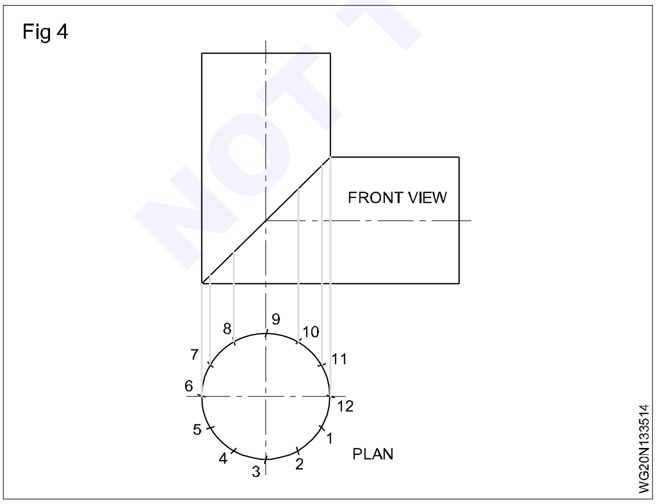
Divide the circle in the plan into twelve equal parts and number the points 0 to 12 as shown in Fig 3.

Fig 3



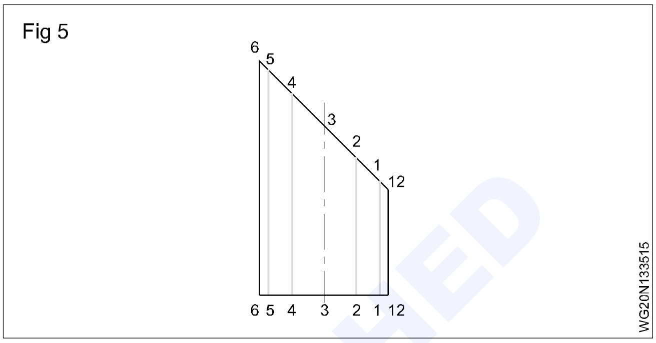
Draw the perpendicular line from these points towards the front view and number 1 to 12 as shown in Fig 4.

Fig 4



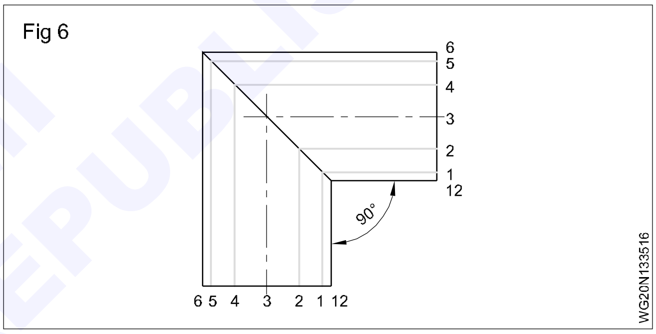
Now you find that the vertical lines are cutting at six different points top and bottom in the elevation line. Number them as shown in Fig 5.

Fig 5



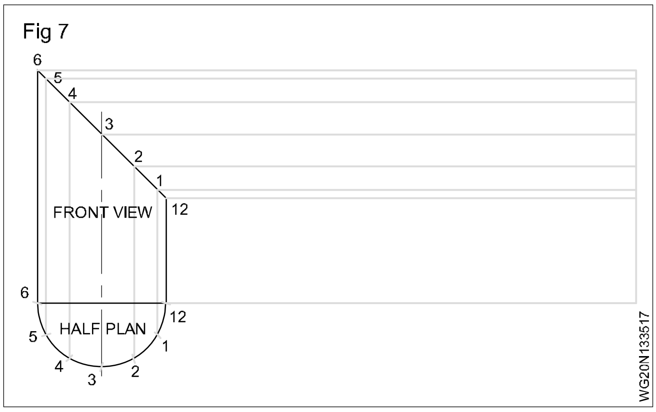
Draw horizontal parallel lines from each point and number them as shown in Fig 6.

Fig 6



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

Fig 7



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

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

Fig 8

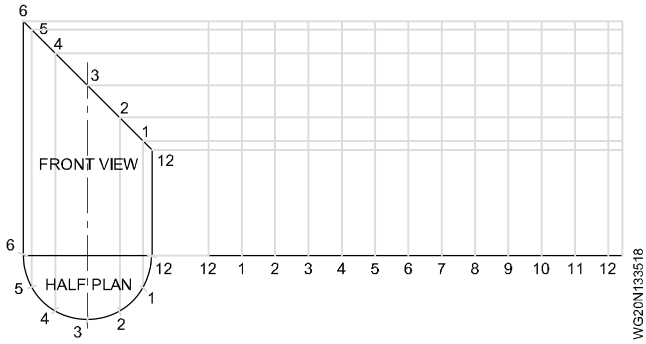
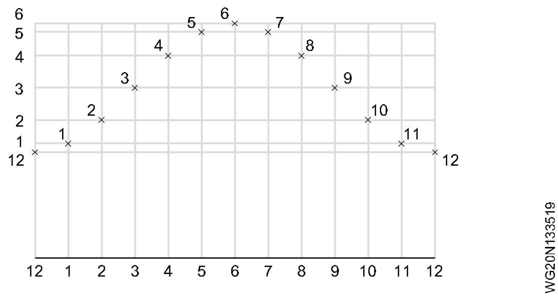
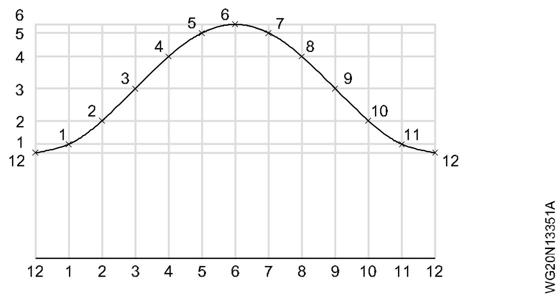


Fig 9



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

Fig 10

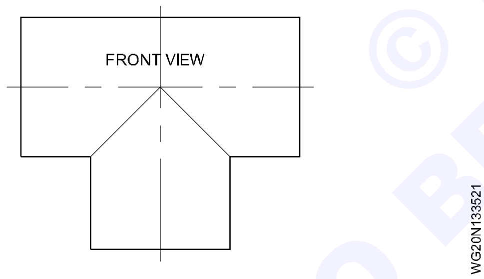


Development of a Pipe “T” joint

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

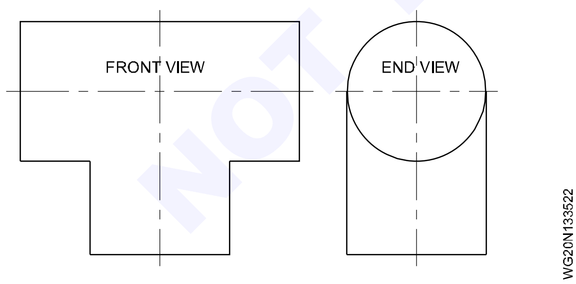
Draw the front view as shown in Fig 1.

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)

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 3

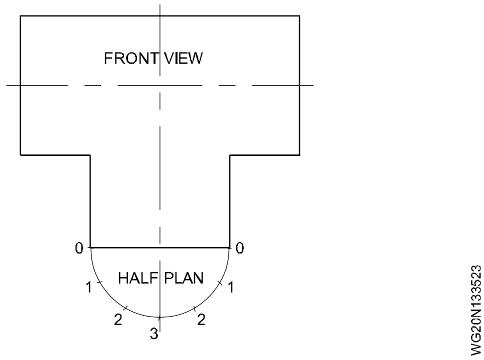
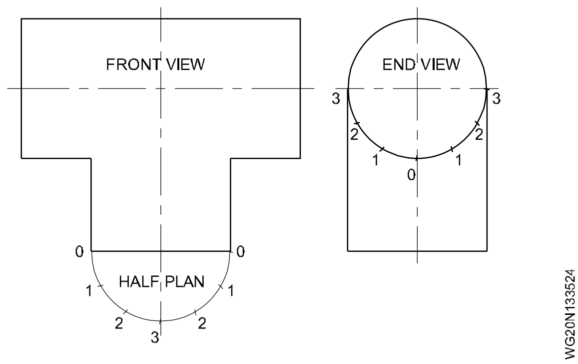


Fig 4



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 5

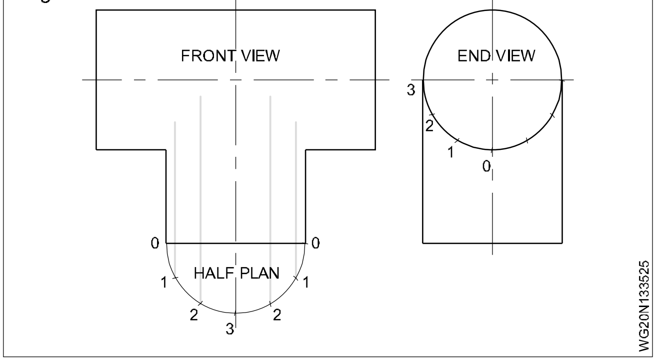
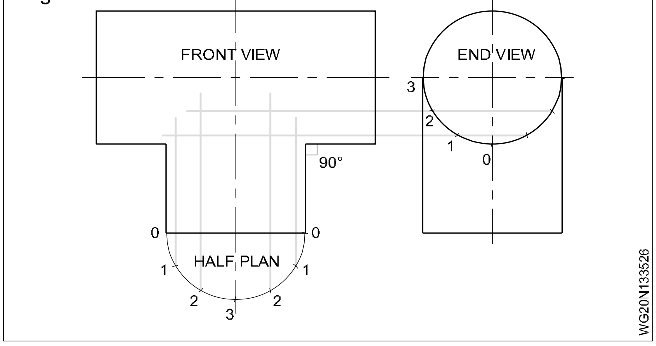


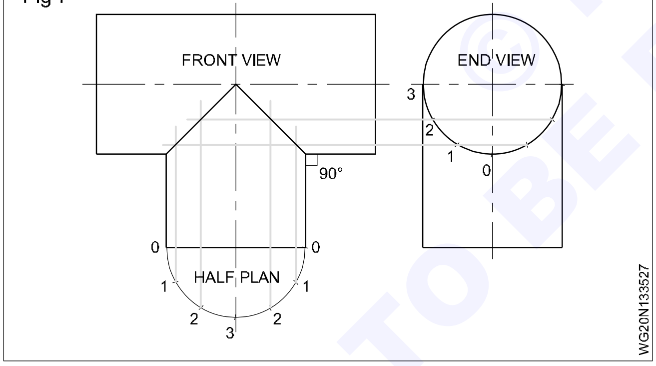
Fig 6



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

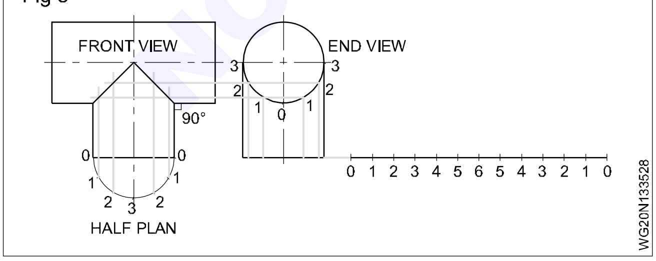
Join these points to get the line of intersection of "T" pipe as shown in Fig 7.

Fig 7



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

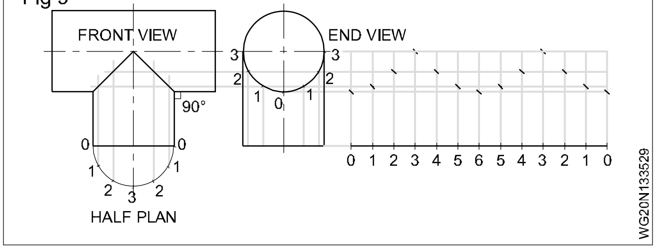
Fig 8



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

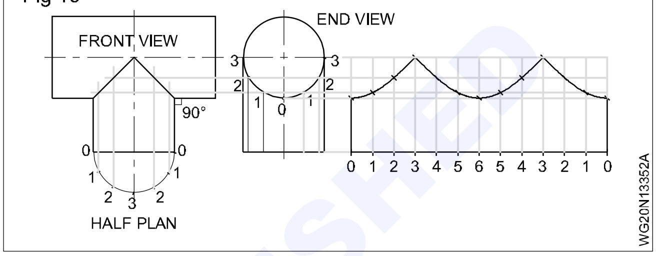
Draw perpendicular lines from these points and draw horizontal lines from the points on the line of intersection of "T". These line meet at their respective points. (Fig 9)

Fig 9



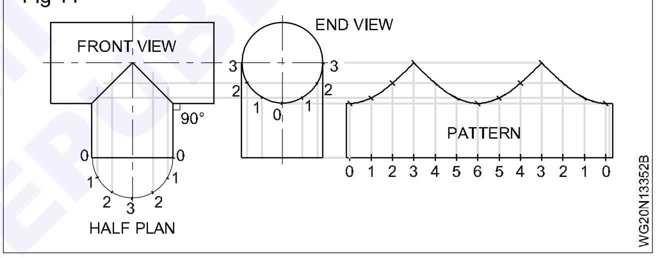
Join these points by free hand curve. (Fig 10)

Fig 10



Provide locked grooved joint allowance as shown in Fig 11.

Fig 11

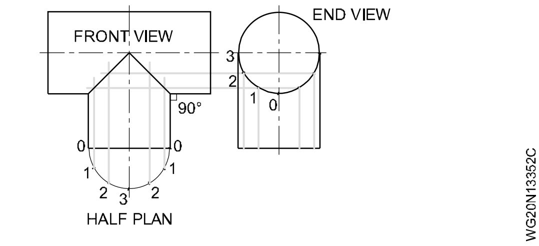


Check the pattern once again and cut. Thus you get the pattern for branch pipe.

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

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

Fig 12



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

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 13

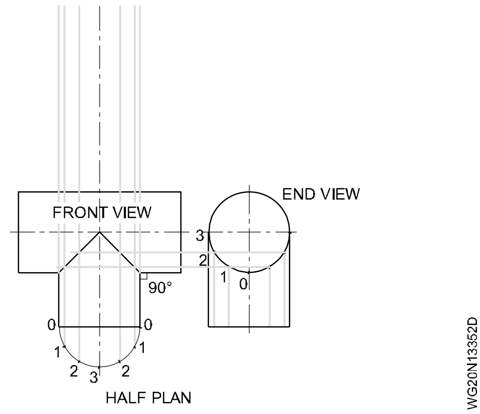


Fig 14

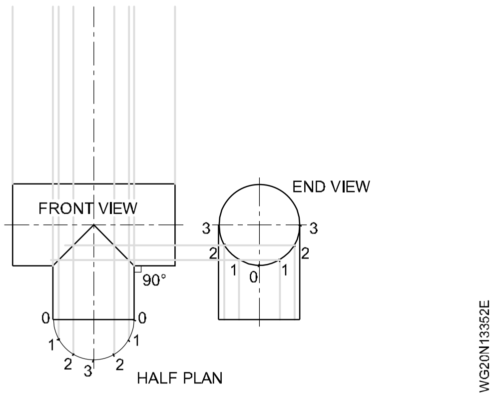
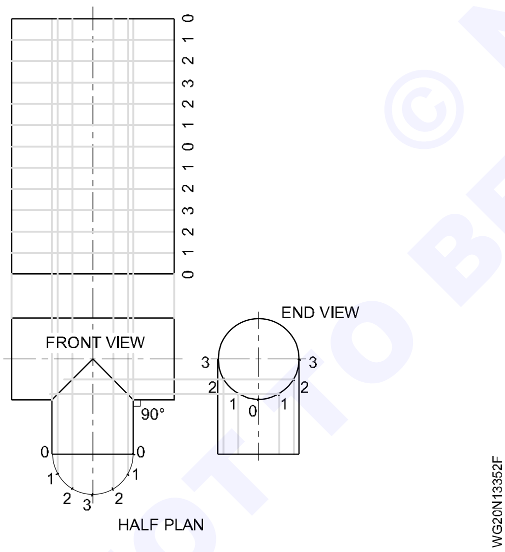
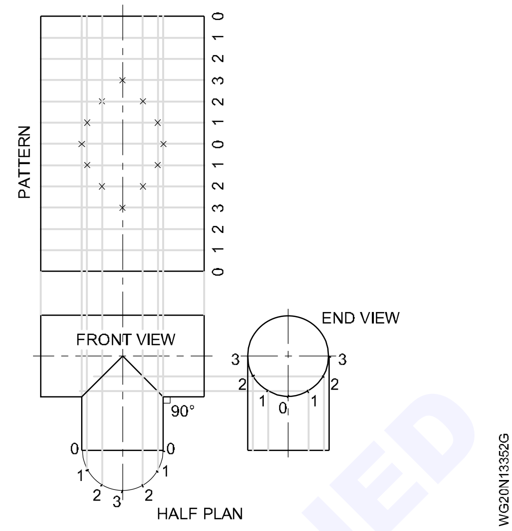


Fig 15



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

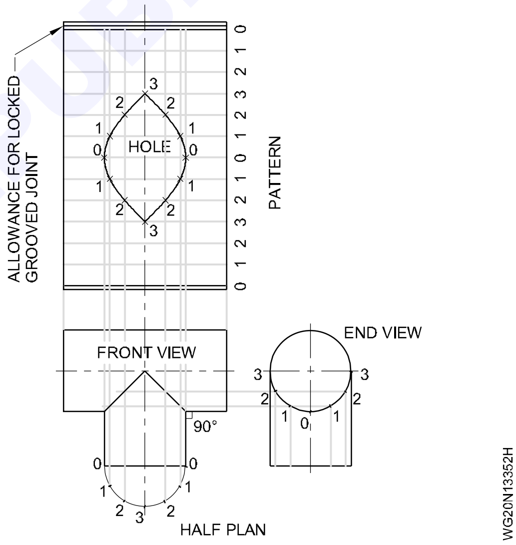
Fig 16



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 17



Pipe development for "Y" joint

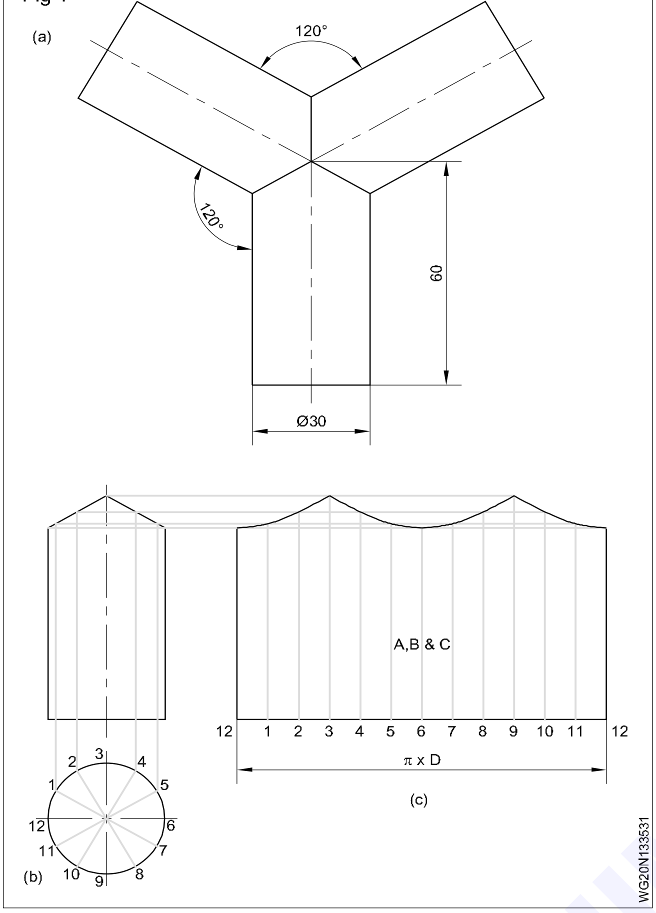
Objectives: At the end of this lesson you shall be able to
- **development of "Y" joint pipes intersecting at 120°.**

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.

Fig 1



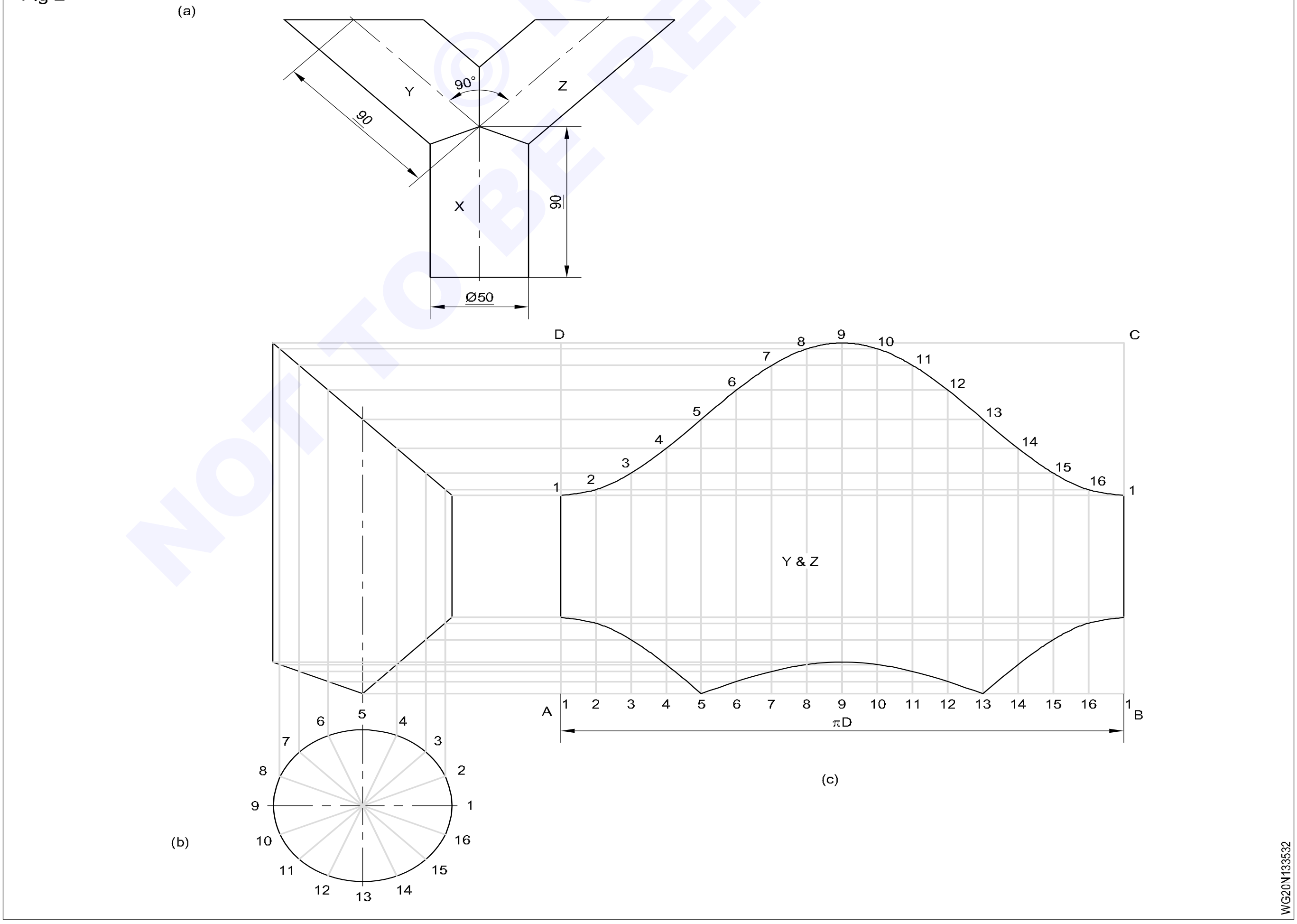
- Draw horizontal projectors from these points on to the development.
- Mark the intersecting points and join with a smooth curve to complete the required development.

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 2



Development of 45° branch pipe

Objectives: At the end of this lesson you shall be able to
- **development of 45° 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.

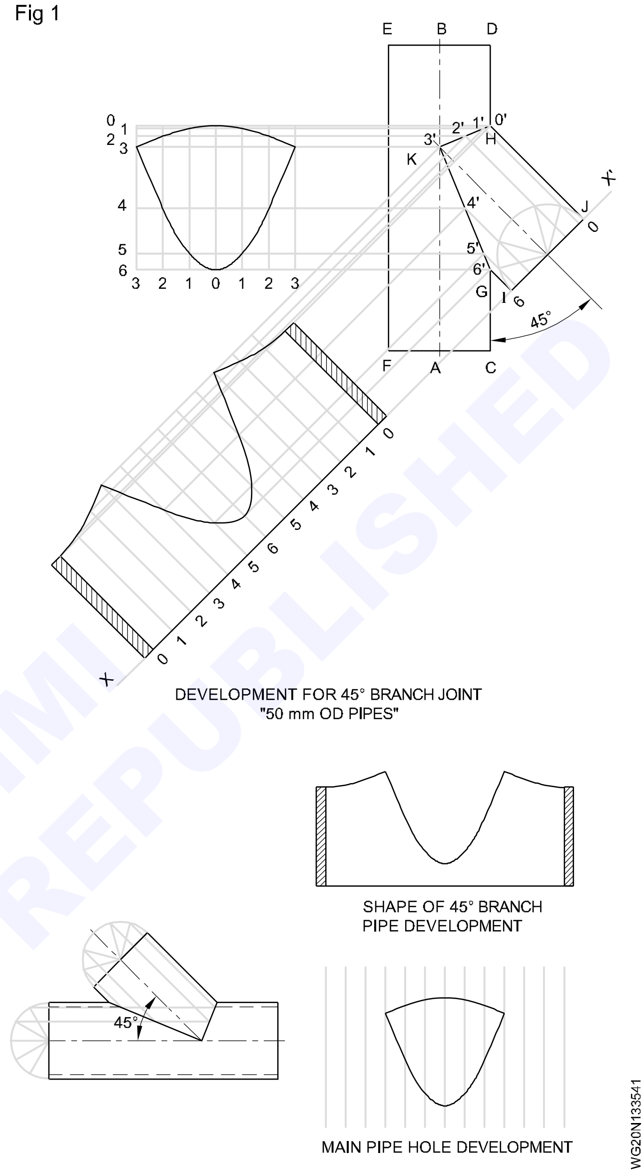
Draw vertical lines from these points 1, 2, 3, 4, 5. Already there will be two vertical lines IG from the points 6 and JH from point 0. These vertical lines will cut the branch pipe lines 'GK' and 'KH' at points 6', 5', 4', 3', 2', 1', & 0'. Note that points 6' and G as points 0' and H are the same points. 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)

Fig 1



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

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

Uses of manifold systems

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.

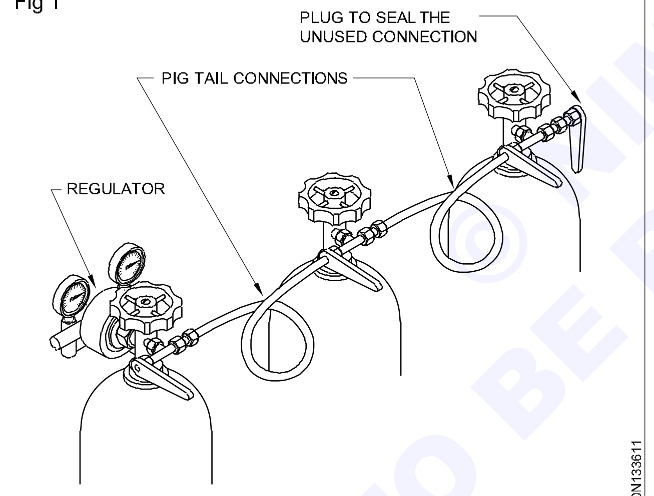
Types

– 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.

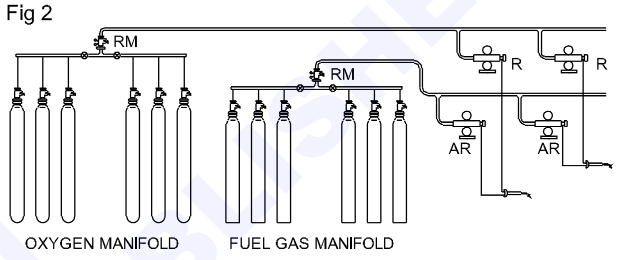
Fig 1



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



R - OXYGEN REGULATOR
AR- ACETYLENE REGULATOR
RM- MANIFOLD REGULATOR
VARIOUS TYPES OF WELDING AND CUTTING INSTALLATIONS

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 rod specification and sizes gas welding flux, types and functions

Objectives: At the end of this lesson you shall be able to
- **state the necessity of filler rods and name the different types of filler rods and their sizes**
- **select filler rods for the jobs to be welded by gas and flux and its functions.**

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.

Different types of filler rods used in gas welding

Definition of filler rod: A filler rod is a metallic wire made out of ferrous or non-ferrous metal to deposit the required metal in a joint or on the base metal.

Types of filler rods: The following types of filler rods are classified in gas welding.

– Ferrous filler rod
– Non-Ferrous filler rod
– Alloy type filler rod for ferrous metals
– Alloy type filler rod for non-ferrous metals

A ferrous type filler rod has a major % of iron.

The ferrous type filler rod contains iron, carbon, silicon, sulphur and phosphorous.

The alloy type filler contains iron, carbon, silicon and any one or many of the following elements such as manganese, nickel, chromium, molybdenum, etc.

The non-ferrous type filler rod which contains elements of non-ferrous metals. The composition of non-ferrous type filler rods is similar to any non-ferrous metal such as copper, aluminium. A non-ferrous alloy type filler rod contains metals like copper, aluminium, tin, etc. along with zinc, lead, nickel, manganese, silicon, etc.

Selection of the correct filler rod for a particular job is a very important step for successful welding. Cutting out a strip from the material to be welded is not always possible and even when it is possible, such a strip cannot replace a recommended welding filler materials. Composition of a filler metal is chosen with special consideration to the metallurgical requirement of a weldment. A wrong choice due to either ignorance or a false consideration of economy may lead to costly failures. IS: 1278-1972* specifies requirements that should be met by filler rods for gas welding. There is another specification IS: 2927-1975* which covers brazing alloys. It is strongly recommended that filler material confirming to these specifications is used. In certain rare cases, it may be necessary to use filler rods of composition not covered by these specifications; in such cases filler rods with well established performances should be used.

To select a filler rod in respect to the metal to be welded, the filler rod must have the same composition with respect to the base metal to be welded.

Factors to be considered for selection of filler rod are:

a the type and composition of base metal

b the base metal thickness

c the type of edge preparation

d the weld is deposited as root run, intermediate runs or final covering run

e welding position

f whether there is any corrosion effect or loss of material from the base metal due to welding.

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

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-resis-tant (niobium bearing)	These rods are intended for use in the welding of corrosion-resisting steels such as those containing 18 percent chromium and 8 percent nickel. (Full fusion technique with neutral flame.)	Necessary
High silicon cast iron-Type S-C11	Intended for use in the welding of cast iron where an easily machinable deposit is required. (Full fusion technique with neutral flame.)	Flux necessary.
Copper filler rod - Type S-C1	For welding of de-oxidized copper. (Full fusion technique with neutral flame.)	Flux necessary.
Brass filler rod - Type S-C6	For use in the braze welding of copper and mild steel and for the fusion welding of material of the same or closely similar composition. (Oxidising flame.)	Flux necessary.
Manganese bronze (high tensile brass) - Type S-C8	For use in braze welding of copper, cast iron and malleable iron and for the fusion welding of materials of the same or closely similar composition. (Oxidising flame.)	Flux necessary.
Medium nickel bronze - Type S-C9	For use in the braze welding of mild steel, cast iron and malleable iron. (Oxidising flame.)	Flux required.
Aluminium (Pure) - Type S-C13	For use in the welding of aluminium grade 1B. (Full fusion technique with neutral flame.)	Flux necessary.
Aluminium alloy-5 percent silicon - Type S-NG21	For welding of aluminium casting alloys, except those containing magnesium, or zinc as the main addition. They may also be used to weld wrought aluminium-magnesium-silicon alloys. (Full fusion technique with neutral flame.)	Flux necessary.
Aluminium alloy-10-13 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 cast iron flux may be used, if necessary
Stellite: Grade 6	Hard facing of components subjected to shock and abrasion, (Surface fusion technique with excess acetylene flame.)	-do-
Stellite: Grade 12	Hard facing of components subjected to abrasion and moderate shock. (Surface fusion technique with excess acetylene flame.)	-do-
Copper-phosphorus brazing alloy - Type BA-CuP2	Brazing copper, brass and bronze components. Brazing with slightly oxidising flame on copper; neutral flame on copper alloys.	Necessary
Copper-phosphorus brazing alloy - Type BA-CuP5	For making ductile joint in copper without flux. Also widely used on copper based alloys of the brass and bronze type in conjunction with a suitable silver brazing flux. (Flame slightly oxidising on copper; neutral on copper alloys.)	None for copper. A flux is necessary for brazing copper alloys.
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 and Function

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.

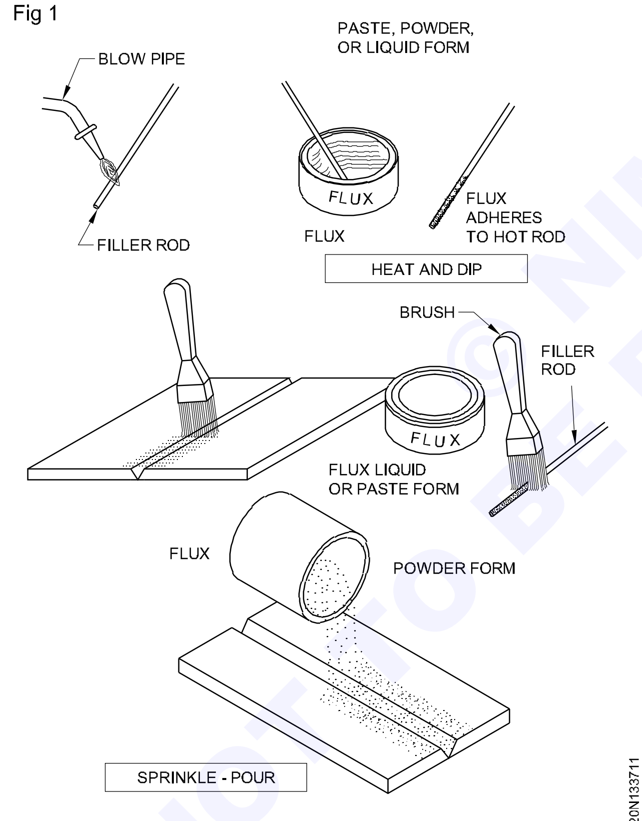
The function of flux in gas welding: To dissolve oxides and to prevent impurities and other inclusion that could affect the weld quality.

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.

Fig 1

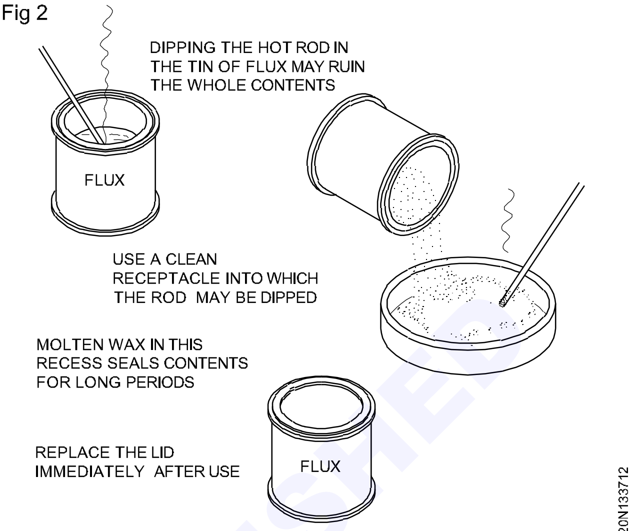


METHOD OF APPLICATION

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

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

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.

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: principles, types of flux & uses

Objectives: At the end of this lesson you shall be able to
- **principle of brazing and solering types of flux and uses**
- **gas welding defects causes and remedies.**

Brazing flux

1 **Borax based flux :** Normal welding process for those wish, lower melting point

2 **Aluminium & megnegsium :** Used handling oxidation problem for brazing aluminium component

3 **Silver flux:** Used for brazing components made of cobalt and nikel.

4 **Alkaline flux:** Used for component require high temperature

Principle (Brazing): Is an agent use for cleaning following, purifying. It removes oxides and other contamants.

Principle (Soldering): Solder flux is a kind of chemicals used in PCB assembly and hand soldering. It helps to clean and remove oxides and other impurities.

Types: Rosin use for surface that are clean flux, water soluble flux good soldering result due to good flux activity.

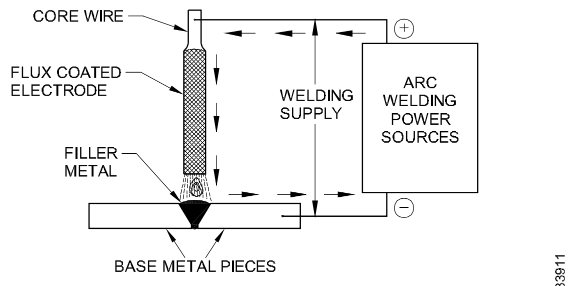
No-clean flux: No need any cleaning after soldering process.

Types, function of flux coating factor size 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

Different types of electrodes used are given in the Electrode chart.

Method of flux coating:

– Dipping

– Extrusion

Dipping method: The core wire is dipped in a container carrying flux paste. The coating obtained on the core wire is not uniform resulting in non-uniform melting; hence this method is not popular.

Extrusion method: A straightened wire is fed into an extrusion press where the coating is applied under pressure. The coating thus obtained on the core wire is uniform and concentric, resulting in uniform melting of the electrode. (Fig 2) This method is used by all the electrode manufacturers.

Coating factor (Fig 3)**:** The ratio of the coating diameter to the core wire diameter is called the coating factor.

$$= \frac{\text{Coating diameter}}{\text{Coating wire diameter}}$$

It is 1.25 to 1.3 for **light coated**,

1.4 to 1.5 for **medium coated**,

1.6 to 2.2 for **heavy coated**, and above 2.2 for super heavy coated electrodes.

Fig 2

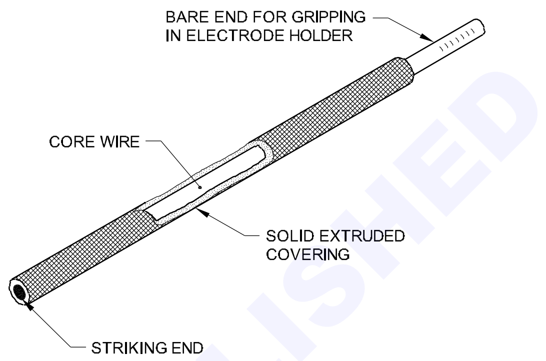
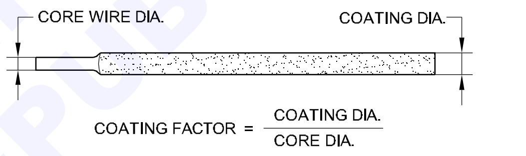


Fig 3



COATING FACTOR

Types of flux coating

– Cellulosic (Pipe welding electrode e.g. E6010)

– Rutile (General purpose electrode e.g. E6013)

– Iron powder (e.g. E7018)

– Basic coated (Low hydrogen electrode e.g. E7018)

Composition/Characteristics Flux

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 of three general types. They are:

Carbon electrodes

Bare electrodes

Flux coated electrodes

Effects of moisture pick up storage and baking of electrodes

Objectives: At the end of this lesson you shall be able to
- **state the necessity of baking a coated electrode**
- **store and handle the electrode properly for better weld quality.**
- **explain about effect of moisture pic up 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**
- **produces porous weld.**

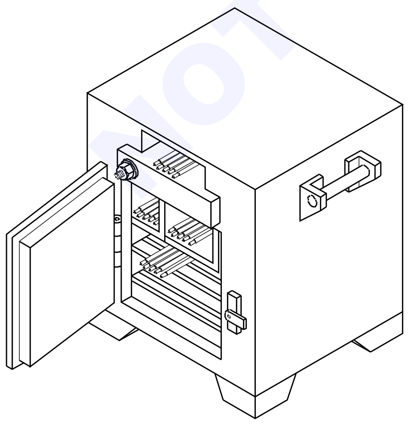
Storage of electrodes: The efficiency of an electrode is affected if the covering becomes damp.

- Keep electrodes in unopened packets in a dry store.
- Place packages on a duckboard or pallet, not directly on the floor.
- Store so that air can circulate around and through the stack.
- Do not allow packages to be in contact with walls or other wet surfaces.
- The temperature of the store should be about 5°C higher than the outside shade temperature to prevent condensation of moisture.
- Free air circulation in the store is as important as heating. Avoid wide fluctuations in the store temperature.
- Where electrodes cannot be stored in ideal conditions place a moisture-absorbent material (e.g. silica-gel) inside each storage container.

Store and keep the electrodes (air tight) in a dry place.

Bake the moisture affected/prone electrodes in an electrode drying oven at 110-150°C for one hour before using. (Fig 1).

Fig 1



ELECTRODE DRYING OVAN

Electrode coating can pick up moisture if exposed to atmosphere.

Baking electrodes: Water in electrode covering is a potential source of hydrogen in the deposited metal and thus may cause:

- Porosity in the weld
- Cracking in the weld.

Indications of electrodes affected by moisture are:

- White layer on covering.
- Swelling of covering during welding.
- Disintegration of covering during welding.
- Excessive spatter
- Excessive rusting of the core wire.

Electrodes affected by moisture may be baked before use by putting them in a controlled drying oven for approximately one hour at a temperature around 110 - 150°C. This should not be done without reference to the conditions laid down by the manufacturer. It is important that hydrogen controlled electrodes are stored in dry, heated conditions at all times.

Warning: Special drying procedures apply to hydrogen controlled electrodes. Follow the manufacturer's instructions.

Remember a moisture-affected electrode:

- has rusty stub end
- has white powder appearance in coating
- produces porous weld.

Always pick up the right electrode that will provide:

- **good arc stability**
- **smooth weld bead**
- **fast deposition**
- **minimum spatters**
- **maximum weld strength**
- **easy slag removal.**

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

Objective: At the end of this lesson you shall be able to
- **explain the effects of weldable quality on ferrous and non-ferrous metals.**

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.

Importance of preheating, post-heating and maintenance of inter-pass temperature

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

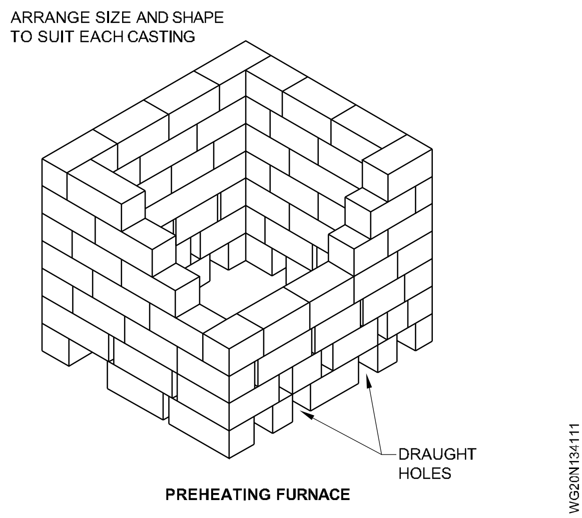
Preheating: Heating the job before welding operation is known as 'preheating'. The purpose of preheating of the cast iron job is to reduce cracking due to distortion. The rate of cooling, and gas consumption etc. are also reduced.

Small casting jobs may be preheated by the application of a blowpipe flame. But larger jobs should be preheated in a 'gas-furnace' or by means of a temporary charcoal furnace.

Methods of preheating

Preheating methods depend upon the size of the job and the technique used for welding. Preheating can be done in a temporarily built gas or charcoal furnace (Fig 1) blacksmith's forge and even by the oxy-acetylene flame. Heavy jobs can be preheated from the furnace and small jobs by a flame from a blowpipe or from the forge.

Fig 1



PREHEATING FURNACE

Types of preheating

The type of preheating depends on the size and nature of the job. There are three types of preheating.

- Full preheating
- Local preheating
- Indirect preheating

Full preheating: The process of heating the entire job before commencing the welding operation is known as full preheating. This is usually done in a furnace for heavy jobs. In this type of preheating the heat of the job will be retained during welding, and also it will cool down at a uniform rate.

Local preheating: In this type, the preheating is done only at the portion to be welded. This is usually done by playing the blowpipe flame just before starting the welding. (Fig 2) In case of welding a cracked cast iron wheel, preheat the area opposite to the area crack. (Fig 3)

Fig 2

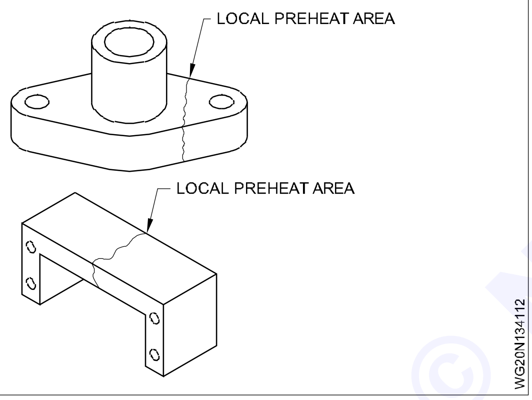
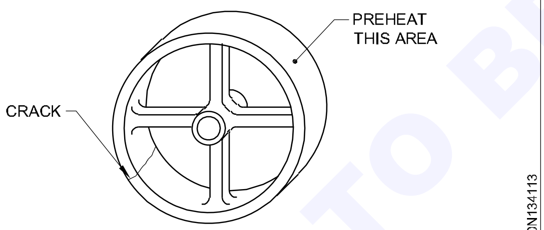


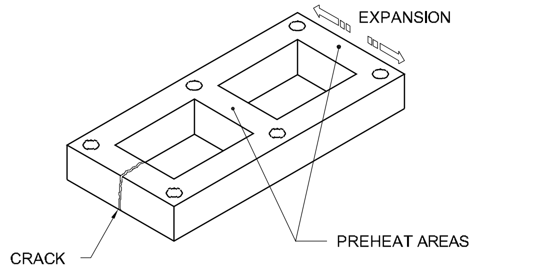
Fig 3



TECHNIQUE OF LOCAL PRE-HEATING

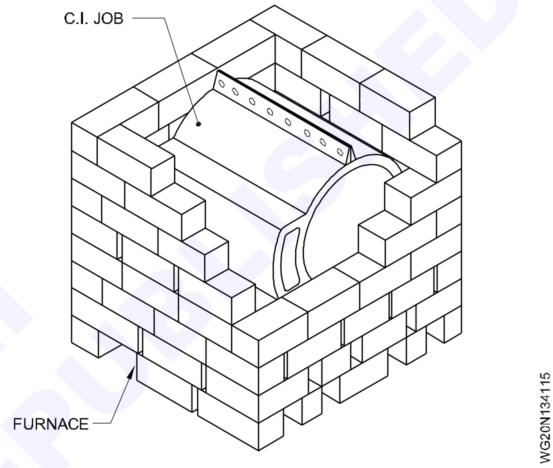
Indirect preheating: In this type, the preheating is being done on the area which may be affected by the uneven expansion and contracting due to the welding heat but not on the portion to be welded. This also can be done by the application of a blowpipe flame before commencing the weld. (Fig 4)

Fig 4



Purpose of post heating: If it is a bigger job, the welded job should be post heated in the same preheating furnace and allowed to cool slowly in the furnace itself so as to avoid any crack or any other distortion due to rapid cooling. (Fig 5)

Fig 5



The slag and oxide on the surface of the finished weld can be removed by scraping and brushing with a wire-brush after cooling. The weld should not be hammered as cast iron is brittle.

Maintenance of inter-pass temperature: The temperature of the preheated job can be checked by wax crayons. Marks are made on the cold job pieces by these crayons before preheating and after the job pieces reach the preheating temperature the marks will disappear.

This indicates that the job has been heated to the required preheating temperature. Different wax crayons are available for checking different temperatures. The temperature which is checked by the crayon will be marked on it.

Welding of low carbon steel, medium and high carbon steel

Objectives: At the end of this lesson you shall be able to
- **state the composition of carbon percentage in low carbon steel and medium carbon steel**
- **state the type of flame needed for welding low carbon steel**
- **describe the method of welding low carbon steel**
- **explain the procedure for the welding of medium carbon steel.**

A plain carbon steel is one in which carbon is the only alloying element. The amount of carbon in the steel controls its hardness, strength and ductility. The higher the carbon the lesser the ductility of the steel.

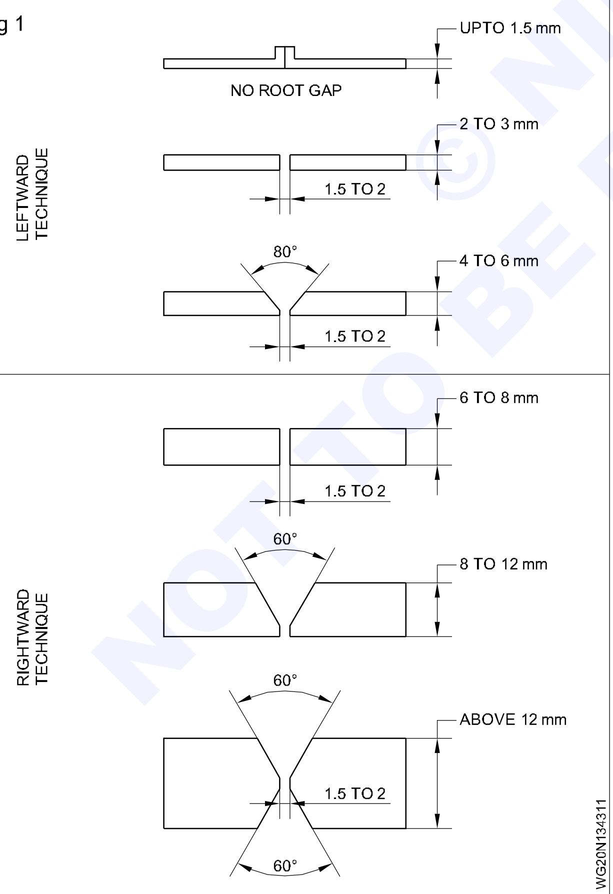
Carbon steels are classified according to the percentage of carbon they contain. They are referred to as low, medium and high carbon steels.

Low carbon steels: Steels with a range of 0.05 to 0.30 per cent are called low carbon steel or mild steel. Steels in this class are tough, ductile and easily machinable and quite easy to weld.

Welding technique: Up to 6 mm, leftward technique is a suitable one. Above 6 mm rightward technique is preferable.

Preparation: (Refer Fig 1 given below)

Fig 1



Type of flame: Neutral flame to be used.

Application of flux: No flux is required

After treatment: Most of them do not respond to any heat treatment process. Therefore except cleaning no post-heat treatment is required.

Medium carbon steel: These steel have a carbon range from 0.30 to 0.6 percent. They are strong and hard but cannot be welded as easily as low carbon steels due to the higher carbon content. They can be heat treated. It needs greater care to prevent formation of cracks around the weld area, or gas pockets in the bead, all of which weaken the weld.

Welding procedure: Most medium carbon steels can be welded in the same way as mild steel successfully without too much difficulty but the metal should be preheated slightly to 160°C to 320°C (to dull red hot). After completion of welding, the metal requires post-heating to the same preheating temperature, and allowed to cool slowly.

After cooling, the weld is to be cleaned and inspected for surface defects and alignment.

Plate edge preparation: Fig 1 shows the plate edge preparation depending on the thickness of the material to be welded.

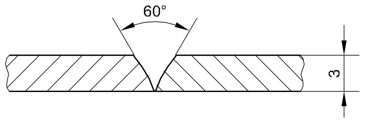
High carbon steel: High carbon steels contain 0.6% to 1.2% carbon. This type of steel is not weldable by gas welding process because it is difficult to avoid cracking of base metal and the weld.

Welding procedure

The type of edge preparation, nozzle size, filler rod size, pitch of tack for different thickness of sheets to be welded are given in Table 1.

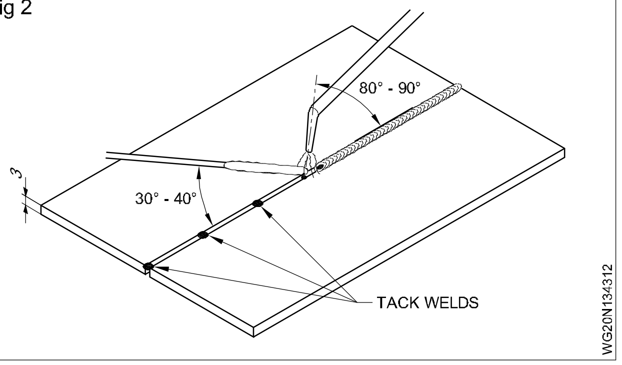
Start welding from the right hand edge of the joint and proceed in the leftward direction.

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

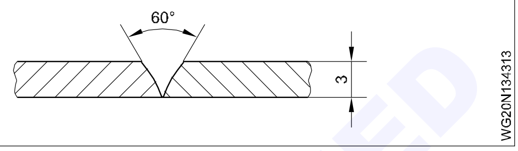
Keep the tip of the inner cone of the flame within 1 to 1.5 mm of the molten puddle, and hold the blowpipe at an angle of 80-90° to the work. (Fig 2)

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.

Alloy effects of alloying elements 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.**

Classification of stainless steel: Stainless steel is an alloy of iron, chromium, and nickel. There are many different classification of stainless steel according to the percentage of its alloying elements. Accordingly there are three main classifications for stainless steel.

One group is FERRITIC, which is non-hardenable and magnetic. The other group is MARTENSITE, which is hardenable by heat treatment and is also magnetic. The third group is 'AUSTENITIC' which is extremely tough and has ductility. This is the most ideal for welding and requires no annealing after welding. But it is mildly subjected to corrosive actions. The other groups ferrite and martensite are non-weldable. Usually the austenitic type of stainless steel is called 18/8 stainless steel which contain 18 percent chromium 8% nickel apart from the iron percentage. To eliminate corrosive action in this type of stainless steel stabilizing elements such as columbium, titanium, molybdenum, zirconium etc. are added in a small percentage. So, this weldable type of stainless steel is called a 'stabilized type' stainless steel. These elements also can be added to filler rods.

Physical properties of stainless steel: The coefficient of expansion of stainless steel of ferrite and martensite are approximately the same as carbon steel whereas the austenitic type of stainless steel has about 50 to 60% greater coefficient of expansion than carbon steel. So, while welding this type of stainless steel, distortion will be more. The heat conductivity is approximately 40 to 50% less than that of carbon steel for austenitic type.

All these types have a brighter colour without having any stain in appearance.

Types of stainless steel filler rods: Specially treated stainless steel filler rods, which contain stabilizing elements such as molybdenum, columbium, zirconium, titanium etc., are available.

The chromium percentage is also sometimes 1 to 1 1/2 percent more than in the base metal, so as to compensate the losses that may occur during the welding operation from the base metal. The melting point of the filler rod also will be 10° to 20°C less than the base metal. Filler rods of different sizes are available in the market.

Flux: A special type powdered flux which contains zinc chloride and potassium dichromate is available. During welding powered flux is to be made into a paste form by adding water and applied on the underside of the joint.

Method of controlling distortion: Since stainless steel has a much higher coefficient of expansion with lower thermal conductivity than mild steel, there are greater possibilities of distortion and warping.

Whenever possible clamps and jigs should be used to keep the pieces in line until they have cooled. And also a thick metal plate of copper should be used as a backing bar during welding so as to reduce distortion in the parent metal. Tacks at frequent intervals (i.e. pitch of tack is 20 - 25 mm) will also reduce distortion.

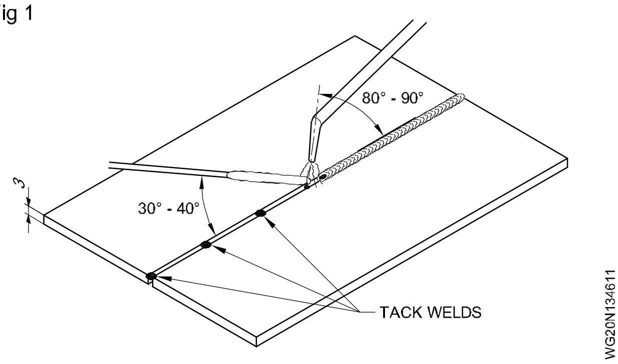
Welding procedure

The type of edge preparation, nozzle size, filler rod size, pitch of tack for different thickness of sheets to be welded are given in Table 1.

Start welding from the right edge of the joint and proceed in the leftward direction.

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

Fig 1



In this way the filler rod which melts at a lower temperature than steel can flow forward and fill up the groove of the metal as it fuses. Fig 2 shows the type of edge preparation used for 3 mm thick metal.

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.**

Table 1

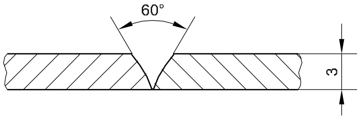
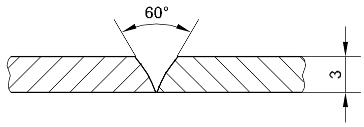
Thickness	Preparation	Assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1 mm	Square edge	No gap	20	1	1.2 mm
1.2 mm	Square edge	No gap	20	2	1.2 mm
1.5 mm	Square edge	No gap	25	2	1.6 mm
3 mm		No gap	40	5	3 mm

Fig 2



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.

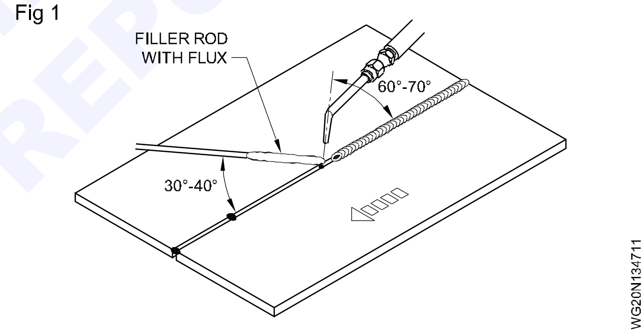
Flux is very important in welding brass. A fresh mixture of borax paste makes a good flux for brass welding.

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.**

Electrolyte copper: This type contains 99.9% pure copper with 0.01 to 0.08% oxygen in the form of cuprous oxide. (Cu_2O). This type of copper is not weldable.

De-oxidized copper: In this type a small quantity of phosphorous, a de-oxidising element is added to the electrolyte copper. This type of copper is weldable.

Characteristics of copper

Reddish in colour.

High thermal and electrical conductivity.

Excellent resistance to corrosion.

Excellent workability in either hot or cold condition and in forming wires, sheets, rods, tubes and castings.

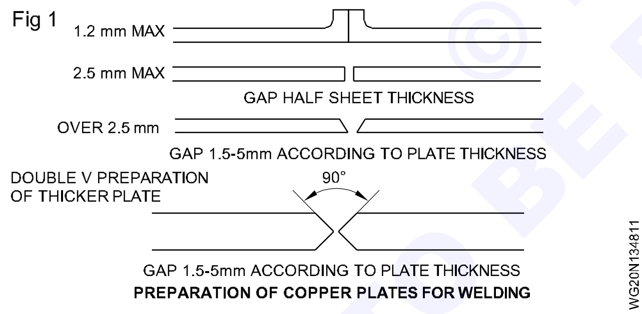
Melting point: 1083°C.

Density: 8.98 g/cm^3

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

Edges preparation (Fig 1)

Fig 1



PREPARATION OF COPPER PLATES FOR WELDING

Up to 1.2 mm - edge or flange point.

Over 1.5 mm up to 2.5 mm - square butt with 50% of sheet thickness as root gap.

2.5 mm to 16 mm - a angle 'V' of 80°-90°.

Over 16 mm - Double 'V' preparation of 90°.

Types of cleaning

Mechanical cleaning is done to remove dirt and any other foreign material. Chemical cleaning is done by applying solutions to remove oil, grease, paint etc.

Filler rod and flux: A completely de-oxidized copper rod (copper-silver alloy filler rod) having a lower melting point than the base metal is used.

Flux: Copper-silver alloy flux is applied on the edges to be joined in paste form.

Nozzle size: Use a nozzle which is one size larger than that used for mild steel.

Flame: Adjust a strictly neutral flame.

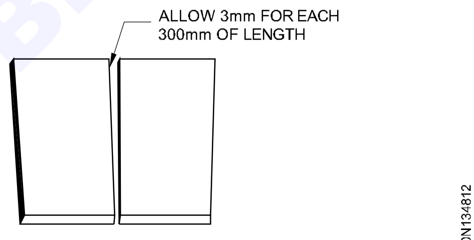
Effects of setting 'carburizing' or 'oxidising' flame

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

Too much acetylene will cause steam to form a porous weld.

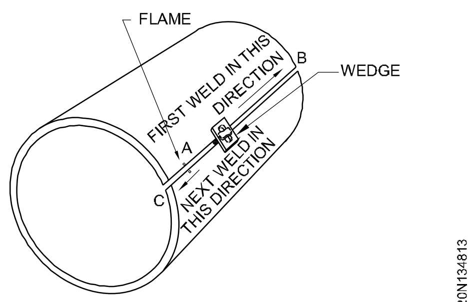
Setting: 1.6 mm root gap between the sheets with a divergence allowance at the rate of 3-4 mm per 300 mm run. (Fig 2) Use wedge for welding long seam in copper. (Fig 3) No tacking is done.

Fig 2



DIVERGENCE ALLOWANCE

Fig 3

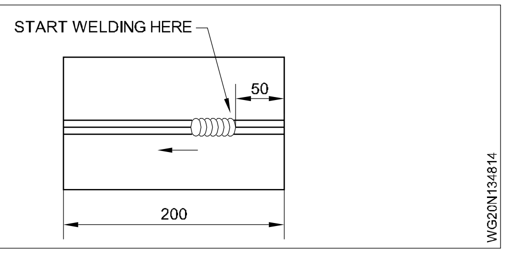


WELDING LONG SEAM IN COPPER

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.

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.

Difficulties in welding of aluminium by gas: Aluminium does not change in colour before it reaches the melting temperature. When the metal begins to melt, it collapses suddenly.

Molten aluminium oxidizes very rapidly form a heavy coating of aluminium oxide on the surface of the seam which has a higher melting point - 1930°C. This oxide must be thoroughly removed by using a good quality flux.

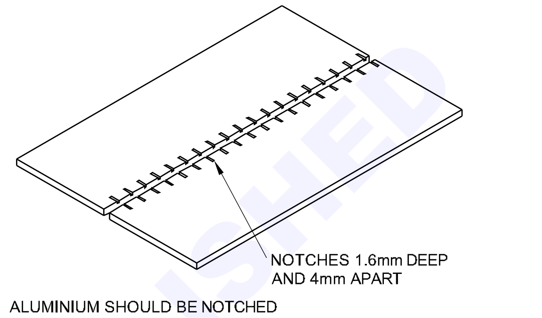
Aluminium, when hot, is very flimsy and weak. Care must be taken to support it adequately during the welding operation.

Joint design: Up to 1.6 mm, the edges should be formed to a 90° flange at a height equal to the thickness of the material.

From 1.6 to 4 mm it can be butt-welded provided the edges are notched with a saw or cold chisel. (Fig 1)

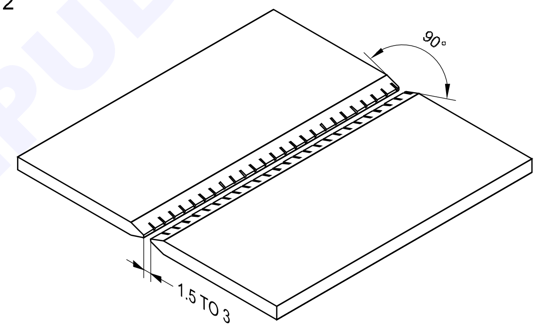
For welding heavy aluminium plates, 4 mm or more in thickness, the edges should be beveled to form 90° included angle with a root gap of 1.6 mm to 3 mm. (Fig 2)

Fig 1



UNBEVELLED BUTT JOINTS ON 1.6mm TO 4mm

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

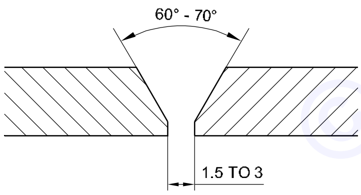
The flux residue, if not properly removed, may result in corrosion.

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:

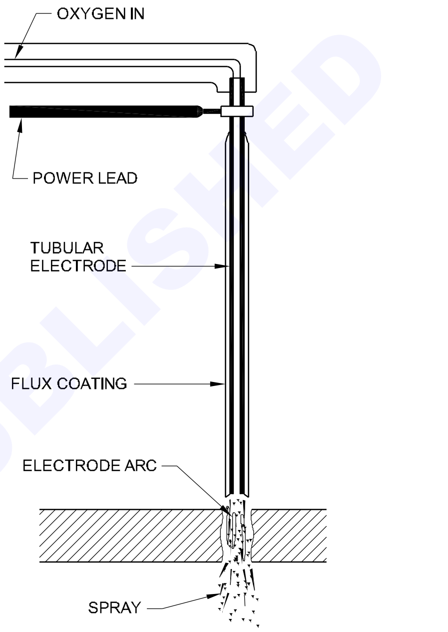
- AC or DC machines
- cables with lugs and earth clamp
- electrode holders
- shield or helmet with suitable glasses (Shade No. 14)
- chipper or chipping hammer
- apron, gloves, safety boots and white goggles.

Electrodes and their properties

Oxy-arc cutting electrode: This electrode is similar to the manual arc welding electrode and is coated with a flux, whose function is to provide an insulated sleeve to stabilise the arc and to make the products of combustion more fluid. The core wire, however, is in the form of a hollow tube through which a stream of oxygen is passed and designed holder, capable of conveying electric current to the electrode as well as oxygen to the arc, is used. (Fig 1)

Metallic arc cutting and gouging electrodes: These electrodes are normally the same as welding electrodes or are sometime specially designed as cutting electrodes (Fig 2) at a current setting which is 20 to 50% higher than that normally used for a given size for welding. Although AC can be used, DC with electrode negative is preferred. Sometimes it helps to make the electrode slightly wet. Water in the coating reduces overheating of the electrode to some extent and disassociates in the arc to render it more penetrating.

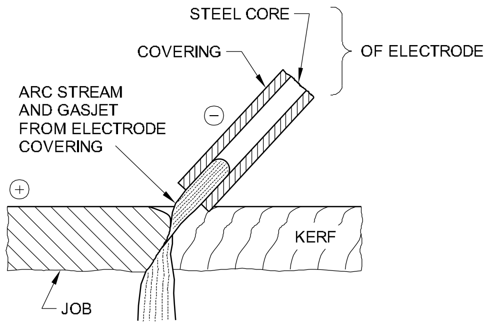
Fig 1



SCHEMATIC OF OXYGEN ARC CUTTING ELECTRODE IN OPERATION

WG20N135111

Fig 2



METAL ARC CUTTING

WG20N135112

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.

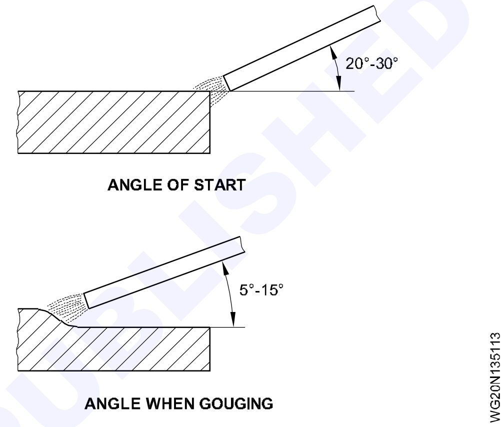
Select suitable sizes of electrodes and set the required current.

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 and its properties-types, welding methods of cast iron

Objectives: At the end of this lesson you shall be able to
- **explain the properties of cast iron and its types**
- **explain the method of edge preparation**
- **describe the cast iron welding technique**
- **select filler rods for the jobs to be welded by gas.**

Cast iron is widely used in the manufacture of machine parts, since it has a good compressive strength and easy to make the castings. There are different problems in the welding of cast iron in comparison to mild steel, even though this is also in the group of ferrous metals.

Types of cast iron

There are four basic types of cast iron available.

- Grey cast iron
- White cast iron
- Malleable cast iron
- Nodular cast iron (or) spheroidal graphite iron

Grey cast iron: Grey cast iron is soft and tougher than the white cast iron which is hard and brittle. The good mechanical properties of grey cast iron are due to the presence of particles of free state carbon or graphite, which separate out during slow cooling. Grey cast iron is of a weldable type. It contains 3 to 4% of carbon.

White cast iron: White cast iron is produced from pig iron by causing the casting to cool very rapidly. The rate of cooling is too rapid and this does not allow the carbon to separate from the iron carbide compound. Consequently the carbon found in white cast iron exists in the combined form. This type of cast iron is very hard and brittle and is not weldable and also not easily machinable.

Malleable cast iron: Malleable cast iron is obtained by annealing white cast iron over a prolonged period of time, and then allowing it to cool slowly. This heat treatment results in greater resistance to impact and shock.

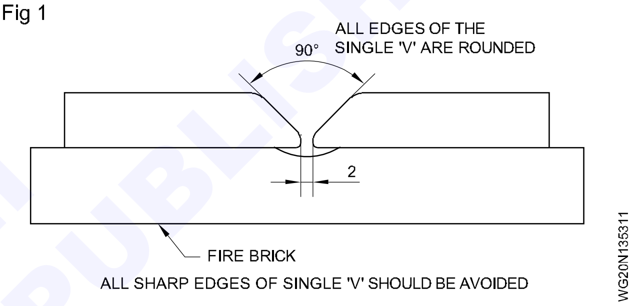
Nodular cast iron: It is also known as spheroidal graphite iron (SG iron). It is obtained by adding magnesium to the molten grey cast iron. The tensile strength and elongation of nodular iron is similar to that of steels which makes this iron a ductile material.

Properties of grey cast iron: Grey cast iron is mostly used in the manufacture of machine components. It has got good mechanical properties due to the free state carbon/graphite. The other constituents are silicon, sulphur, manganese and phosphorous. The grey cast iron has a much higher compressive strength than steel but has low ductility and tensile strength.

Since the carbon is in free graphite form it gives a grey colour to the fractured structure.

Method and types edge preparation: The edges of grey cast iron can be prepared by different methods such as chipping, grinding, machine and filing. The above methods are used according to the condition and type of the job. Usually it is required to weld, a cracked casting or a butt joint. Also the thickness of the casting to be welded or repaired will be 6 mm and above. So usually a single V butt joint is prepared as shown in Fig 1.

Fig 1



Method of cleaning

There are two methods used for cleaning cast iron jobs.

- Mechanical cleaning
- Chemical cleaning

Mechanical cleaning is mostly used to clean the surface of the cast iron jobs.

In this method grinding, filing and wire brushing tec. are done.

The chemical cleaning process is applied to remove oil, grease and any other substances which cannot be removed by mechanical cleaning.

Flame (strict neutral flame): Nozzle no. 10 is used in the blow pipe and a strict neutral flame should be adjusted. Care should be taken that there is not even the slightest trace of oxygen which would cause a weak weld through oxidation.

Filler rod: A 5 mm size round or square high (super) silicon cast iron filler rods containing 2.8 - 3.5 percentage silicon are used for cast iron welding. The weld metal by this rod is easily machinable. (The S-CI 1 as per IS 1278 - 1972).

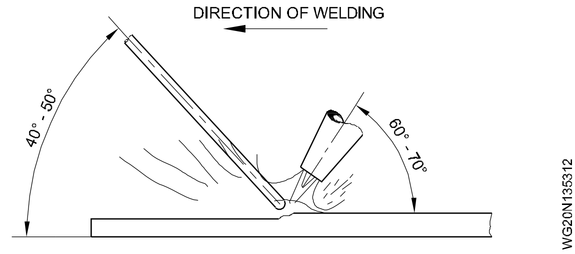
Flux: The flux should be of good quality to dissolve the oxides and prevent oxidation.

Cast iron flux is composed of borax, sodium carbonate, potassium carbonate, sodium nitrate and sodium bicarbonate. This is in a powder form.

Technique of cast iron welding: The welding operations should be performed on the preheated, dull red hot, cast iron piece. The preheating temperature for C.I welding varies from 200°C to 310°C.

The blowpipe angle should be 60° to 70° and the filler rod angle 40° to 50° to the line of weld. (Fig 2)

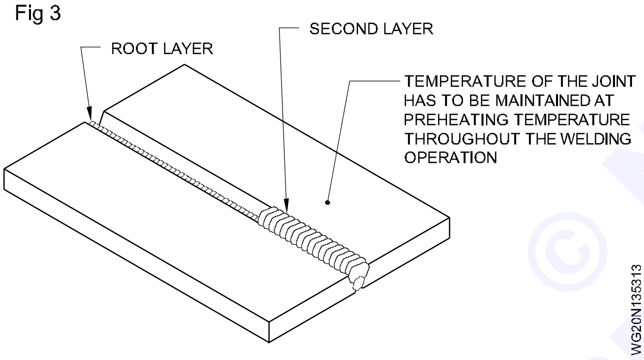
Fig 2



Using the leftward or forehead technique, the first layer should be complete by giving a slight weaving motion to the blowpipe but not to the filler rod. The hot rod end should be dipped into the powdered flux at intervals.

After the completion of the first layer, play the flame on the job so as to heat evenly and then deposit the second layer with a slight reinforcement of weld metal from the surface of the job. (Fig 3)

Fig 3



The technique of welding the second layer is the same as that for the first layer.

After completion of the second layer, play the flame again on the whole job for getting an even heat. This is called 'post heating'.

Then allow the job to cool slowly by covering with a heap of lime or ash or dry sand.

Selection of filler rod

Filler rod should be selected according to the:

– kind or type of metal to be welded, i.e. ferrous, non-ferrous, hard facing (Table 1).

  thickness of metal to be welded (including joint edge preparation) (Table 2)

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

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

Table 1

Metals	Filler rods
Mild steel and wrought iron	Copper coated mild steel (C.C.M.S)
High carbon and alloy steel	High Carbon steel Silicon-manganese steel Wear-resisting alloy steel 3.5% Nickel steel
Stainless steel	Columbium stainless steel
Cast iron	Super silicon cast iron Ferro silicon cast iron Nicotectic cast iron
Copper and its alloys (brass, bronze)	Copper-silver alloy Silicon-brass, silicon-bronze Nickel bronze Manganese bronze
Aluminium and its alloys	Pure aluminium 5% Silicon aluminium alloy 10-13% Silicon aluminium alloy

Table 2

Thick-ness mm	Edge preparation mm	Root gap	Dia. of filler rod mm
0.8	Square	-	1.6
1.6	Square	2.4	1.6
2.4	Square	3.2	1.6
3.2	80° Vee	3.2	2.4
4.0	80° Vee	3.2	3.2
5.0	80° Vee	3.2	4.0

More the thickness of the metal welded, more the diameter of the filler rod used. Less the number of weld runs deposited, less the distortion and faster the welding.

Outline of the subjects to be covered

Objectives : At the end of this lesson you shall be able to
- **describe the outline of subjects.**

Welder (Welding & Inspection) is an one year course under the capital goods and manufacturing sector of craftsman tracing scheme (CTS). Competancy based cuuriculam of this trade has been categorized under NSQF level 3.

Syllabus for the course provided witu 86 batch of trade practicals (professional skills) and 85 related topics of trade theory (progessional knowledge). Each practical exercise is sub divided into different tasks.

The syllabus for trade theory (progressional knoweldge is categorized into 8 modules and each module is sub divided into different topics.

Module 1 of the syllabus covers the area related to general discipline, safety, introduction to welding various welding processes, various welding joints etc…..

Module 2 covers the portions relate to welding such as welding cutting equipemnts power sources, positions symbols arc its characteristics etc.

Module 3 deals in depth related to generation of oxy-acetylene gas, welding techniques causes, effects and remedial measures of various welding defects, development of pipe and pipe joints, weldability and welding methids of various metals and alloys.

After completion of module 4 trainees shall be while to understand in about quality, measuring instrucments CNC profile cutting, welding metallurgy etc.

In module 5 techniques of shielding metal arc welding process has been explained in detail. Module 6 exhibits the gas tungsten arc welding process in etail that the franchee can understand easily module 7 expalins the advcanced techniquies of gas metal arc welding process, pipes pipe joints, methods of inspecion on finished weld etc.

Module 8 explains in details about various destructive and non destructive testing methods to evaluate the defect of weldments.

It further exhibits the certification methods of welding inspector, codes and standards of welding insepction, welding procedure specification and procedure qualification record.

After completing the topics of the syllabus, the professionl knowledge of the franchee will be developed and he/she will be able to become a qualified welder.

Safety precautions pertaining to GTAW & GMAW

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

Safety in GMA welding/CO_2 welding

The general safety precautions for arc welding (SMAW) are also applicable to GMAW.

Ultra violet light

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

Adequate eye protection should always be worn. If welding for long periods, flash goggles with A#12 lens shade should be worn under the arc helmet. A#11 lens is recommended for nonferrous GMAW and A#12 for ferrous GMAW. All welding should be done in booths or in areas protected by curtains. This is done to protect others in the weld area from arc flashes.

Heat

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

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

Fumes

Fumes from the MIG welding process are produced by the burning of contaminants on the surface of the material being heated.

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

Ventilation should be provided. This ventilation and/or filtering equipment is necessary to keep the atmosphere around the welder clean. Carbon monoxide is generated when doing GMAW and using CO_2 as a shielding gas. It is suggested that all welding be done in well ventilated areas.

Ozone is also produced when doing GMAW and ozone is a highly toxic gas. Metals still covered with chlorinated hydrocarbon solvents will form poisonous, toxic phosgene gas when welded.

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

Shielding gas cylinders must be handled with caution.

Welding environment safety rules (GMAW & GTAW)

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

GTAW safety: GTAW/TIG welding is a skill which may be performed safely with a minimum of risk if the welder used good common sense and safety rules. It is recommended that you establish good safety habits as you work in this industrial area. Check your equipment regularly and be sure that your environment is safe. Safety in TIG welding covers the following major areas and includes

Electrical current: Primary current to the electrical powered welding machine is usually 220V A/C or more, and this amount of voltage can cause extreme shock to the body and possible death. For this reason

- never install fuses higher than specified
- always ground/earth the welding machine properly
- install electrical components as per the codes given by the electricity boards
- ensure electrical connections are tight
- never open a welding machine when it is operating
- lock primary voltage switches, open and remove fuses when working on electrical components inside the machine
- welding current supplied by the power supply has a maximum of 80 open circuit volts. At this low voltage, the possibility of lethal shock is very small. However, it will still produce a good shock. To reduce the possibility of this occurrence.
- keep the welding power supply dry

- keep the power cable, ground cable and torch dry
- do not weld in damp area. If you must, wear rubber boots and gloves
- make sure the ground clamp is securely attached to the power supply and the work piece
- High frequency components in some GTAW machines produce a spark for starting the initial arc or maintenance of the arc during the alternating current welding. The high frequency voltage is very high, however the amperage is very low. Since the amperage is so low, the high frequency voltage will not usually travel through the body and is therefore not as dangerous as other currents.

Inert gases: Inert gases used in GTAW are produced and distributed to the user in two forms: high pressure gas and liquid. All storage vessels used for inert gases are approved by the department of transportation and are so stamped on the vessel name plate or the cylinder wall.

Most of the gases used in GTAW are inert, colourless and tasteless. Therefore special precautions must be taken when using them. Nitrogen, argon,and helium are non toxic. However they can cause asphyxiation (suffocation) in a confined or closed area that does not have adequate ventilation. Any atmoshphere that does not contain at least 18 % oxygen can cause dizziness, unconsciousness or even death. The gases cannot be detected by the human senses and will be inhaled like air. So ensure the welding area is well ventilated with good air circulation.

Introduction to GMAW equipment and accessories

Objective: At the end of this lesson you shall be able to
- **state the power sources for GMAW**

Introduction to GMAW welding: Fusion welding of metal plates and sheets is the best method of joining metals because in this process the welded joint will possess the same properties and strength as the base metal.

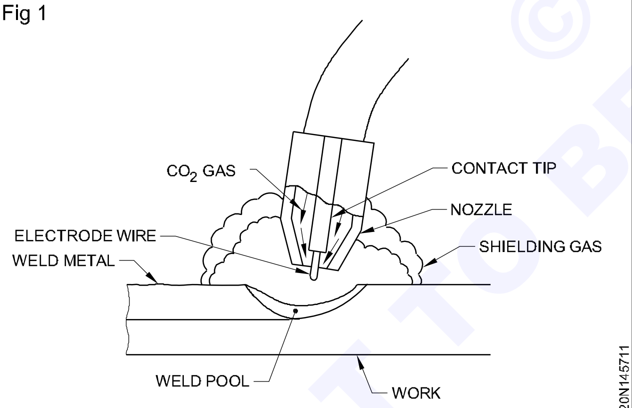
Without a perfectly shielded arc and molten puddle, the atmospheric oxygen and nitrogen will get absorbed by the molten metal. This will result in weak and porous welds.

In shielded metal arc welding (SMAW) the arc and molten metal are protected/shielded by the gases produced by the burning of the flux coated on the electrode.

The above mentioned shielding action can be done by passing an inert gas such as argon, helium, carbon-di-oxide through the welding torch/gun. The arc is produced between the base metal and a bare wire consumable electrode fed continously through the torch.

Principle of GMA welding: In this welding process, an arc is struck between a continuously fed consumable bare wire electrode and the base metal. The heated base metal, the molten filler metal and the arc are shielded by the flow of inert/noninert gas passing through the welding torch/ gun. (Fig 1)

Fig 1



PRINCIPLE OF CO_2 WELDING

If an inert gas is used to protect the arc produced by a consumable metal electrode, this process is called Metal Inert Gas Welding (MIG).

When carbon-dioxide is used for shielding purposes, it is not fully inert and it partly becomes an active gas. So CO_2 welding is also called as Metal Active Gas (MAG) welding.

> **MIG/MAG welding is a name with respect to gas used for shields purpose**
>
> **On the other hand Gas Metal Arc Welding is the common name.**

Basic equipment for a typical GMAW semiautomatic setup: (Fig 2)

- Welding Power Source - provides welding power.
- Wire Feeders - controls supply of wire to welding gun.
- Supply of Electrode Wire.
- Welding Gun - delivers electrode wire and shielding gas to the weld puddle.
- Shielding Gas Cylinder - provides a supply of shielding gas to the arc.

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 2

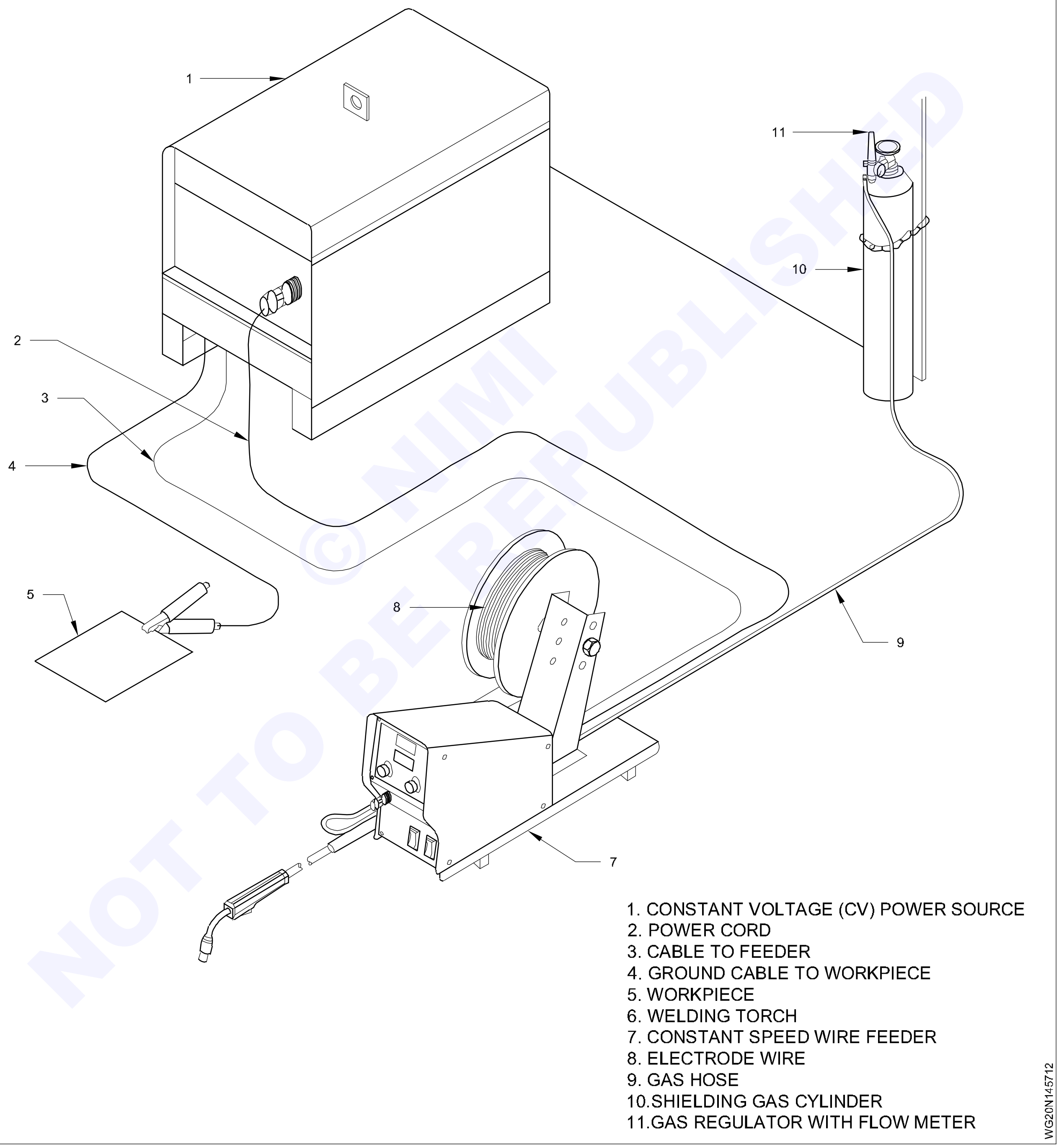
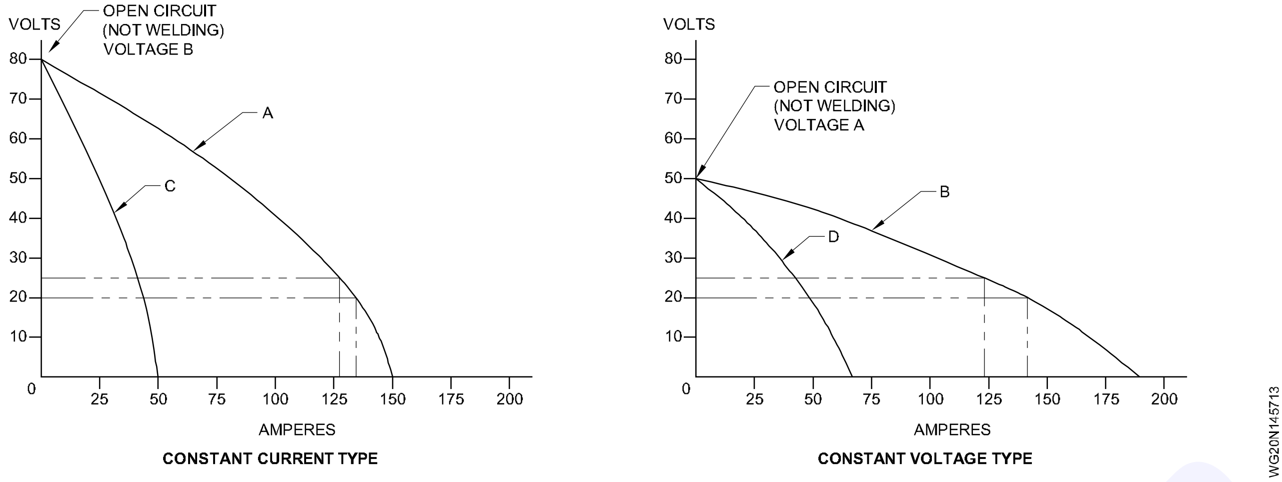


Fig 3


OPEN CIRCUIT
(NOT WELDING)
VOLTAGE B
VOLTS
80
70
60
50
40
30
20
10
0
25
50
75
100
125
150
175
200
A
C
AMPERES
CONSTANT CURRENT TYPE
VOLTS
OPEN CIRCUIT
(NOT WELDING)
VOLTAGE A
B
D
AMPERES
CONSTANT VOLTAGE TYPE
WG20N145713

Various names of the process (MIG-MAG/CO_2 WELDING, FCAW)

Objective: At the end of this lesson you shall be able to
- **various name of the process MIG (MAG).**

MIG/MAG and FCAW are both welding processes commonly used in industry. Here are some of the various name sfor each process.

MIG/MAG

- Metal Inert Gas (MIG) welding
- Gas Metal Arc Welding (GMAW)
- Metal Active Gas (MAG) welding
- Wire - feed welding

FCAW

- Flux - Cored Arc Welding (FCAW)
- Self - Shielded Flux - Cored Arc Welding (SSFCW)
- Gas - Shield Flux - Cored Arc Welding (DSFCW)
- Innershied Flux - Cored Arc Welding (IFCAW)

Co_2 welding is a common welding process that used carbon dioxide gas as a shiedling gas to protect the welidng area from atmospheric contamination. Here are some of the various name for Co_2 welding

- Gas Sheilding Metal Arc Welding (GMAW)
- Co_2 Gash Shielding Arc Welding
- Metal Active Gas (MAG) Welding
- Metal Inert Gas (MIG) Welding with Co_2
- Co_2 Shielding Welding
- Carbon Dioxide Gas Metal Arc Welding (GMAW - Co_2)

Advantages & Limitations

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

Power source & accessories Wire Feed unit

Objectives: At the end of this lesson you shall be able to
- **explain flour sources & accessories of GMAW**
- **state the types and functions of wire feeder unit.**

GMAW welding process parameters/variables

The following parameters must be considered in the welding procedure of GMAW/CO_2 welding.

Electrode size

Rate of wire feed (Welding current)

Arc voltage

Stick out

welding position

Shielding gas

Travel speed

electrode position

Electrode: Best results are obtained by using the proper size wire for the thickness of the metal to be welded and the position in which the welding is to be done.

Electrode wires should be of the same composition as that of the material being welded.

Basic wire diameters are 0.8 mm, 1.0 mm, 1.2 mm, 1.6 mm and 2.4 mm.

Welding current: The wire feed speed will control the current. A wide range of current values can be used with each wire diameter. This permits welding metal of various thicknesses without having to change the wire diameter. The current selected should be high enough to secure the desired penetration and low enough to avoid under-cutting or burn through.

The success of GMA welding is due to the concentration of high current density at the electrode tip.

General data on current selection is given in the table given below.

The current varies as the wire feed varies.

Arc voltage: This is a very important variable in GMAW/CO_2 welding process, mainly because it determines the type of metal transfer by influencing the rate of droplet transfer across the arc. The arc voltage to be used depends on the base metal thickness, type of joint, electrode composition and size, shielding gas composition, welding position, type of weld and other factors.

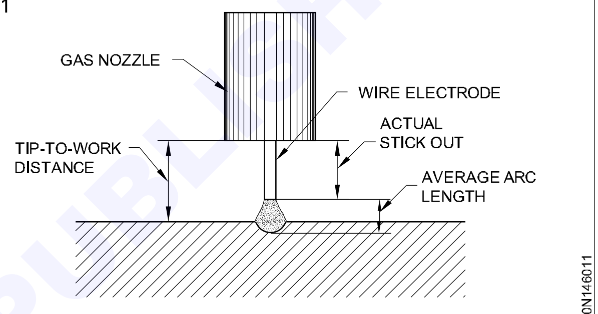
For details refer to the table of General guide to welding conditions.

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

If the arc travel speed is lowered, the weld pool becomes larger and shallower. As the travel speed is increased, the heat input rate of the arc is decreased; consequently there is decreased penetration and narrower weld bead. When the travel speed is excessive, undercutting occurs along the weld bead, because the deposition of the filler metal is not sufficient to fill the paths melted by the arc.

Stick out: It is the distance between the end of the contact tube and the tip of the electrode. (Fig 1)

Fig 1



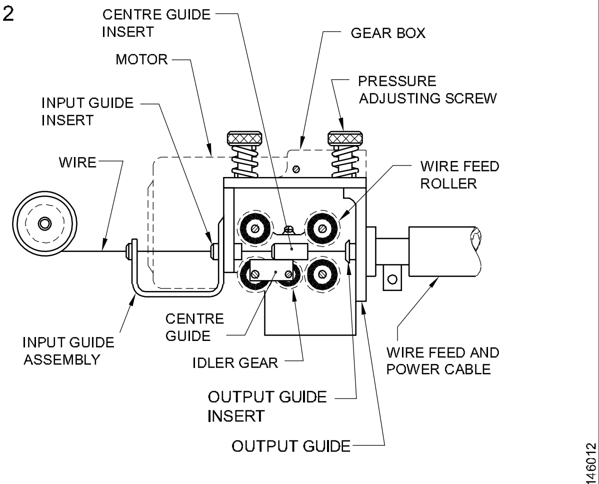
CORRECT WIRE STICK OUT IS IMPORTANT TO ACHIEVE SOUND WELDS

Too long a stick out results in excess weld metal being deposited at low arc heat, giving rise to badly shaped weld and shallow penetration.

When the stick out is too short, excessive spatter gets deposited on the nozzle, which can restrict the shielding gas flow and cause porosity in the weld.

Wire feeder (Fig 2)

Fig 2



A SIMPLIFIED WIRE FEED MECHANISM FOR GMAW

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.

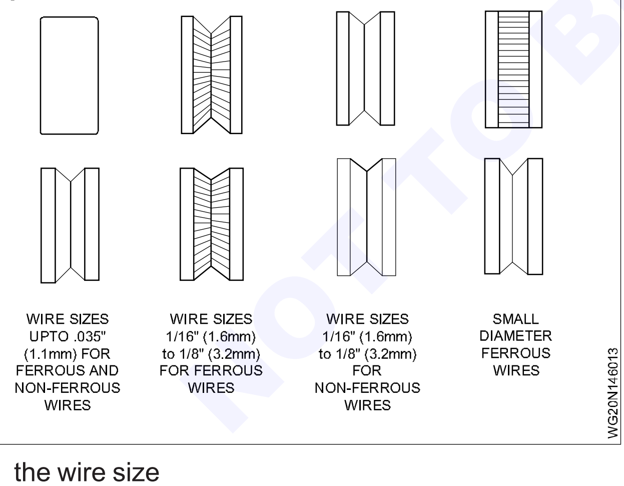
Wire feeders come in many different shapes and sizes, but they all do the same basic job roles. Feeders can be separated from the power source or built into the power source itself. Feeders are made up of different parts, each having a different job role.

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.

Drive motor MIG/MAG welding relies on smooth and constant wire feed. The wire drive motor has the job of turning the drive rollers (this can be one or more sets of rollers). Undersize drive motors can result in poor feeding of the wire electrode down the MIG welding torch . This will have the effect of making the overall performance of the MIG machine sub-standard as compared to a machine with a quality drive system.

Drive rollers: The drive rollers grasp the wire electrode and continuously feed the wire down the MIG torch into the welding arc (Fig 3 & 4). The rollers need to be selected by :

Fig 3



i the wire size

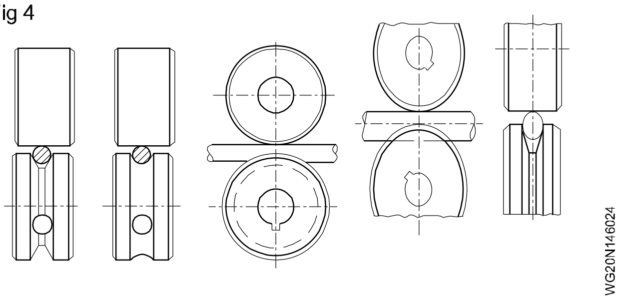
ii the type of wire to be fed. Each type of wire may need a different style of roller groove – eg

V rollers for steel and other hard wires

V-Knurled for Fluxcored wire

U-Grooved for aluminium and other soft wires

Fig 4



The idea of using the correct roller is to have a good wire drive without crushing the wire. The pressure roller is also used to set the wire tension. This must be set with enough pressure to feed the wire electrode, but not too much tension as to crush the wire.

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

Wire feed controls

The wire feeder will have its own built-in control system. The number of controls that will be built into the feeder will depend on the type of feeder but the most common are

i Wire speed - this control is the adjustment for how fast the drive rollers will turn and as stated earlier, the faster the wire speed for each wire size the more amperage the power source will produce. The wire speed controls can be labelled as wire speed, eg ipm (inches per minute) or mpm(metre per minute), or as a percentage from the slowest speed being zero to the highest speed being 100%. Usually mpm will be the range of 1 m/min to 25 m/min.

The amperage being set by the wire speed setting will also have an effect on the speed of travel and the deposition rate of the wire (how fast the weld metal is being put onto the weldpiece); with the advantage of, the higher the amperage the thicker the material that can be welded.

ii Purge switch - Some feeders have a purge switch. This is to allow the gas flow setting to be set on the gas regulator without turning of the wire feed roller or without any welding power being turned on.

iii Burnback - Burnback is the setting of the degree that the wire electrode will melt back towards the contact tip at the completion of the weld. If there is too much burnback the wire electrode will melt back onto the contact tip, possibly damaging it. If there is not enough burnback set, the wire electrode will not melt away from the weldpool and can be left stuck to the weld metal.

iv Spot timers or stitch modes are to be found on some feeders. These controls normally control the time the drive roller will turn for after the trigger contactor has been activated.

Types of shielding gases & advantages

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**
- **state the advantages of shielding gases.**

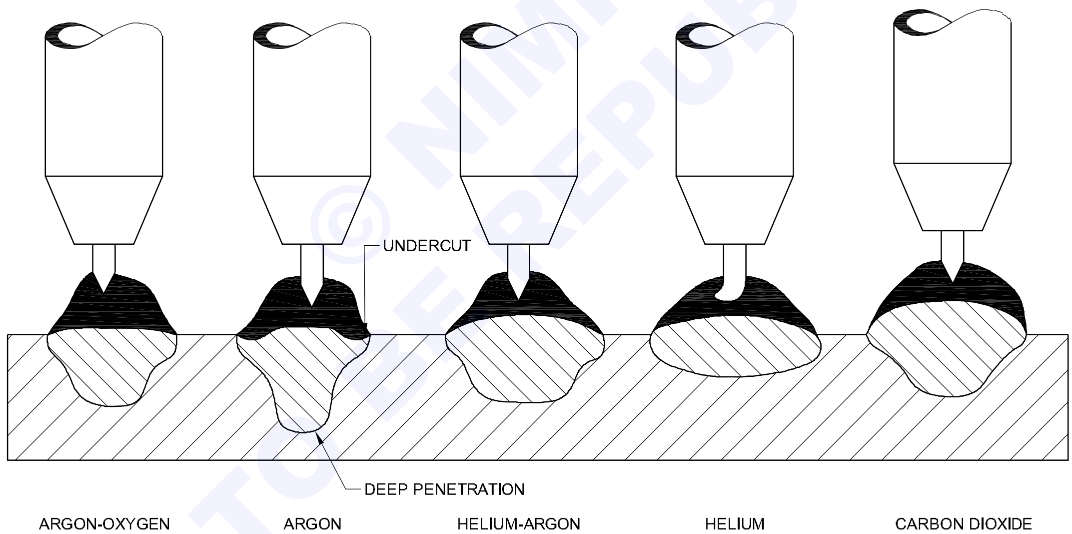
There are three types of shielding gases used for GMAW. They are inert gases, reactive gases and gas mixtures.

Inert gases: Pure argon and helium gas are excellent for protecting the arc, metal electrode and weld metal from contamination. Argon and helium are generally used for GMAW of non ferrous metals. Helium has very good conductivity and conducts heat better than argon. Therefore helium is choosen for welding thicker metals as well as high conductivity metals like copper and aluminium.

For thinner metal welding, lower conductivity argon is the better choice. Also argon is often used for welding out of position because of its lower thermal conductivity. Argon gas is 10 times heavier than helium gas, hence less argon gas is required to provide a good shield as compared to helium gas.

The weld bead contour and penetration are also affected by the gas used. Welds made with argon generally have deeper penetration. They also have a tendency to under cut at the edges. Welds made with helium have wider and thicker beads. Fig.1 shows the shape of welds made with various gases and gas mixtures.

Fig 1



GMAW BEAD SHAPES AND DEPTH OF PENETRATION FOR VARIOUS GASES AND GAS COMBINATIONS.
THESE SHAPES ARE TYPICAL FOR DCEP (DCRP).

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 75% Helium 25% argon	0.1 in.(2.5mm) thick; best metal transfer and arc stability; least spatter 1-3 in.(25-76mm) thick; higher heat input than argon
Copper, nickel and alloys	Argon	Provide good wetting;good control of weld pool for thickness up to 1/8 in.(3.2mm)
Magnesium	Argon	Excellent cleaning action
Carbon Steel,	Argon 5-8% CO_2	Good arc stability; produces a more fluid and controllable weld pool; good coalescence and bead contour, minimizes undercutting ; permits higher speeds compared with argon.
Low alloy Steel	Argon 2% oxygen	Minimizes undercutting; provides good toughness
Stainless Steel	Argon 1% oxygen Argon 2% oxygen	Good arc stability; produces a more fluid and controllable weld pool, good coalescence and bead contour, minimizes under cutting on heavier stainless steels Provides better arc stability, coalescence and welding speed than 1% oxygen mixture for thinner stainless steel materials
Aluminium copper, magnesium, nickel and their alloys	Argon and argon helium	Argon satisfactory on sheet metal argon-helium preferred on thicker sheet metal
Carbon steel	Argon 20-25% CO_2 CO_2	Less than 1/8 in.(3.2mm) thick; high welding speeds without melt through; minimum distortion and spatter; good penetration Deeper penetration; faster welding speeds;minimum cost
Stainless Steel	90% helium 7.5% argon 2.5% CO_2	No effect on corrosion resistance small heat affected zone; no undercutting; minimum distortion; good arc stability

Welding Gun & its parts

Objectives: At the end of this lesson you shall be able to
- **state the types and function of torches.**

MIG/MAG torch connection

The torch connection is the system in which the MIG torch is connected to the wire feeder. There are various types of MIG torch connections. Different manufacturers can use any one of many systems to connect their torch to the wire feeder.

When ordering a new Torch tell the supplier

a the type of torch you need, including amperage rating

b the type of connection on the feeder so the torch can be supplied to match the connection

The Torch connection is also the area where the wire electrode, welding current and welding gases are passed onto the welding torch. This means these components should be checked for damage or leaky seals etc, so the connection will do its job correctly.

MIG/MAG torches: The MIG Torch is connected to the wire feeder, and its job is to deliver the wire electrode, shielding gas and the electrical welding current to the welding area. There are a lot of different shapes and styles of MIG Torch out in the marketplace but they all have things in common.(Fig 1, 2 & 3).

Fig 1

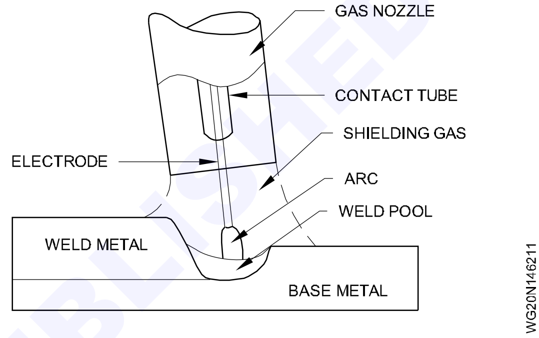
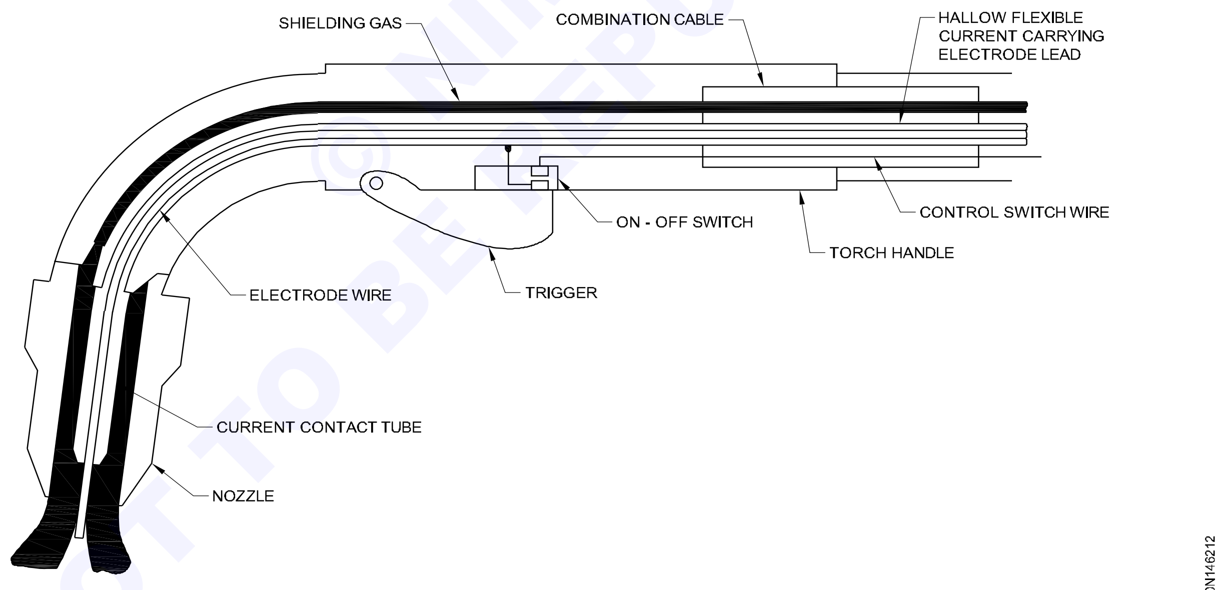


Fig 2



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

1 Aircooled (less than 200 Amps) or watercooled (above 200 Amps) (Fig 2)

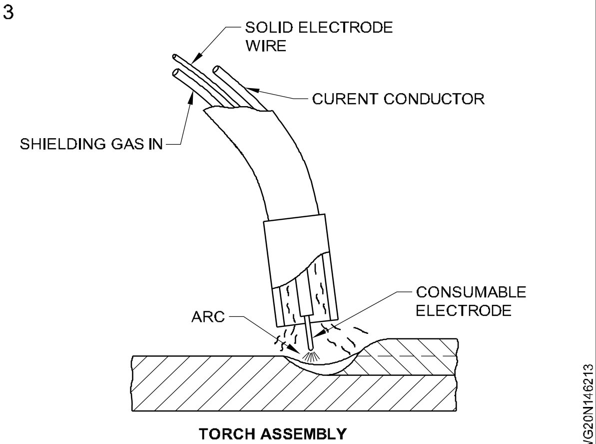
2 Current rating. The operator must select the correct size Torch. Using a torch that is not sufficiently rated for the machine may result in the Torch overheating. This may result in a poor weld and damage to the torch. A Torch with an excessive rating will be larger and heavier than the smaller Torch, which could result in discomfort for the operator.

3 They all have parts that will wear out (consumables eg liners, tips, diffuser, nozzle, etc.)

Let's take a look at each part (Fig 4)

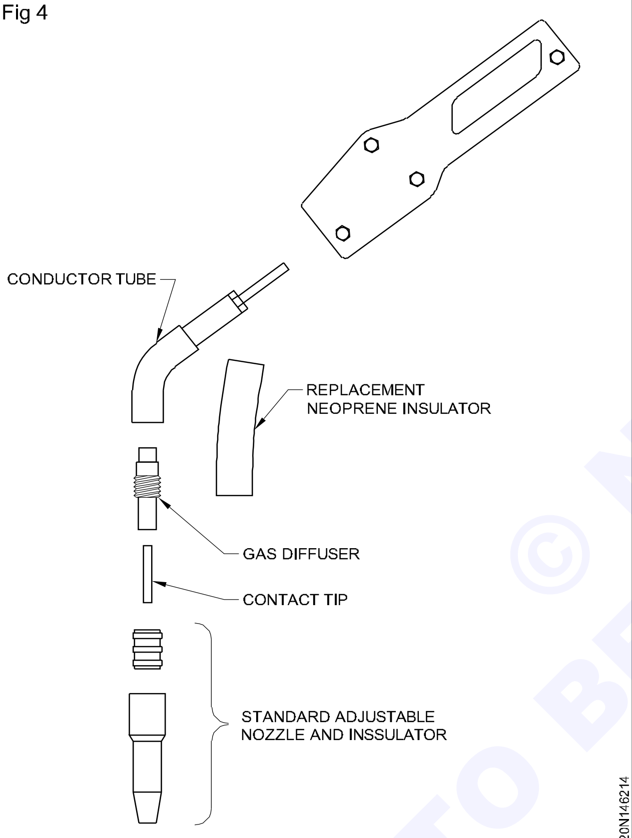
Liner: The liner causes the most problems. First, they have a life span that is approximately one to four rolls of MIG wire depending on the quality of the liner and wire. The life of the liner will also be increased if the operator removes and cleans it by soaking in non-corrosive and a non-toxic solvent. Each wire size needs to have the correct wire size liner. Be aware some liners may fit more than one size of wire.

Fig 3



TORCH ASSEMBLY

Fig 4



WELDING TORCH

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

The liner length is most important. In the field it is very common to find even newly fitted liners that have been cut too short. This results in the wire being able to move around behind the welding tip and leading to bad wire feeding. The liner has to be fitted correctly and different MIG Torch will often have a different way of ending up with a liner that is the correct length.

Don't just take out the old liner and cut the new one to the same length. It could end up with an incorrect result. Please refer to MIG Torch manual.

All MIG Torch should be laid out straight ont he floor before trimming the liner, to prevent the new liner being cut too short. Do not cut the liner if the torch lead is coiled up.

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

Contact tip holder This is the item which holds the welding tip in place. Again, tip holders can be very different in design and are very often unique to that brand of MIG torch.

Contact tips The Contact tip/tube is the key to good welding. First of all, it is the way that welding amperage is delivered to the welding wire electrode, often with a very high amperage.

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

The size is important. The right size contact tip must be selected contact. If the selected tip size is too large the wire electrode will not make a good contact, leading to poor welding performance.

If a contact tip selected is too small, the wire electrode will feed poorly and may even jam in the contact tip.

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

Torch angle

The position of gun and electrode with respect to the joint affects the weld bead shape and penetration rather than arc voltage or travel speed. The gun is usually maintained within 10 - 20º on either side of the vertical. Depending on which way the gun is incline, the technique is referred to as forehead and backhand. The various electrode positions and techniques and their effects are shown in Fig 5. It is observed that as the electrode is changed from perpendicular to the forehand technique, the weld bead becomes shallower and wider and has less penetration.

Backhand technique gives a more stable arc, less spatter and a narrower, more convex weld bead with deep penetration. Perpendicular technique is used more in automatic welding and avoided in semi-automatic mode because the end of the gas nozzle restricts the operator's view of the weld pool.

Modes of metal transfer - Dip, Globular, spray &pulsed transfer and its significance

Objectives: At the end of this lesson you shall be able to
- **explain the difference types of metal transfer in GMAW welding**
- **state the advantages of metal transfer.**

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)

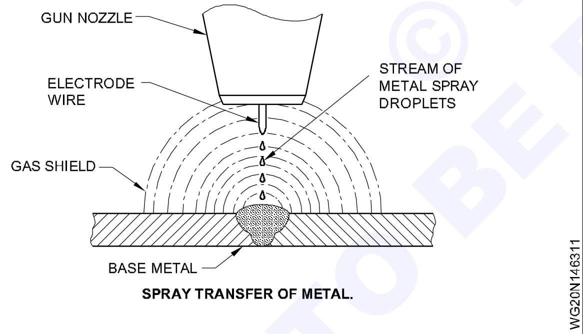
– Short circuit or Dip transfer

– 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

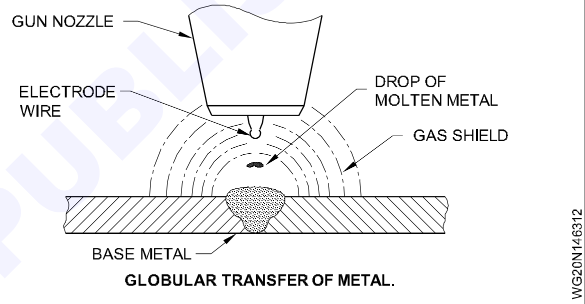
ii weld position is limited to flat and horizontal fillet

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.

Fig 2

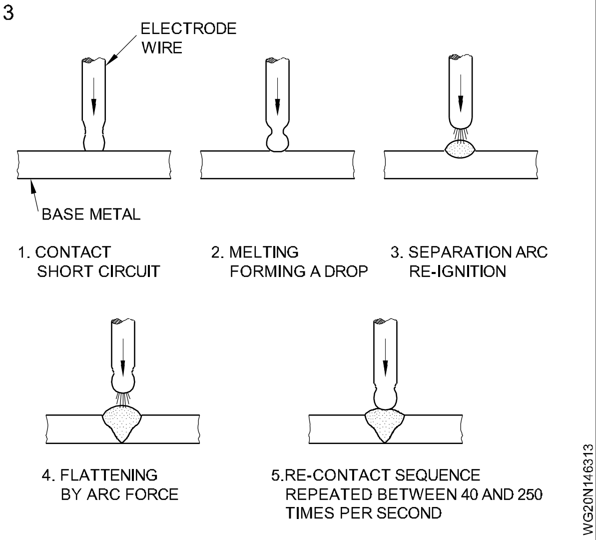


GLOBULAR TRANSFER OF METAL.

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.

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

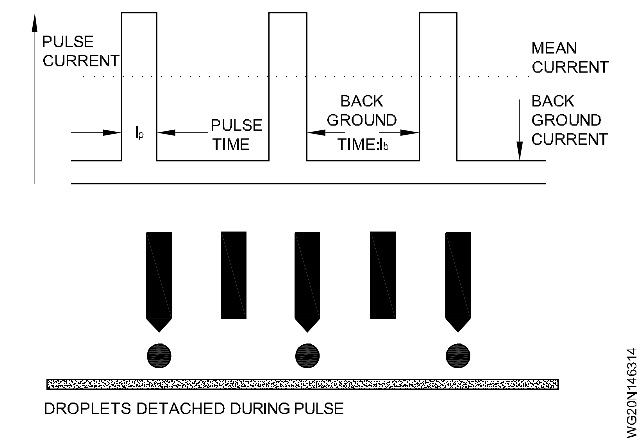


It permits welding thinner sections with greater ease, and is extremely practical for welding in all positions.

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

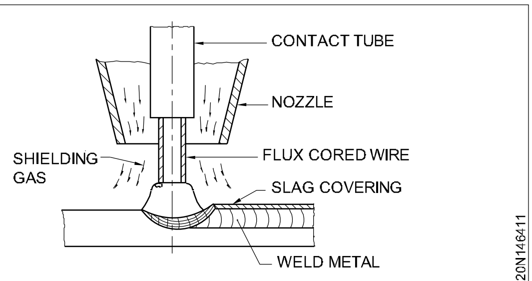
iii lower deposition rate

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**
- **describe the type and specification of 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.

Fig 1



FLUX CORED ARC WELDING

There are two major versions of the process, namely self shielded type (in which the flux performs all the functions of shielding) and the 'gas shielded type', which requires additional gas shielding.

The gas shielded type FCAW is widely employed for welding of carbon steel, low alloy steel and stainless steel in flat, horizontal and overhead positions.

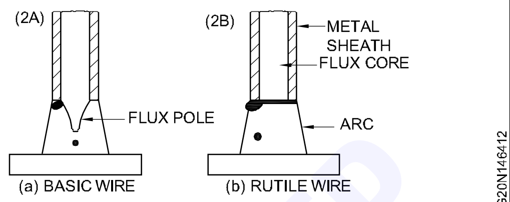
However, the self shielded type FCAW is mainly used for carbon steel welding and the quality of weld produced by this type is generally inferior to that of welds made with gas shielded type.

Equipment: The noticeable differences in the equipment used for GMAW and FCAW, are in the construction of welding torch and feed rollers.

The welding torch used for self shielded wire is very simple in construction as there is no need for the gas nozzle. Similarly the feed rollers used for flux cored wires have to ensure positive feeding of the wire without applying too much pressure on the soft tubular wire.

Metal transfer in FCAW: The metal transfer in FCAW differs significantly from GMAW process. FCAW process exhibits two distinctly different modes of metal transfer, namely large droplet transfer and small droplet transfer. However, both are classified as free flight transfer. The FCAW process does not produce a stable dip transfer as that of solid wire GMAW. The large droplet transfer occurs at the lower current voltage ranges. At higher current voltage ranges, the transfer mode changes to smaller droplet transfer. An important aspect to be observed during FCAW metal transfer is the presence of the 'flux pole' at the core of the arc column, protruding into the arc. The 'flux pole' appears only during welding with basic type flux cored wire. Fig 2(a) However, with rutile wire 'flux pole' does not occur and the metal transfer is of spray type. Fig 2(b)

Fig 2



APPEARANCE OF FLUX POLE

Classification of flux cored wires: The basic functions of the flux contained within the tubular wire include providing protective slag on the weld bead, introducing the required alloying elements and deoxygenerators into the weld pool and providing stability to the arc, besides producing the required shielding medium to protect the arc and weld pool.

Flux cored wires are now available for welding of plain carbon steel, low alloy steel and stainless steel and also for hard facing applications. These wires based on the nature of flux, may be classified as rutile gas shielded, basic gas shielded, metal cored and self shielded.

Rutile gas shielded wires have extremely good arc running characteristics, excellent positional welding capabilities and good slag removal and mechanical properties.

Basic gas shielded wires give reasonable arc characteristics, excellent tolerance to operating parameters and very good mechanical properties.

Metal cored wires contain very little mineral flux, the major constituent being iron powder and ferro alloys. These wires give smooth spray transfer in Argon/CO_2 gas mixtures. They generate minimum slag and are suitable for mechanised welding applications. Self shielded wires are available for general purpose down hand welding.

The flux cored wires are available in both seamless and folded types. The seamless type is generally coated with copper, whereas the folded type wires (i.e. close butt and overlapped type) are treated with special compounds.

Deposition rate and efficiency: Deposition rate is defined as the weight of metal deposited per unit time. The deposition efficiency is defined as the ratio of weight of weld metal effectively deposited to the weight of wire consumed.

In GMAW welding the deposition efficiency is generally between 93% to 97% and in FCAW the corresponding figure is between 80% to 86%. These values are determined by the spatter losses and slag formation. The low deposition efficiency in the case FCAW is due to the slag formation.

Generally the spatter loss can be minimised by using Argon/CO_2 mixed gas instead of CO_2 gas.

Welding wire types and specification

Objectives: At the end of this lesson you shall be able to
- **state the chemical composition of different electrode wires.**

Electrode wire - consumable wire for GMAW: Performance & metal transfer characteristics are largely governed by the diameter of the wire and the machine settings such as arc voltage and amperage and chemical properties of the filler wire employed.

Machine settings: Diameter of the wire and ampere/ current employed for welding decide the type of metal transfer. The various recommended diameter, voltage and current ranges are tabulated in tables below for welding mild steel, low alloy steel and stainless steel.

Approx. machine settings for short circuit metal transfer on mild and low alloy steel

Electrode diameter(mm)	Arc voltage	Amperage range
0.8	16-22	80-190
1.2	17-22	100-225

Approx. machine settings for spray arc transfer on mild and low alloy steel

Electrode diameter(mm)	Arc voltage	Amperage range
0.8	24-28	150-265
1.2	24-30	200-315
1.6	24-32	275-500

Approx. machine settings for short circuit transfer on series 300 stainless steel

Electrode diameter(mm)	Arc voltage	Amperage range
0.8	17-22	50-180
1.2	17-22	100-210

Approx. machine settings for spray transfer on series 300 stainless steel

Specification of electrode wires

The GMAW electrode specification as per AWS is as given below.

Eg: E 70S-2 or ER70S-2 or E70T-2

E — Electrode

ER — Electrode can also be used as a filled Rod in GTAW.

70 — 70 x 1000 PSI — Tensile strength of the weld metal in pounds per square inch.

S — Solid wire / Rod

T — Tubular wire used in FCAW.

2 — Chemical composition of the wire.

Trouble shooting in MIG welding

Objectives: At the end of this lesson you shall be able to
- **explain GMAW welding trouble shooting.**

Troubleshooting welding conditions and defects

Defects	Possible causes	Remedy
Too much spatter	Welding conditions are not proper. Arc voltage is too high, compared with welding current	Select proper welding conditions
Arc is unstable	The contact tipes is too large compared with wire dia. The contact tip is worn out Wire is entangled The wire reel does not rotate smoothly The groove of the feed roll is worn out The pressure roll is not firmly tightened Conduit resistance is high Improper welding conditions Primary voltage of the welding power supply fluctuagtes excessively	Use a contact tip matching wire dia. Replace the contact tip with a new one Staighten the wire Lubricate the reel bearing so that the reel rotates smoothly Replace the feed roll. When flux cored wire is used, the groove is worn out frequently Firmly tighten the pressure roll. When flux cored wire is used, do not tighten the roll too firmly, as the wire may be damaged and the wire feeding becomes unstable If the conduit is excessively bent, straighten the conduit. Also, clean the inside of the conduit and apply lubricating oil Make the welding conditions proper Eliminate voltage fluctuations by increasing capacity of the power transformer
Atc is generated between the nozzle and base metal	The nozzle and tip or guide tube is short circuited	As a short circuit is caused by spatter in many remove spatter. Further use a torch that is insulated by a magnetic tube.
The torch (nozzle) is overhead	Currents is too high	Use current within the allowable value of the torch
Wire adheres to the tip	The tip to base metal distance is too short Wire feeding is not smooth	Generate the arc at the proper distance Clean the inside of the conduit to feed the wire smoothly
Blow hole	No gas fed Air is mixed with the gas. The gas shiedling effect is not sufficient due to strong wind. The nozzle is blocked by spatter CO_2 gas is wet Rust and oil in the joint The wire is stained with oil The arc is too long The nozzle dia. is too small	Check the CO_2 gas cylinder to see if it is full and the valve is open. Also, check the gas regulator for ice Check the gas tube and connection for holes Protect the machine from the wind. Change the direction of fan Remove spatter adhered to the nozzle Chenage the cylinder Clean the joint Remove oil from such wire passages as the wire straightening roller Reduce voltage Replace the nozzle with one of proper diameters (Current used must be smaller than nozzle dia. (mm) x 20

Undercut	The grounding point is not adequate. Welding speed is too high Voltage is too high	Earth at the starting point of welding Reduce the speed Adjust arc voltage to the proper level
Overlap	Arc voltage is too low not matching welding Travel speed is low	Raise arc voltage Increase speed of welding
Meandering of	The wire straightener does not work The wire is bent The tip is worn out	Adust the straightener so that the wire is pushed properly by the roller. Straighten the ben wire Replace the contact tip with anew one.
Reinforcement of weld comes down the horizon-tal fillet welding	Welding conditions are not proper. The direction of the torch is not correct. Travel speed is too low. Current and voltage are not correct.	Correct the welding parameters
Crack	Welding conditions are not proper	Correct the welding conditions
	Current is high and voltage low	Raise voltage
	Welding speed is high	Reduce the speed
	Angle of bevel is too small	Increase the angle of bevel
	Contents of alloying elements such as carbon and others in base metal are hgih (cracks at the heat affected zone)	Preheat the base metal
	Gas of low purity (containing much mositure) is used	Use gas suitable for welding
	Generation of the arc is suddenly stopped at a crater	Fill up the crater

Data and Tables related to CO_2 welding

Objectives: At the end of this lesson you shall be able to
- **data sheet for CO_2 welding**
- **plate thick, wire & welding current**
- **arc voltage welding time, gas quantity interrupted force.**

Nr.of sample	Plate thickness (mm)	Wire diameter (mm)	Welding current (A)	Arc voltage (V)	Welding time (sek)	Gas quantity (1/min)	Interrupted force (kN)	Comment
1	2/2	ϕ1,2	210	28	2,5	9	3,8	-
2	2/2	ϕ1,2	240	28	2,7	9	8,8	Clean sample
3	2/2	ϕ1,2	245	28	2,9	9	9,0	Clean sample
4	2/2	ϕ1,2	250	28	3,0	9	12,2	Clean sample
5	2/4	ϕ1,2	255	28	3,2	9	17.0	The sampe is bun
6	2/4	ϕ1,2	260	30	3,0	9	17,1	The sample is bun
7	2/4	ϕ1,2	280	30	2,5	9	14,0	Clean sample
8	2/4	ϕ1,2	290	30	2,8	9	14.3	Clean sample

Data and Tables related to CO_2 welding

Objectives: At the end of this lesson you shall be able to
- **state chemical composition of different electrode**
- **select and votage and current for different diameter of electrode.**

Machine settings: Diameter of the wire and ampere/ current employed for welding decide the type of metal transfer. The various recommended diameter, voltage and current ranges are tabulated in tables below for welding mild steel, low alloy steel and stainless steel.

Approx. machine settings for short circuit metal transfer on mild and low alloy steel

Electrode diameter(mm)	Arc voltage	Amperage range
0.8	16-22	80-190
1.2	17-22	100-225

Approx. machine settings for spray arc transfer on mild and low alloy steel

Electrode diameter(mm)	Arc voltage	Amperage range
0.8	24-28	150-265
1.2	24-30	200-315
1.6	24-32	275-500

Specification of electrode wires

The GMAW electrode specification as per AWS is as given below.

Eg: E 70S-2 or ER70S-2 or E70T-2

E — Electrode

ER — Electrode can also be used as a filled Rod in GTAW.

70 — 70 x 1000 PSI — Tensile strength of the weld metal in pounds per square inch.

S — Solid wire / Rod

T — Tubular wire used in FCAW.

2 — Chemical composition of the wire.

Chemical composition, Weight percent

Reading of Welding procedure specifications (WPS) & Reading of Procedure qualification Record (PQR)

Objectives: At the end of this lesson you shall be able to
- **explain about WPS & PQR.**

Welding procedure, Performance, Qualification and codes

Introduction

'Code' is any set of standards set forth and enforced by a local government for the protection of public safety, health etc.. as in the structural safety of building, (building code) health requirements for plumbing, ventilation etc.... (Sanitary or health code) and the specifications for fire escapes or exits (Fire code)

'Standard' is defined as 'something considered by an authority or by general consent as a basis of comparison, an approved model'.

As a practical matter, codes tell the user what to do and when and under what circumstances to do it. Codes often legal requirements that are adopted by local jurisdictions that then enforce their provisions.

Standards tell the user how to do it and are usually regarded only as recommendations that do not have the force of law.

The uses of welding in Engineering Industries are Boilers, Heat Exchangers, Pressure Vessels, Bridges, Ships, Pipelines, Reactors, Storage tanks, Construction Structures and Equipment etc. When a design engineers designs a welding structure, the function of production & Quality control personnel is to translate that design in to a real component.

From a design point of view properties of the weld joint are designed as

1 Physical soundness (free from discontinuities)
2 Related Theory for Exercise 2.6.06 Metallurgical compatibility (Chemistry of weldment, base metal, gas etc.)
3 Mechanical Properties

The welding Procedure Specification (WPS) is written exactly to translate these property requirements on to relevant welding variables.

The procedure has to be testified on a test piece for its intented performance by a qualified welder. To draw a correct weld procedure, performance methods and qualification criteria, there are popular codes and standards are available.

All the codes specifies the rules for the preparation of welding procedures specification and the qualification of welding procedures, welders and welding operators. This code specifies the rules for all manual and machine welding processes.

Reading of Welding Procedure specifications (WPS) & Reading of Procedure Qualification Record (PQR)

Government as well as private organizations develop and issue standards that apply to a particular area of interest. Many standards with regard to the welding industry are prepared by the American Welding Society (AWS). Many countries have their own national standards on the subject of welding.

The following are examples of the various standards, and the bodies responsible for them Table 1.

Table 1

Standard codes	Country	Responsible bodies
IS	India	Bureau of Indian Standards (BIS)
BS	U.K	British Standard issued by British Standard Association
ANSI	U.S.A	The American National Standards Institute (ANSI)
AWS	U.S.A	American Welding Society
ASME	U.S.A	American Society of Mechanical Engineers
API	U.S.A	American Petroleum Institute
DIN	Germany	German standard issued by the Deutsches Institute fuer Normung
JIS	Japan	Japanese industrial standard issued by the Japanese standards Association

There is also the International Organization for Standardisation (ISO). The main goal of ISO is to establish uniform standards for use in international trade.

The American Welding Society publishes numerous documents on welding and some of them are listed below:

Welding procedure qualification

A welding procedure qualification is the test to prove that the properties of a weld to withstand the service conditions as designed for particular/specific purpose.

Welder performance qualification

A welder's performance qualification is the test to certify a welder's or a welding operator's ability to deliver consistently quality welds. This performance qualification is always done in accordance with a qualified weld procedure specification.

Weld procedure specification

A WPS is deemed to have been qualified if through tests that are conducted on the weld test coupon meeting the requirements or the acceptance criteria. Acceptance criteria and the specification format may vary depending on the code of design and manufacture. The tests that are carried out on the weld test coupon are destructive tests, and they help to evaluate the mechanical properties of the weldment carried out in accordance with WPS.

The results of this qualification are generally recorded in a format and these are generally recorded in a particular format and this is usually referred to as an Procedure Qualification Record (PQR). Thus for every WPS there has to be at least ONE PQR and vice versa.

A performance qualification is generally done to evaluate the performance of a welder on a welding operator. It is done to evaluate the ability of a welder or operator to perform consistently and deliver sound and good quality welds. As this is done to a WPS which has already been qualified most codes of practice generally permit the evaluation to be done by the use of non destructive tests viz, radiography. Welders and operators who fulfill the requirements are deemed to be certified for welding to the specific WPS/WPSs.

ASME sections IX, AWS B2.1, API 1104 are some of the popular American codes specifying welding procedures and welder performance qualification.

BS 2633, BS 4870/4871, BS 4872, DIN 8560, AD Merkblatt HP 2 and HP 3, eN 288-2 and EN 287-1 are some of the European standards for welding procedures and performance qualification.

IBR chapter 13, IS 2825, IS 7307, IS 7310, IS 7318 are the major Indian codes on welding qualifications.

Weld procedure specifications, variables and logic for requalification

A WPS (Weld Procedure Specification) is a document which lists out all the essential characteristics for performing a weld. For purposes of qualifying for the WPS, a test coupon is welded adhering to all parameters as stated/listed in the WPS. A WPS is valid only when supported by a relevant PQR.

The characteristics listed in the WPS, those in this chapter, are otherwise known as variable. As the term signifies, these characteristics may be changed or varied. When these "variables" are changed we have a new WPS. Whenever a change in a particular "variable" is bound to influence the mechanical properties of the weld, then that "variable" is termed as an ESSENTIAL variable. The variable which do not have any impact on the mechanical properties of the weld are generally termed as NON-ESSENTIAL variables. However, under certain conditions, some of the variables could influence the mechanical properties of the weld. Such variables are termed as supplementary essential variables. A more detailed treatment of these is made in the code of manufacture and the same could be referred to.

Similarly those variable that have an influence on the welder's ability to produce sound welds are referred to as essential variables for purposes of Welder Performance Qualification. An example that comes to one's mind right way would be the position in which a weld is made.

Introduction to ASME Sec.IX

Welding procedure and performance qualification

Section IX of the ASME code specifies the rules for the preparation of welding procedure specification and the qualification of welding procedures, welders and welding operators.

This code specifies the rules for all manual and machine welding processes.

Materials

All the materials that can be used for pressure vessel manufacture have been grouped (Table 2) under different 'P' numbers. The object of grouping the base materials is to reduce the number of qualifications required. The 'P' numbers grouping of materials is based essentially on comparable metal characteristics such as composition, weldability and mechanical properties.

Table 2

'P' Number grouping

P1 to P11	Steel and steel alloy
P21 to P30	Aluminium and aluminium based alloys
P31 to P35	Copper and copper based alloys
P43 to P47	Nickel and nickel based alloys
P51 to P52	Titanium and titanium based alloys.

Filler metals

The filler metals are grouped as both "F" numbers and "A" numbers.

"F" numbers

All the electrodes and filler metals are grouped under different "F" numbers. The object of the "F" number grouping (Table 3) is to reduce the number of welding procedures and performance qualifications.

Table 3

"F" Number grouping

F1 to F6	Steel and steel alloys
F21 to F24	Aluminium and aluminium based alloys
F31 to F 37	Copper and copper based alloys
F41 to F45	Nickel and nickel based alloys
F51	Titanium and titanium alloys
F61	Zirconium and zirconium alloys
F71 to F72	Hard facing weld metal overlay.

The "F" number grouping is based essentially on their usability characteristics, with respect to coating. This fundamentally determines the ability of the welder to make a satisfactory weld with a given filler metal. For example, the low hydrogen electrodes have been grouped under "F" Number 4 and rutile steel electrode4s under "F" Number 2.

Obviously, a welder who is able to produce a sound weld with a E6013 (rutile) electrode may not be able to produce a sound weld with a low hydrogen lime powder coated electrode.

The skill required to use these electrodes is definitely not the same. "F" Number 1 is thus the easiest (iron powder) electrode used only in downhand fillet/butt and horizontal fillet positions.

'A' Numbers

A part from classifying the filler metals under "F" numbers, they are again classified under 'A' number as shown in Table 4. 'A' number classification of the filler metals is based on the weld metal chemical analysis whereas the 'F; number classification is based on the usability, or rather operation characteristics. With these definitions of 'P' numbers and 'A' numbers, we shall now see what the code says regarding welding procedures and welders qualification.

Table 4

'A' number grouping

A 1	Mild steel
A 2	Carbon - Molybdenum
A 3 to A 5	Chrome - Molybdenum
A 6	Chrome - Martensitic
A 7	Chrome - Ferritic
A 8 to A 9	Chrome - Nickel
A 10	Nickel - 4%
A 11	Manganese-Molybdenum
A12	Nickelchrome-Molybdenum

Welding procedures qualification

The codes stipulate that all the details of the welding procedure should be listed in the 'Welding procedure specification' (WPS).

Each of these welding procedure specifications shall be qualified by the welding of test coupons, and the mechanical testing of the specimens cut from these coupons are required by this code. The welding date for these coupons and the results of these tests shall be recorded in a document known as 'procedure qualification record (PQR)'.

A WPS may require the support of more than one PQR, while alternatively, one PQR may support a number of WPSs. A WPS will be applicable equally for a plate, pipe and tube joints. The WPS should contain the following nine points in detail.

1 Joints: details

The groove design, the type of backing used etc. are to be specified in this. If a change in the type of edge preparation (Single Vee, Single 'U' or double Vee etc.) is made or if the joint backing is removed, a new WPS has to written but need not be qualified by a test.

2 Base metals

The base metal (P) number and the thickness ranges for which the procedure is applicable etc. have to be mentioned here. If the range of thickness has to be increased or a change of base metal from one 'P' number to another 'P' number is required, a new WPS should be prepared and supported by a PQR after due tests.

3 Filler metals

The details of the electrodes, and filler wires such as the 'F' number, 'A' number and the type of the filler metals have to be specified here. The electrodes, flux compositions, (basic, rutile, etc.) are also to be mentioned. A change in 'F' number or 'A' number shall require a new WPS and PQR. A change in the diameter of the electrode also requires a new WPS but need not be qualified by a test. The addition or deletion of filler metals requires a new WPS and PQR after re-tests.

4 Position

The positions in which the welding should be done shall be mentioned here. The qualification test can be done in any position but still the same procedure is applicable to all positions.

5 Preheating

The preheating temperature, interpass temperature etc. shall be clearly specified. If the preheat is to be decreased by more than 550C, then a new WPS has to be prepared and qualified by a test.

6 Post - weld heat treatment

The temperature and soaking time of the post-weld heat treatment shall be shown here. Any change in this shall require a new procedure qualification.

7 Electrical characteristics

The type of current, (AC or DC) polarity, amps and voltage etc. have to indicated here.

8 Gas

The shielding gases flow rate, details of gas purging etc. will be shown here. Change in gas composition will call for re-qualification.

9 Technique

The details of the welding techniques string or weave bead, method of initial and interpass cleaning, back gouging, single or multiple passes, root grinding etc., shall be written here. The test welding can be done either in a plate or pipe material and in any position. The maximum thickness for which the procedure is applicable is generally twice the thickness of the test plate or pipe. The welder who welds the test joint is also qualified for that procedure but only in that position in which he welds whereas the procedure is applicable to all positions. The results of the tests shall be recorded in the PQR including welding, NDT and mechanical test results.

Welder's qualification

The purpose of the welder's qualification is to determine the ability of the welder to make sound welds.

The welder may be qualified, based on the results of the mechanical test (two face bends and two root bend tests or four side bend tests) or by radiographic examination of a minimum length of 150 mm for a plate or the entire weld for a pipe. The position of the weld joint has been classified as 1G, 2G, 3G, 4G, 5G and 6G. Table 5 shows the positions qualifying for other positions.

Table 5

Range of positions qualified

Test position	Also qualifies
1G	1G
2G	1G
3G	1G
4G	1G & 3G
5G	1G & 3G
2G & 5G	All positions
6G	All positions

For positions 1G and 2G (flat and horizontal) qualification on a plate shall also qualify the welder in pipes. For all other positions, qualification on a pipe shall qualify for plate but not vice versa.

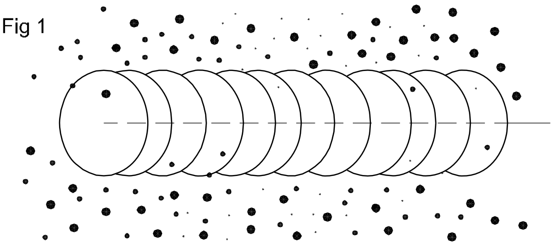
A qualification in a plate or pipe butt joint shall also qualify the welder for fillet welding in all plate thickness and pipe diameters.

Types of weld defects, causes and remedy in GMAW process

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

Excessive spatter (Fig 1)

Fig 1

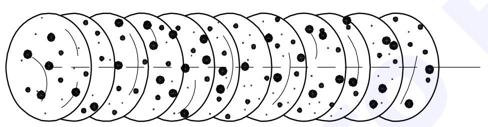


Excessive Spatter : scattering of molten metal particles that cool to solid form near weld bead.

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 feeder or liner.

Porosity (Fig 2)

Fig 2

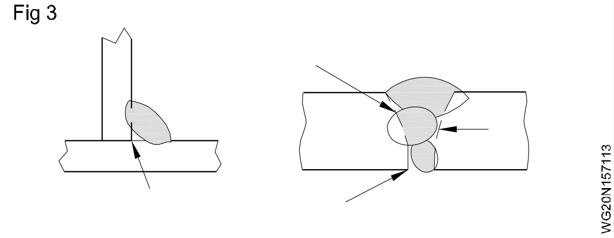


Porosity — small cavities or holes resulting from gas pockets in weld metal.

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

Incomplete fusion (Fig 3)

Fig 3

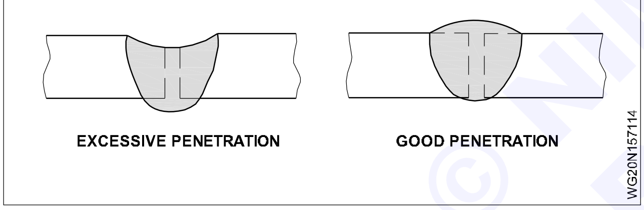


Incomplete Fusion — failure of weld metal to fuse completely with base metal or a preceeding weld bead.

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

Excessive penetration (Fig 4)

Fig 4

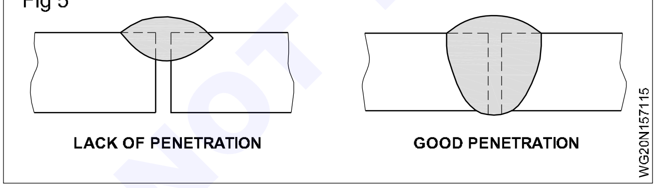


Excessive Penetration — weld metal melting through base metal and hanging underneath weld.

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

Lack of penetration (Fig 5)

Fig 5



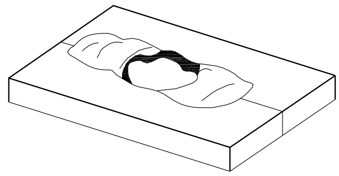
Lack of Penetration — shallow fusion between weld metal and base metal.

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

Insufficient heat input.	Select higher wire feed speed and/or select higher voltage range. Reduce travel speed.

Burn through (Fig 6)

Fig 6

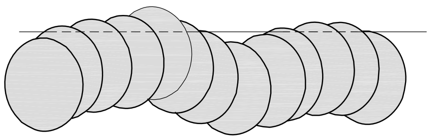


Burn-Through — weld metal melting completely through base metal resulting in holes where no metal remains.

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

Waviness of bead (Fig 7)

Fig 7

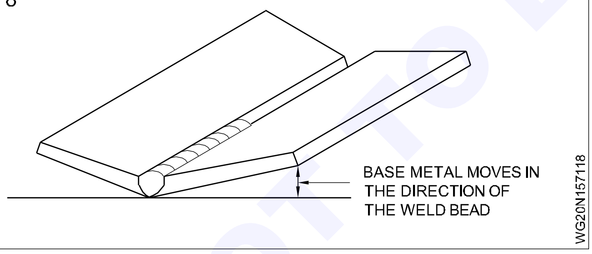


Waviness of Bead — weld metal that is not parallel and does not cover joint formed by base metal.

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

Distortion (Fig 8)

Fig 8



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

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

Introduction to GTAW welding

Objective: At the end of this lesson you shall be able to
- **understand the history and overview of GTAW.**

History of Gas Tungsten Arc Welding (GTAW)

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

GMAW's development came about to help in the welding of difficult types of material, eg aluminium and magnesium. The use of GMAW today has spread to a variety of metals like stainless mild and high tensile steels.

GTAW is most commonly called TIG (Tungsten Inert Gas welding).

The development of TIG welding has added a lot in the ability to make products, that before the 1940's were only thought of.

Like other forms of welding, TIG power sources have, over the years, gone from basic transformer types to the highly electronic power source of the world today.

Overview

TIG welding is a welding process that uses a power source, a shielding gas and a TIG torches. The power is fed out of the power source, down the TIG torches and is delivered to a tungsten electrode which is fitted into the torches. An electric arc is then created between the tungsten electrode and the workpiece. The tungsten and the welding zone is protected from the surrounding air by a gas shield (inert gas). The electric arc can produce temperatures of up to 3000^0C and this heat can be very focused local heat.

The weldpool can be used to join the base metal with or without filler material.

The TIG process has the advantages of -

1 Narrow concentrated arc

2 Able to weld ferrous and non-ferrous metals

3 Does not use flux or leave a slag

4 Uses a shielding gas to protect the weldpool and tungsten

5 A TIG weld should no spatter

6 TIG produces no fumes but can produce ozone

The TIG process is a highly controllable process that leaves a clean weld which usually needs little or no finishing. TIG welding can be used for both manual and automatic operations.

The TIG welding process is so good that it is wisely used in the so-called high-tech industry applications such as

1 Nuclear industry

2 Aircraft

3 Food industry

4 Maintenance and repair work

5 Some manufacturing areas

6 The off shore industry

7 Combined heat and power plants

8 Petro chemical industry.

9 Chemical industry.

Equipment, accessories, Advantages & Limitations

Objective: At the end of this lesson you shall be able to
- **name the parts of a GTAW equipment.**

TIG welding equipment (Fig 1)

– An AC or DC arc welding machine.

– Shielding gas cylinders or facilities to handle liquid gases

– A shielding gas regulator

– A gas flowmeter

– Shielding gas hoses and fittings

– A welding torch (electrode holder)

– Tungsten electrodes

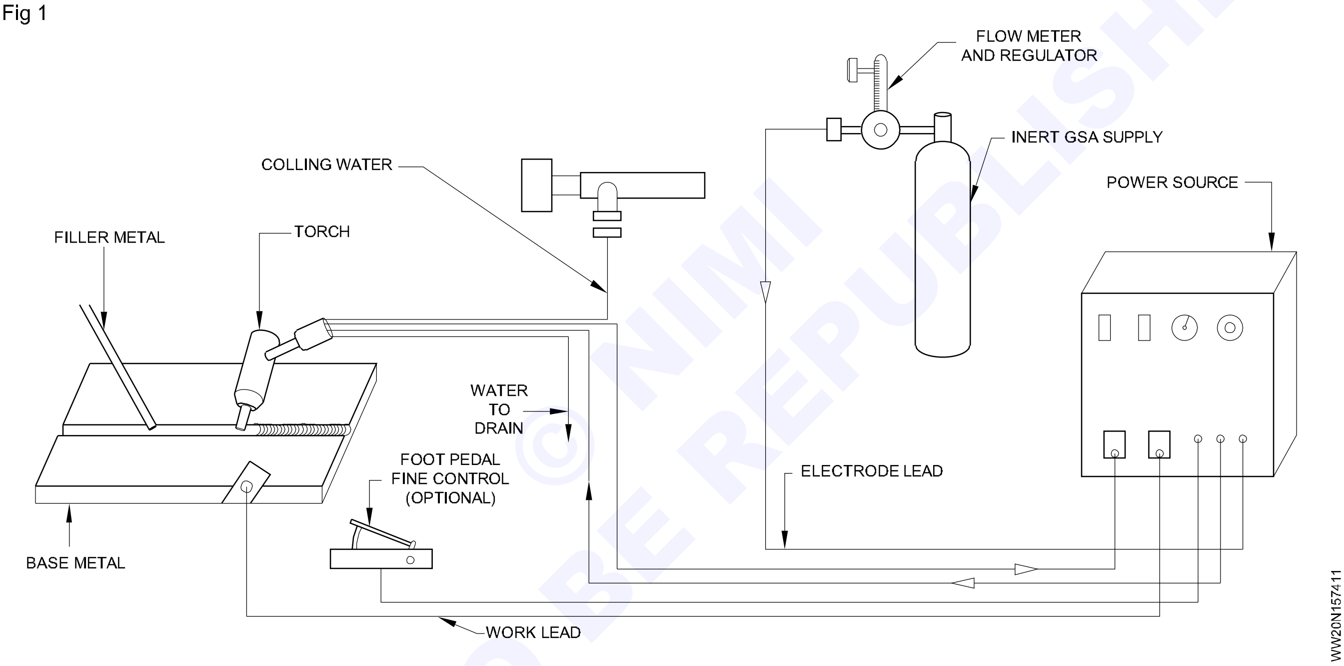
– Welding filler rods

– Optional accessories

– A water cooling system with hoses for heavy duty welding operations

– Foot rheostat (switch)

Fig 1



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 nonferrous

metals.

Bare wires and light coated electrodes can be easily used.

Positional welding is easy due to polarity advantage.

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

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

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

It is easy to strike and maintain a stable arc.

Remote control of current adjustment is possible.

Disadvantages of DC welding

DC welding power source has:

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

Power source - Types, polarity and application

Objective: At the end of this lesson you shall be able to
- **describe the poer sources of GTAW**
- **explain the types of polarity of GTAW.**

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.

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.

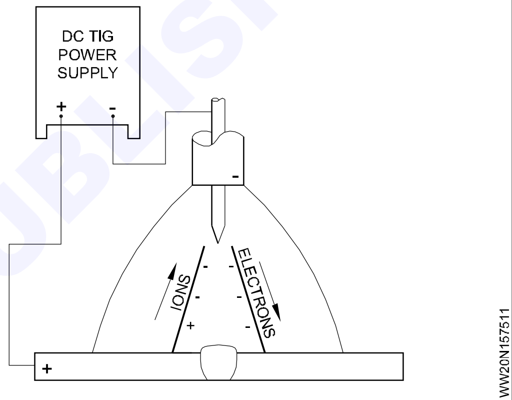
Types of welding current used for GTAW: When TIG welding, there are three choices of welding current. They are: Direct Current Straight Polarity, Direct Current Reverse Polarity, and Alternating Current with High Frequency stabilisation. Each of these has its applications, advantages, and disadvantages. 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 1): (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. (Table 1)

Table 1

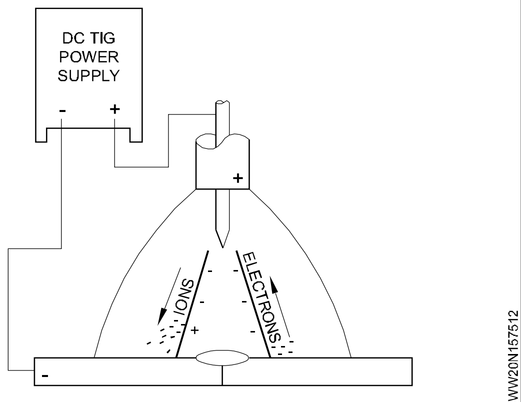
Current type	DCSP
Electrode Polarity	Electrode Negative
Oxide Cleaning Action	No
Heat Balance in the Arc	70% at work end 30% at electrode end
Penetration Profile	Deep, narrow
Electrode Capacity	Excellent

Fig 1



DCRP - Direct Current Reverse Polarity (Fig 2): (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 ove heat and burn away. DCRP produces a shallow, wide profile and is mainly used on very light material at low amps. (Table 2)

Fig 2



AC - Alternating Current (Fig 3) is the preferred welding current for most white metals, eg aluminium and magnesium. The heat input to the tungsten is averaged out as the AC wave passes from one side of the wave to the other. (Table 3)

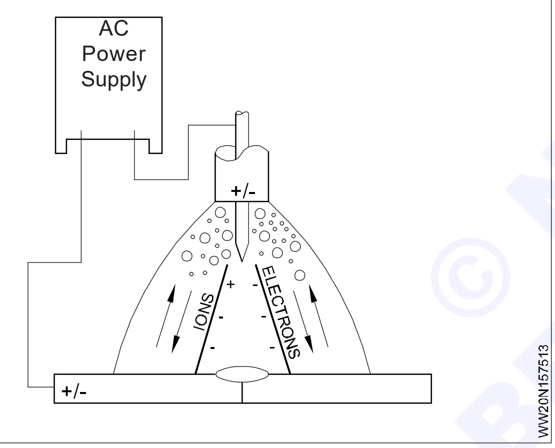
Table 2

Cueent type	DCRP
Electrode Polarity	Electrode Positive
Oxide Cleaning Action	Yes
Heat Balance in the Arc	30% at work end 70% at electrode end
Penetration Profile	Shallow, wide
Electrode Capacity	Poor

Table 3

Current type	ACHF
Electrode Polarity	Alternating
Oxide Cleaning Action	Yes (once every half cycle)
Heat Balance in the Arc	50% at work end 50% at electrode end
Penetration Profile	Medium
Electrode Capacity	Good

Fig 3

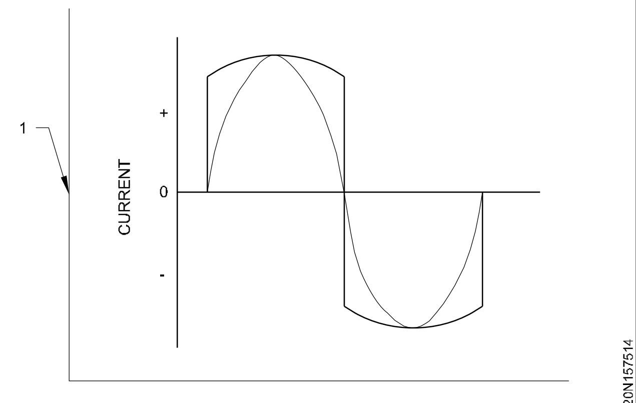


On the half cycle, where the tungsten is positive electron welding current will flow from base material to the tungsten. This will result in the lifting of any oxide skin on the base material. This side of the wave form is called the cleaning half. As the wave moves to the point where the tungsten becomes negative the electrons (welding current) will flow from the welding tungsten to the base material. This side of the cycle is called the penetration half of the AC wave form.

Because the AC cycle passes through a zero point the arc goes out. This can be seen with fast film photography. At this point the arc would stay out if it wasn't for the introduction of HF (high frequency). High frequency has very little to do with the welding process; its job is the reignition of the welding current as it passes through zero. HF is also often used for starting the welding arc initially without the tungsten touching the workpiece. This helps on materials that are sensitive to impurities. HF start can also be used on DC welding current to initially start the welding current without the tungsten touching the workpiece.

AC - Alternating Current - Square Wave (Fig 4)

Fig 4



1. SQUAREWAVE IMPOSED OVER SINE WAVE

With the advent of modern electricity AC welding machines can now be produced with a wave form called Square Wave. The square wave has the benefit of a lot more control and each side of the wave can be, in some cases, controlled to give a more cleaning half of the welding cycle, or more penetration.

Once the welding current gets above a certain amperage (often depends on the machine) the HF can be turned off, allowing the welding to be carried on with the HF interfering with anything in the surrounding area.

Extended Balance Control (Fig 5 ,6 & 7)

AC balance control allows the operator to adjust the balance between the penetration (EN) and cleaning action (EP) portions of the cycle. Some inverters have adjustable EN as great as 30 percent to 99 percent for control and fine-tuning of the cleaning action.

Fig 5

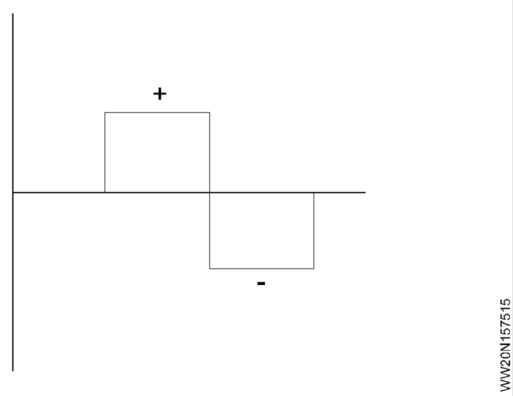


Fig 6

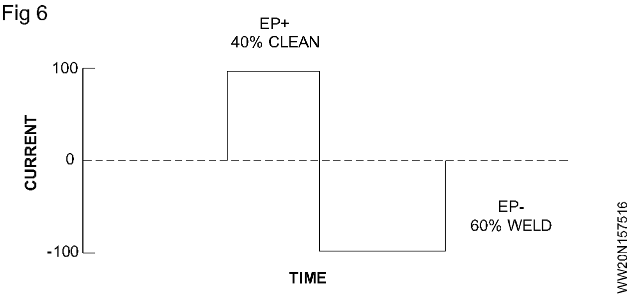
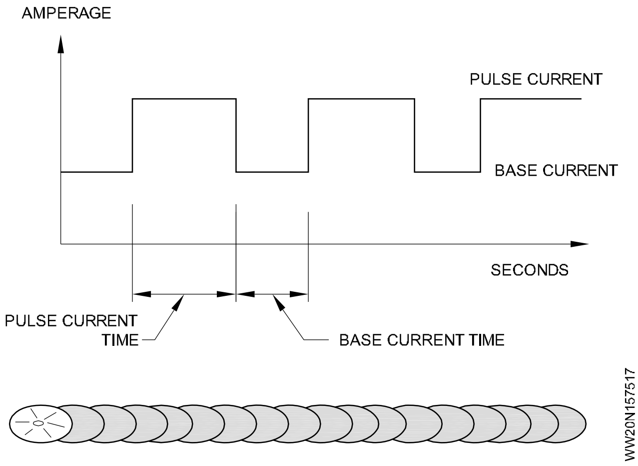


Fig 7



For instance, if the operator sets EN at 60 percent, it means that 70 percent of the AC cycle is putting energy into the work, while 40 percent of the cycle is cleaning.

Pulsed TIG (Fig 8)

In this type of power source, the supply current is not constant and it is being fluctuated from low level to high level. This causes low heat input to the metal and hence distortion effect will be less.

Pulsed TIG has the advantages of

1 better penetration with less heat

2 less distortion

3 better control when welding out of position

4 easy to use on thin materials

The down side is - more set-up cost and more operator training.

Pulsed TIG consists of

Peak current - This is set up higher than for non-pulsed TIG.

Background current - This is set lower than peak current and is the bottom current the pulse will drop to, but must be enough to keep the arc alive.

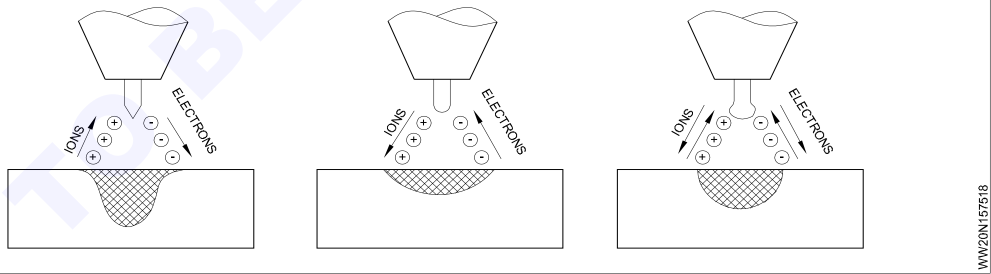
Pulses per second - This is the number of times per second that weld current reaches peak current.

% on Time - This is the pulse peak duration as a percentage of the total time, which controls how long the peak current is on for before dropping to the background current.

The pulse and base current periods are also controllable.

When welding is done with pulsing welding mode the weld is in principle a row of spot welds overlapping to a lerger or smaller extent depending on the welding speed.

Many double-current machines are equipped with a control function which makes it possible to modify the curve of the alternating current in balance between thew positive and the negative semi-periods.

Current Type	DCEN	DCEP	AC (Balanced)
Electrode Polarity	Negative	Positive	
Electron and ion flow Penetration Charateristics	Fig 8 		
Oxide Cleaning Action	No	Yes	Yes-once every Half Cycle
Heat Balance in the arc (approx.)	70% at work end 30% at electrode end	30 % at work end 70% at electrode end	50 % at work end 50 % at electrode end
Penetration	Deep Narrow	Shallow Wide	Medium
Electrode Capacity	Excellent e.g., 1/8 in. (3.2 mm) 400 A	Poor e.g. 1/4 in. (6.4 mm) 120 A	Good e.g. 1/8 in. (3.2 mm) 225 A

Tungsten electrode, Types, sizes, and uses

Objective: At the end of this lesson you shall be able to
- **state the types and colour coating of tungsten**
- **explain the shieding gases and its properties.**

Electrodes for TIG welding

For TIG welding the applied electrode is mainly made of tungsten.

Pure tungsten is a very heat resistance material with a fusion point of approximately 3,380^{0}C.

By alloying tungsten with a few per cent of a metal oxide the conductivity of the electrode can be increased which has the advantage that it can thereby resist a higher current load.

The alloyed tungsten electrodes therefore have a longer lifetime and better ignition properties than electrodes of pure tungsten.

The most frequently used metal oxides used for alloying of tungsten are:

- Thorium oxide ThO_2
- Zirconium oxide ZrO_2
- Lanthanum oxide LaO_2
- Cerium oxide CeO_2

Colour indications on tungsten electrodes

As the pure tungsten electrodes and the different alloyed ones look the same, it is impossible to tell the difference between them. Therefore a standard colour indication on the electrodes has been agreed.

The electrodes are marked with a particular colour on the last 10 mm.

The most commonly used types of tungsten electrodes are:

- Pure tungsten is marked with green colour. This electrode is especially used for AC welding in aluminium and aluminium alloys.
- Tungsten with 2% thorium is marked with red colour. This electrode is mostly used for welding of non-alloyed and low-alloyed steels as well as stainless steels.
- Tungsten with 1% lanthanum is marked with black colour. This electrode is equally suited for welding of all TIG weldable metals.

Colour code and alloying elements for various tungsten electrode alloys Table 1.

Table 1

AWS classifications	Colour*	Alloying element	Alloying oxide	Current type
EWP	Green	Pure	-	AC/DC
EWCe-2	Orange	Cerium	CeO_2	AC/DC
EWLa-1	Black	Lanthanum	$La2O_3$	AC/DC
EWTh-1	Yellow	Thorium	ThO_2	DC
EWTh-2	Red	Thorium	ThO_2	DC
EWZr-1	Brown	Zirconium	ZrO_2	AC

- Colour may be applied in the form of bands, dots, etc, at any point on the surface of the electrode.

Electrode dimensions

Tungsten electrodes are available in different diameters from 0.5 to 8 mm. The most frequently used dimensions for TIG welding electrodes are 1.6 - 2.4 - 3.2 and 4 mm.

The diameter of the electrode is chosen on basis of the current intensity, which type of electrode that is preferred and whether it is alternating or direct current.

Grinding angle

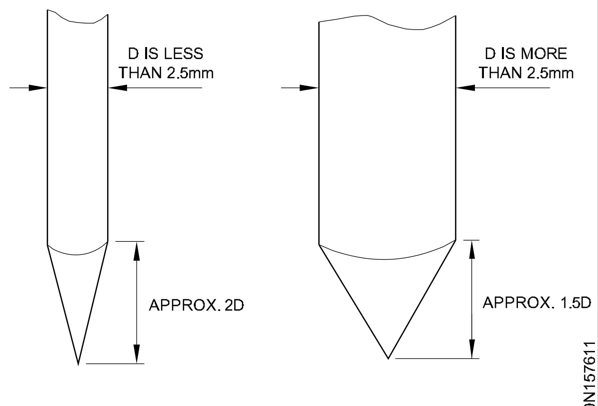
An important condition for obtaining a good result of TIG welding is that the point of the tungsten electrode must be ground correctly.

When welding is done with direct current and negative polarity, the electrode point should be conical in order to obtain a concentrated arc that will provide a narrow and deep penetration profile.

The following thumb rule indicates the relation between the diameter of the tungsten electrode and the length of its ground point.

A small pointed angle gives a narrow weld pool and the larger the pointed angle the wider the weld pool (Fig 1).

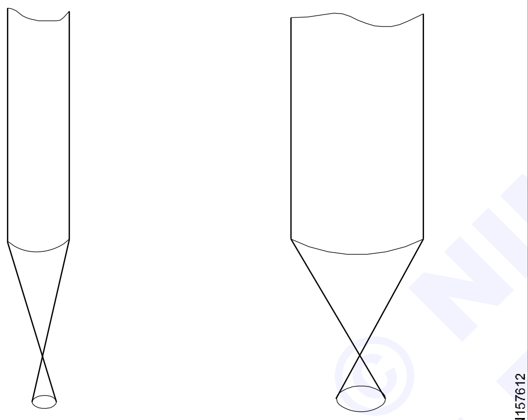
Fig 1



EXAMPLE OF GRINDING OF TUNGSTEN ELECTRODES FOR DC WELDING

The pointed angle also has an influence of the penetration depth of the weld (Fig 2).

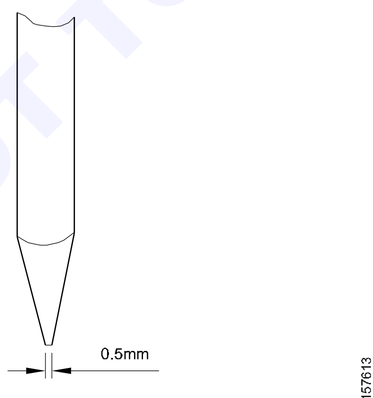
Fig 2



CONNECTION BETWEEN THE POINTED ANGLE AND THE WELD POOL

Blunting the electrode point to make a flat area with a diameter of about 0.5 mm can increase the lifetime of the tungsten electrode (Fig 3).

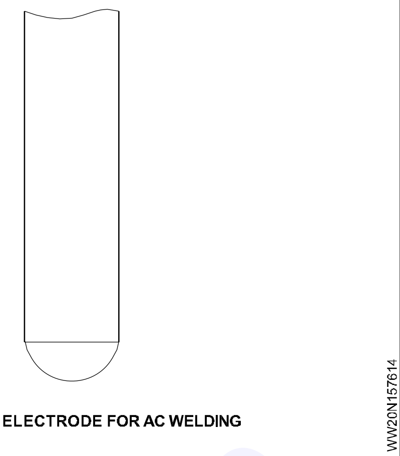
Fig 3



FLAT ELECTRODE POINT

For AC TIG welding the tungsten electrode is rounded as during the welding process it is so heavily loaded that it is melted into a half globular form (Fig 4).

Fig 4



TUNGSTEN ELECTRODE FOR AC WELDING

Grinding of the tungsten electrode

When grinding the electrode its point must point in the direction of the rotation of the grinding disc so the grinding traces will lie lengthways the electrode (Fig 5, 6, 7).

Fig 5

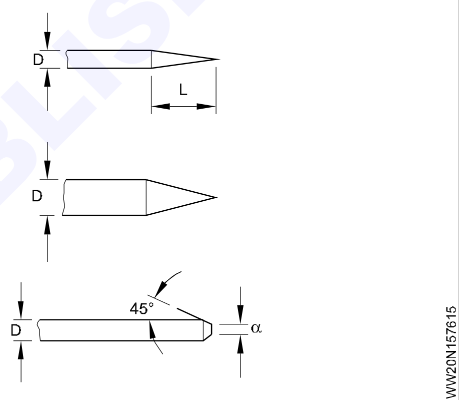


Fig 6

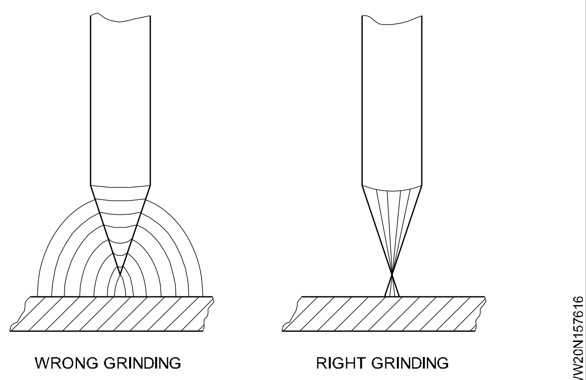
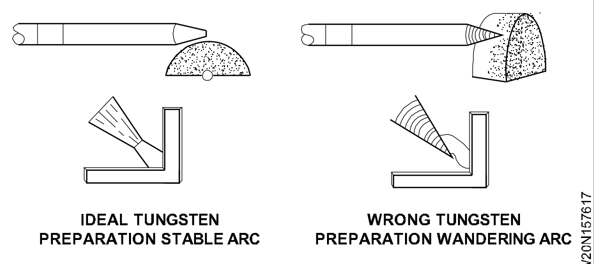
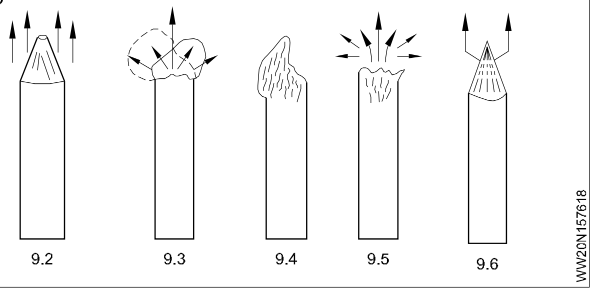


Fig 7



Electrode condition: Fig. 8 shows tungsten electrode conditions associated with TIG welding.

Fig 8



Comments

a Well sharpened and healthy electrode (color 'silver white') and used with normal current. Sharpening to a cone (without a point) allows a rapidly forming and stable arc, centered in relation to the electrode.

b The point of the electrode has melted under the action of too great a current. The point is deformed, the arc is erratic and poorly directed because the ball 'vibrates' during welding. Welding is therefore difficult, if not impossible.

c The electrode has been used without protection of argon shielding gas. The flow has been cut off too soon. The electrode has turned blue, is contaminated with oxygen and disintegrates rapidly. It is necessary to reshape it.

d This fault occurs mostly in the welding of light alloys with an electrode of thoriated tungsten and a low current. The current must be increased to form a ball shape at the electrode tip. If this is not done the arc will remain 'erratic.

e Electrode point too sharp. Rapid wear occurs since the point carries current densities which are too high. this leads to systematic inclusions of tungsten in the weld which are highly visible on radiographics.

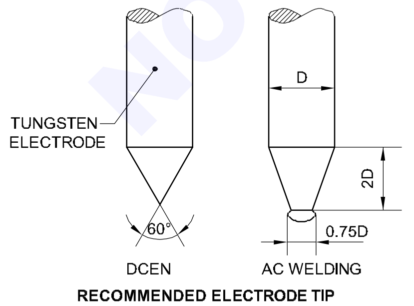
Tungsten selection and preparation (Table 2)

Table 2

Base metal type	**Welding current**	**Electrode type**	**Shield gas**
Aluminium alloys and Magnesium alloys	AC/HF	Pure (EW-P)	Argon
		Zirconiated(EW-Zr)	Argon
Copper Alloys, Cu-Ni alloys and nickel alloys	DCSP	2% Thoriated (EW-Th2	Argon
		2% Ceriated(EW-Ce2	Argon, Helium mixture
Mild steels, Carbon steels, alloy steels and Titanium alloys	DCSP	2% Thoriated (EW-Th2)	Argon
		2% Ceriated(EW-Ce2	Argon, Helium mixture
		2% Lanthanated (EWG-Th2)	Argon

GTAW electrodes: The electrode is made of tungsten or an alloy of it and this provides easy arc starting and steady arcing. The Fig.9 show the recommended tip shape for DC EN polarity and AC polarity for TIG welding.

Fig 9



The common varieties of the tungsten electrodes are

- pure tungsten
- 1% or 2% thorium oxide and tungsten

Tungsten with thorium oxide is used welding with DC. An addition of 1% or 2% thorium oxide increases the maximum current carrying capacity by approx. 45-50% for a given electrode and does not form hemispherical blobs as does the pure tungsten.

Thoriated tungsten electrodes are however preferred for DC as the arc wanders when used on AC. Red and yellow colour bands are used widely to indicate 2% and 1% alloyed thoriated tungsten electrodes. The current carrying capacity depends upon the type of shielding gas (whether argon or helium).

Type of shielding gases- Types & properties

Objective: 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.**

Shielding gases

Chemical activity of shielding gases: The behaviour of gases in welding is related to their chemical activity so it is convenient to group them according to this activity.

Inert gases: These are argon and helium. Other inert gases such as krypton, Radon, xenon and neon have been tried, but their low availability results in them being expensive. Also their characteristics do not, at present, give them any particular advantage.

Argon and helium are monatomic (their molecule contains only one atom) and do not react with other bodies (in the arc plasma) and hence the designation 'inert'. This precious property allows them to protect the electrode and molten metal against the atmospheric gases. However they are not suitable in every case. Pure argon for example does not allow a smooth droplet transfer when welding carbon steels. To obtain the desired transfer mode it is necessary to add a certain proportion of oxygen or carbon di oxide.

The different ionisation potential of argon and helium cause them to behave differently.

Properties of argon and helium gas

These gases are colourless, odourless.

Argon is heavier than air and helium is lighter than air.

They do not chemically react with any metals in hot or cold conditions.

They give a good shielding action for molten metal from the atmosphere.

Gases for TIG welding of aluminium

Argon gas

An argon cylinder is identified by the peacock blue colour painted on it.

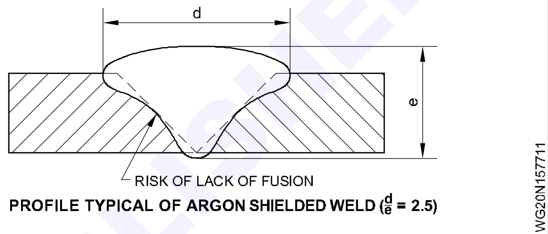
Quality : Argon gas of welding quality should be used.

The rate of flow of argon should be adequate to obtain a clean weld. This depends on several factors such as type of parent metal, current used, shape and size of nozzle, type of joint and whether the work is done indoors or outdoors. Generally a higher rate of flow is required with higher welding currents, for outside corner joints, edge welds and work outdoors. Generally flow rates 2 to 7 litres per minute will be found sufficient to weld all thicknesses.

If tungsten inert gas welding has to be done outdoors during inclement weather, especially during period of high wind, the welding area should be effectively protected. Draughts tend to break the gas shielding, resulting in porous and oxide contaminated welds.

The penetration profile of argon shielded welds has a characteristic shape in the form of a finger.Fig 1

Fig 1



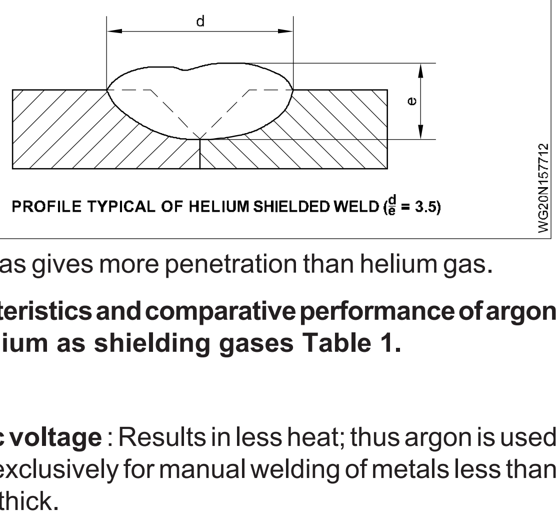
PROFILE TYPICAL OF ARGON SHIELDED WELD ($\frac{d}{e}$ = 2.5)

Helium: Helium is used mainly in TIG welding and is normally used with direct current whatever the metal being welded (light alloys, copper, etc.)

The main advantages of helium shielding are:

- Increase in welding speeds
- More intense local heating, important with metals which are good conductors of heat
- Fig 2 shows the penetration, profile typical of a helium shielded weld

Fig 2



PROFILE TYPICAL OF HELIUM SHIELDED WELD ($\frac{d}{e}$ = 3.5)

Argon gas gives more penetration than helium gas.

Characteristics and comparative performance of argon and helium as shielding gases Table 1.

Argon

Low arc voltage : Results in less heat; thus argon is used almost exclusively for manual welding of metals less than 1.6mm thick.

Good cleaning action: Preferred for metals with refractory oxide skins, such as aluminium alloys or ferrous alloys containing a high percentage of aluminium.

Easy arc starting: Particularly important in welding of thin metal.

Arc stability is greater than with helium

Low gas volume: Being heavier than air, argon provides good coverage with low gas flows and it is less affected by air drafts than helium

Vertical and overhead welding: Sometimes preferred because of better weld puddle control but gives less coverage than helium.

Automatic welding: May cause porosity and undercutting with welding speeds of more than 60cm per min. Problem varies with different metals and thicknesses and can be corrected by changing to helium or a mixture of argon and helium.

Thick work metal: For welding metal thicker than 5mm a mixture of argon and helium may be beneficial

Welding dissimilar metals: Argon is normally superior to helium

Helium

High arc voltage: Results in a hotter arc, which is more favorable for welding thick metal (over 5mm) and metals with high heat conductivity.

Small heat affected zone: With high heat input and greater speeds, the heat affected zone can be kept narrow. This results in less distortion and often in higher mechanical properties.

High gas volume: Helium being lighter than air, gas flow is normally 1 1/2 to 3 times greater than with argon. Being lighter, helium is more sensitive to small air drafts, but it gives better coverage for overhead welding and often for vertical position welding.

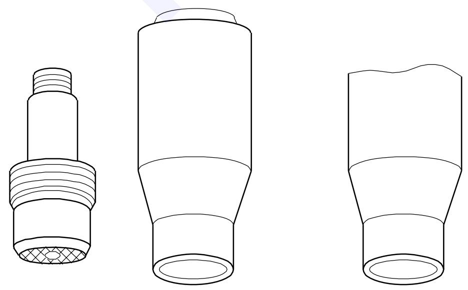
Automatic welding: With welding speeds of more than 60cm per min. welds with less porosity and undercutting may be attained (depending on work metal and thickness).

Table 1

Comparision between argon and helium shielding	
Argon	**Helium**
1 Smoother arc.	1 Smaller heat affected zone.
2 Easy starting.	2 Best for thicker metal welding due to higher arc voltage.
3 Best for thinner metal welding due to lower arc voltage.	3 Better for welding at higher speed.
4 Good cleaning action while welding Al.	4 Gives better coverage in vertical and overhead positions.
5 Heavier than air - Lower flow rates.	5 When used in back shieldings flatens the root face.
6 Lowe cost, more availability.	
7 Better for welding dissimilar metals.	
8 Better control of puddle on positional joints.	

Ceramic shields/nozzles: Gas nozzles are usually designed for installation into a particular type of torch and generally do not adapt to another make or model. They come in all sizes, shapes and materials. Gas nozzles are reasonable in cost, therefore they should be replaced when they become unusable. A nozzle which has chips or cracks or a metal build up on the outlet end should be discarded. These types of defects can alter the gas flow pattern from the nozzle and cause contamination of the weld metal. Typical nozzle configuration are shown in Fig 3.

Fig 3

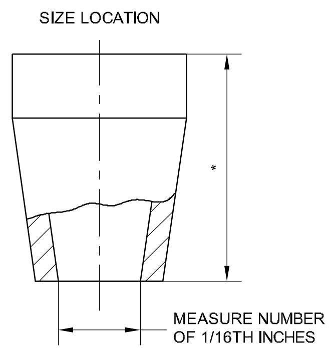


COMMON GAS NOZZLE AND GAS NOZZLE WITH GAS LENS

WG20N157713

Nozzles are identified by the size of the orifice (opening) and the length of the nozzle as shown in Fig 4 Each torch manufacturer assigns part numbers to the various nozzles for individual type torches and these must be used when ordering for replacement of nozzles.

Fig 4



WG20N157714

GTAW Welding consumables - Types & Specifications as per BIS & AWS

Objective: At the end of this lesson you shall be able to
- **decribe the GTAW consumables**
- **explain types and specifications.**

In the welding process (GTAW or gas tungsten) is an arc welding process taht operates the filler rods.

The TIG torch may be cooled by air or water and the process uses a filler metal in road form. The tungsten electrode selection and parameters for welds are guided them.

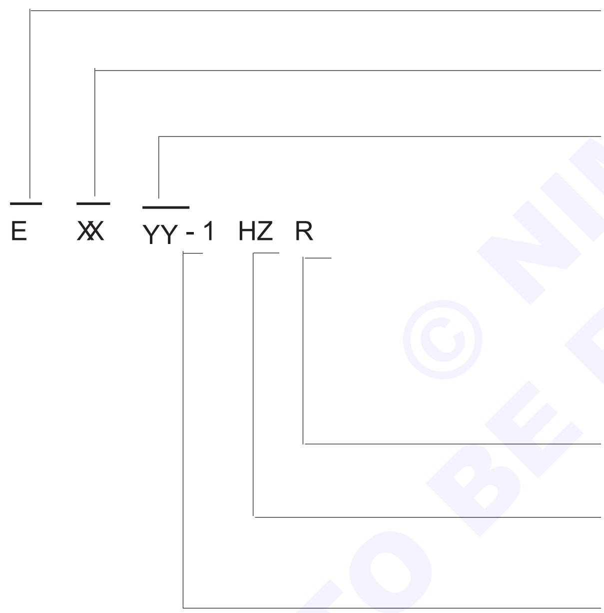
Gas tungsten arc welding also know as tungsten inert gas (TIG) welding, is an arc development within the GTAW process.

Now always the filler rods is withdraw from the weld pool each time the electrode can be changed.

The welding consumable used during TIG welding is usually rod-shaped. In the fully mechanical method, it is fed in wire form through a separate feed mechanism. Welding consumables are usually selected in the same way as the parent metal.

Welding filler metal designators

1 Carbon steel electrodes



Mandatory classification designators

Designates an electrode

Designates minimum tensile strength, in Ksi, of the as-deposited weld metal.

Designates the welding position, the type of covering and the type of welding current for which the electrodes are suitable (See table below)

Optional supplemental designators (Table 1)

Designates that the electrode meets the requirements of absorbed moisture.

Designates that the electrode meets the requirements of the diffusible hydrogen test - with an average value no exceeding "Z" mL of H2 per 100gms of deposited metal.

Designates that the electrode meet the requirements for improved toughness and ductility.

Table 1

Optional supplemental designators			
AWS Classification	**Type of covering**	**Welding position**	**Type of current [b]**
E6010	High cellulose, sodium	F,V,OH, H	dcep
E 6011	High cellulose, potassium	F,V,OH,H	as or dcep
E 7018	Low hydrogen, Potassium, Powder	F,V,OH,H	ac or dcep
E7024	Iron Powder, Titania	H-Fillets, F	ac, dcep or dcen

Note

a The abbreviations indicate the welding positions

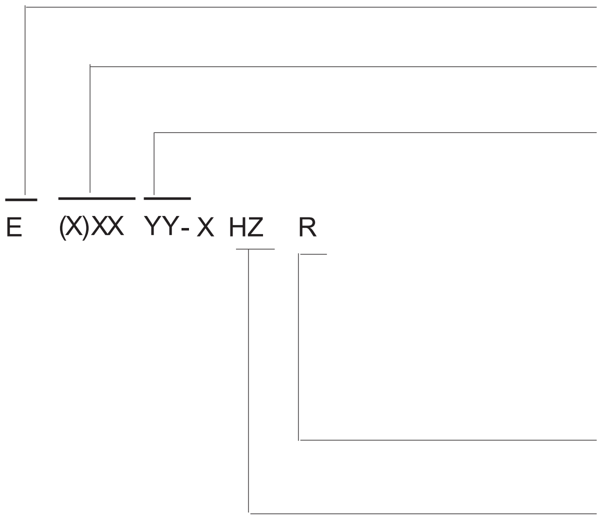
F=Flat; V=Vertical, OH=overhead, H=Horizontal, H=Fillets = Horizontal fillets.

b The term dcep refers to direct current electrode positive (dc, straight polarity)

Also note that the above electrode classifications are the most widely used and does not include all of the available classifications. **Refer to AWS A 5.1 for complete listing.**

2 Alloy steel electrodes

Mandatory classification designators



Designates and electrode

Designates minimum tensile strength, in Ksi, of the as-deposited weld metal

Designates the welding position, the type of covering and the type of welding current for which the electrodes are suitable.

Designates the chemical composition of the undiluted weld metal produced by the electrode using SMAW process.

Optional supplemental designators

Designates that the electrode meets the requirements of absorbed moisture.

Designates that the electrode meets the requirements of the diffusible hydrogen test - with an average value not exceeding "Z" mL of H2 per 100gms of deposited metal, where "Z" is 4,8 or 16.

Refer to AWS A 5.5 for complete listing of mechanical properties, chemical composition of as deposited weld metal and testing procedures for SMAW process.

3 Stainless steel filler metal (Table 2)

Usability classification

Table 2

Types of welding current and position of welding		
AWS classification	**Welding current**	**Welding position**
EXXX (X) - 15	dcep	All
EXXX (X) - 16	dcep or ac	All
EXXX (X) - 17	dcep or ac	All
EXXX(X) - 25	dcep	H,F
EXXX (X) - 26	dcep or ac	H,F

For more details on the usability classifications, refer to AWS A 5.4

Table 3: Carbon and low - alloy steel welding consumables for SMAW process

Table 3

Types of welding current and position of welding						
Base material	**Carbon steel**	**Carbon-molybdenum steel**	**1 and 1 1/4 Cr-1/2 Mo steel**	**2 1/4 Cr-1 Mo steel**	**5 Cr-1/2 Mo Steel**	**9 Cr - 1 Mo steel**
Carbon steel	AB	AC	AD	AE	AF	AG
Carbon-Molybdenum steel		C	CD	CE	CF	CH
1 and 1 1/4 Cr-1/2 Mo steel			D	DE	DF	DH
2 1/4 Cr-1 Mo steel				E	EF	EH
5 Cr - 1/2 Mo steel					F	FH
9 Cr-1 Mo steel						H

Legend

A AWS A 5.1 classification E 70XX low hydrogen (E7018 preferred)

B AWS A 5.1 classification E 70XX low hydrogen (E7018 preferred)

C AWS A 5.5 classification E70XX - A1, low hydrogen

D AWS A 5.5 classification E70XX - B2L or E80XX-B2, low hydrogen

E AWS A 5.5 classification E80XX-B3L or E80XX-B6L, low hydrogen

F AWS A 5.5 classification E80XX-B6 or E80XX-B6L, low hydrogen

G AWS A 5.5 classification E80XX-B7 or E80XX-B7L, low hydrogen

H AWS A 5.5 classification E90XX-B8 or E80XX-B8L, low hydrogen

1 Table 1 refers to coated electrodes (SMAW process) only. For bare wire welding (SAW, GMAW, GTAW and FCAW), use equivalent electrode classifications (AWS A 5.14, A 5.17, A5.18, A 5.20, A 5.23, At 28)

2 Higher allow electrode specified in the table should normally be used to meet the required tensile and toughness after post weld heat treatment (PWHT). If no PWHT is required, the lower alloy electrode specified may be required to meet the hardness requirements.

Table 4: Austenitic, super-austenitic and duplex stainless steel alloys

Types of welding current and position of welding										
Base Material	**304L SS**	**304H SS**	**316L SS**	**317L SS**	**904L SS**	**6% Mo SS**	**7% Mo SS**	**Alloy 20Cb-3**	**2304 Duplex SS**	**2205 Duplex SS**
Carbon and low alloy steel	ABC	ABC	ABC	ABC	ABC	ABC	ABC	ABC	N	N
Type 304L stainless stell	D	DE	DF	DG	DC	C	C	DCH	NL	NL
Type 304H stainless steel		E	EF	EG	*	*	*	ECH	*	*
Type 316L stainless steel			FG	FG	FC	FC	FC	FCH	NL	NL
Type 317L stainless steel				GC	GC	GC	GC	GC	L	L
Type 904L stainless steel					C	C	C	C	L	L
Type 6% Mo stainless steel						CJK	CJK	*	*	*
Eg: 254 SMO, AL 6XN							CJK	*	*	*
Type Alloy 20Cb-3								H	*	*
Type 2304 Duplex SS									LM	LM
Type 2205 Duplex SS										LM

Legend

A-AWS A 5.4 classification E309L-XX

B-AWS A 5.11 classification ENiCrFe-2 or -3 (-2 is alloy 718 and -3 is inconel 182)

C-AWS A 5.11 classification ENiCrMo-3 (Inconel 625)

D-AWS A 5.4 classification E308L-XX

E-AWS A 5.4 classification E308H-XX

F-AWS A 5.4 classification E316L-XX

G-AWS A 5.4 Classification E317L-XX

H-AWS 5.4 classification E320LR-XX

J-AWS A5.11 classification ENiCrMo-4 (Hastelloy C-276)

K-AWS A 5.11 classification ENiCrMo-11 (Hastelloy G-30)

L-AWS A 5.4 classification E2209-XX

M-AWS A 5.4 classification E2553-XX

N-AWS A 5.4 classification E309MoL-XX

Table 2 refers to coated electrodes only. For wire welding (GMAW & GTAW) use equivalent electrode classification (AWS A5.14)

There are many proprietary alloys available in the market and material combinations you might encounter. Consult the manufacturer or the DFD for proper filler metal selection.

Tables & data relating to TIG welding, Different type of weld joints- plates & pipes

Objective: At the end of this lesson you shall be able to
- **state the types of plate and pipe weld joints**
- **describe the parameters related to TIG welding.**

Welding low alloy steel

Mild and low carbon steels with less than 0.30% carbon and less than 25 mm thick, generally do not require preheat. Low alloy steels such as the chromium-molybdenum steels will have hard heat affected zones after welding, if the preheat temperature is too low. This is caused by rapid cooling of the base material and the formation of martensitic grain structures. A 90^0 to 200^0C preheat temperature will slow the cooling rate and prevent the martensitic structure.

Low alloy steel (DCSP) **Table 1**

Metal Gauge	Joint Type	Tungsten size	Filler Rod Size	Cup Size	Shield Gas Flow			Welding Amperes	Travel Speed
					Type	CFH (L/Min)	PSI		
1.6 mm	Butt Fillet	1.6 mm	1.6 mm	4, 5, 6	Argon	15 (7)	20	95-135	400 mm
3.2 mm	Butt Fillet	1.6 mm 2.4 mm	2.4 mm	4, 5, 6	Argon	15 (7)	20	145-205	300 mm
4.8 mm	Butt Fillet	2.4 mm	3.2 mm	7, 8	Argon	16 (6.5)	20	210-260	250 mm
6.4 mm	Butt Fillet(2)	3.2 mm	4.0 mm	8, 10	Argon	18 (8.5)	20	240-300	250 mm

Typical manual GTA (TIG) welding parameters (Table 2)

Aluminium (ACHF) **Table 2**

Metal Thickness	Joint Type	Tungsten size	Filler Rod Size	Cup Size	Shield Gas Flow			Welding Amperes	Travel Speed mm/min
					Type	CFH (L/Min)	PSI		
1.6 mm	Butt Fillet	1.6 mm	1.6 mm	4, 5, 6	Argon	15 (7)	20	60-80 70-90	300 250
3.2 mm	Butt Fillet	2.4 mm	2.4 mm 3.2 mm	6, 8	Argon	17 (8)	20	125-145 140-160	300 250
4.8 mm	Butt Fillet	3.2 mm	3.2 mm	6, 8	Argon/ Helium	21 (10)	20	190-220 210-240	250 230
6.4 mm	Butt Fillet	4.8 mm	3.2 mm	8, 10	Argon/ Helium	25 (12)	20	260-300 280-320	250 200

CFH - Cubic Feet per hour ACHF - Alternative current with high frequency L/Min - Litre per minute

Welding aluminium

The use of TIG welding for aluminium has many advantages for both manual and automatic processes. Filler metal can be either wire or rod and should be compatible with the base alloy.

Filler metal must be dry, free of oxides, grease, or other foreign matter.

Magnesium (ACHF) (Table 3)

Table 3

Metal Gauge	Joint Type	Tungsten size	Filler Rod Size	Cup Size	Shield Gas Flow Type	CFH (L/Min)	PSI	Welding Amperes	Travel Speed mm/min
1.6 mm	Butt Fillet	1.6 mm	2.4 mm 3.2 mm	5, 6	Argon	13 (5)	15	60 60	500
3.2 mm	Butt Fillet	2.4 mm	3.2 mm 4.0 mm	7, 8	Argon	19 (9)	15	115 115	450
6.4 mm	Butt Butt(2)	4.8mm	4.0 mm	8	Argon	25 (12)	15	100-130 110-135	550 500
12.8 mm	Butt(2)	6.4 mm	4.8 mm	10	Argon	35 (17)	15	260	250

Welding magnesium

Magnesium alloys are in three groups, they are (1) aluminium-zinc-magnesium, (2) aluminium-magnesium, and (3) maganese-magnesium. Since magnesium absorbs a number of harmful ingredients and oxidize rapidly when subjected to welding heat, TIG welding in an inert gas atmosphere is distinctly advantageous, the welding of magnesium is similar, in many respects, to the welding of aluminium. Magnesium was one of the first metals to be welded commercially by TIG. Magnesium requires a positive pressure of argon as a backup on the root side of the weld.

Welding stainless steel

In TIG welding of stainless steel, welding rods having the AWS-ASTM prefixes of E or ER can be used as filler rods. However, only bare uncoated rods should be used. Stainless steel can be welded using ACHF, however, recommendations for DCSP must be increased 25%. Light gauge metals less than 1.6 mm thick should always be welded with DCSP using argon gas. Follow the normal precautions for welding stainless such as: Clean surfaces; dry electrodes; use only stainless steel tools and brushes, carefully remove soap from welds after pressure testing; keep stainless from coming in contact with other metals.

Stainless steel (DCSP) Welding parameters (Table 4)

Table 4

Metal Gauge	Joint Type	Tungsten size	Filler Rod Size	Cup Size	Shield Gas Flow Type	CFH (L/Min)	PSI	Welding Amperes	Travel Speed mm/min
1.6 mm	Butt Fillet	1.6 mm	1.6 mm	4, 5, 6	Argon	11 (5.5)	20	80-100 90-100	300 250
3.2 mm	Butt Fillet	1.6 mm	2.4 mm	4, 5, 6	Argon	11 (5.5)	20	120-140 130-150	300 250
4.8 mm	Butt Fillet	2.4 mm 2.4 mm 3.2 mm	3.2 mm	5, 6, 7	Argon	13 (6)	20	200-250 225-275	300 250
6.4 mm	Butt Fillet	3.2 mm	4.8 mm	8, 10	Argon	13 (6)	20	275-350 300-375	250 200

What is welding joint

A welding joint is referred to an arrangement or configuration of two metal plates that will be fit together. The purposes of welding are infinite, and different processes require different types of welds and joints.

Types of Welding Joints

Following are the 5 main types of welding joints:

1 Butt joint welding

2 Lap joint welding

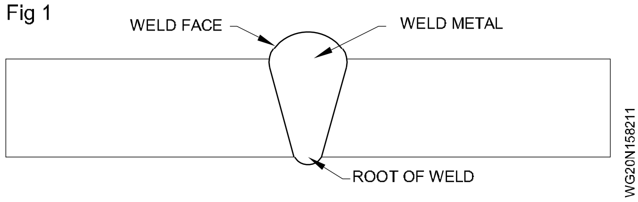
3 Edge joint welding

4 Tee joint welding

5 Corner joint welding

1 Butt Joint Welding (Fig 1)

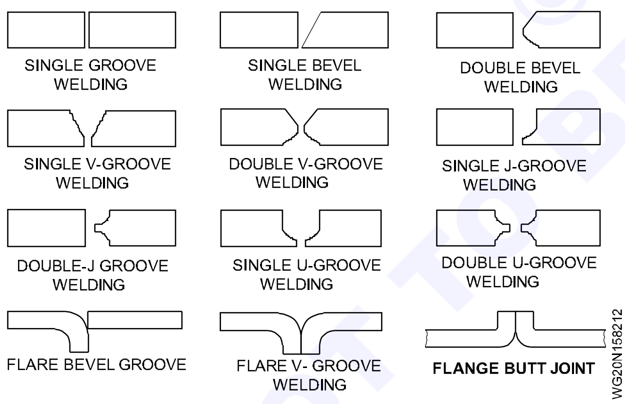
Fig 1



These types of welding joints form when the two metal pieces are placed end to end together in the same plane surface, it is known as butt joint welding. In welding, this is the most common type of joint. (Fig 2)

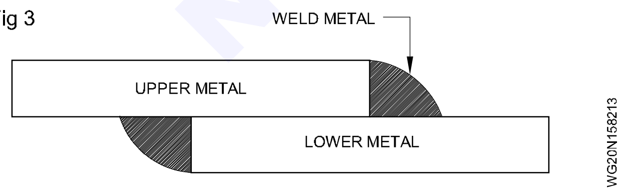
Usually, butt joint welding is used for the fabrication of structures, welding pipes, valves, fittings, and others.

Fig 2



2 Lap joint welding (Fig 3&4)

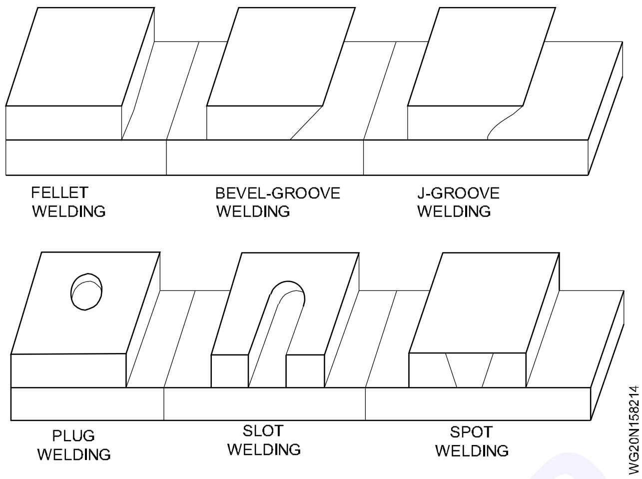
Fig 3



It is basically a modification of butt welding, in which the two metal plates are placed in an overlapping position that is on top of each other, it is known as lap joint welding.

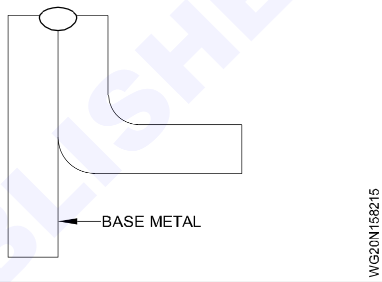
The lap joint welding is applied for welding two metal plates that are different in their thickness. In this, welding can be done on both sides of the plates for greater strength.

Fig 4



3 Edge joint welding (Fig 5&6)

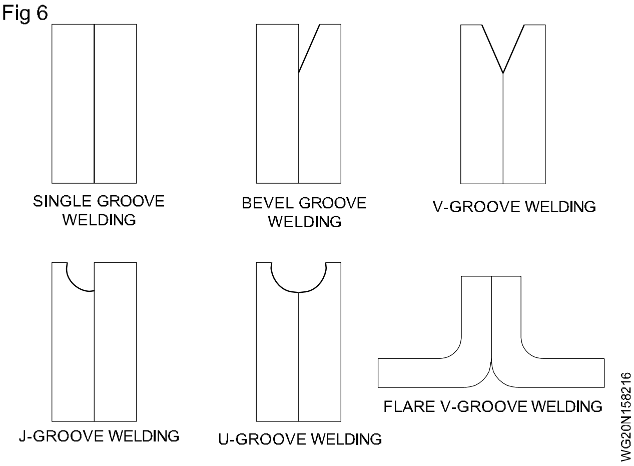
Fig 5



This is quite similar to the lap joint. In this, both the metal plate surfaces are placed together, that they are adjacent and generally parallel in position at the point of welding. It is known as edge joint welding.

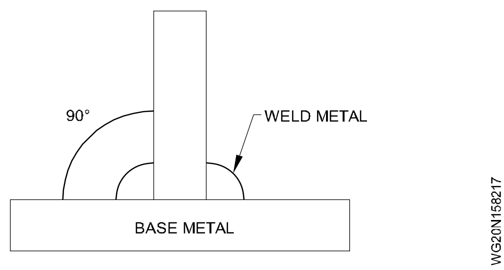
It is formed by bending both plates at an angle. In edge joint welding, the same edge of two plates is welded.

Fig 6



4 Tee joint welding (Fig 7&8)

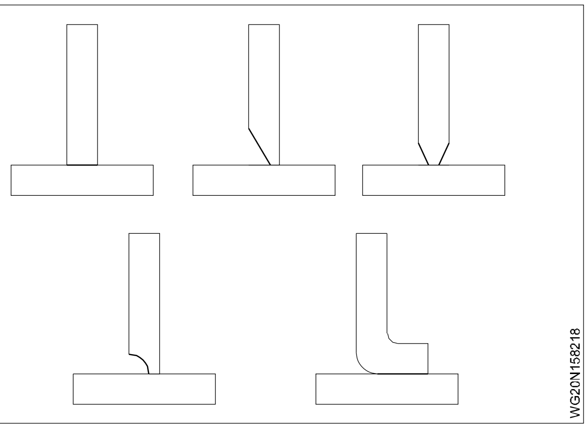
Fig 7



It is formed, when the two metal plates are intersected to an angle of 90° with one plate is lie on the center of the other plate like a "T" shape. It is known as tee joint welding.

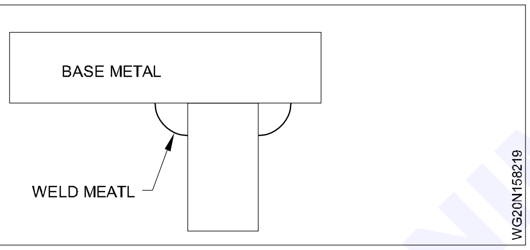
These types of welding joints are considered the use of fillet welds mounted on both sides. It is formed when a pipe is welded over a base metal. Commonly, tee joints are prepared with grooves, until the base metal is thick.

Fig 8



5 Corner joint welding (Fig 9&10)

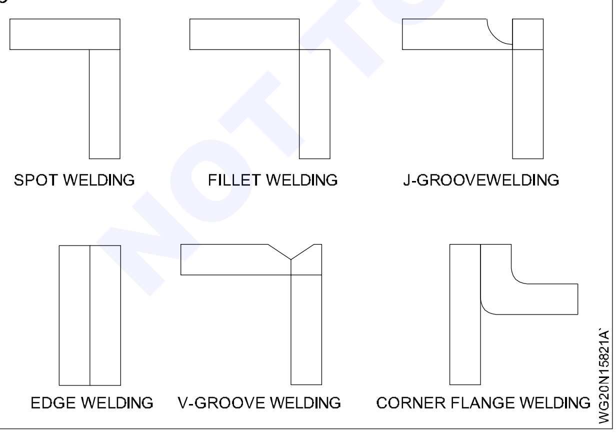
Fig 9



It is almost similar to the tee joint welding, the only difference is that in the position of the metal plates. As compared to the tee joint, plates are placed in the middle, whereas in the corner joint, both the plates meet in either an open or closed way to form a shape like "L".

These joints are some of the common types in the industries of sheet metals, such as in the manufacture of boxes, frames, and other applications.

Fig 10



Types of Pipe Joints in Plumbing

Different types of pipe joints used in plumbing system are as follows.

1 Threaded joint

2 Brazed joint

3 Soldered joint

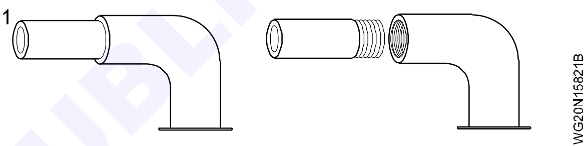
4 Welded joint (butt welded, socket welded)

5 Flanged joint

Threaded joint means, pipes are connected by screwing with the help of threads provided for each pipe. One pipe having internal threads and the other one having threads externally. Cast iron pipes, copper pipes, PVC and G.I pipes are available with threads. (Fig 11)

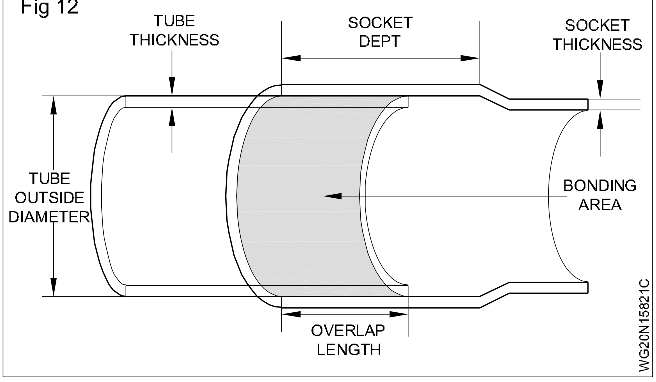
Threaded joints are available from 6mm diameter to 300mm diameter pipes. They are preferable for low temperature areas and low pressure flows. In the areas of high temperature, the joints may expands and leaked due to thermal expansion. Installation of threaded joint is easy but good maintenance required.

Fig 11



Brazed joints are generlly used to achieve higher joint strength or fatigue resistance. Yo accomplish this, filler metals stronger than those composed primarily of tin must be used. (Fig 12)

Fig 12

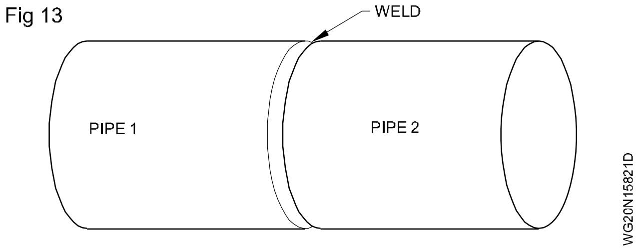


Soldering joint are material are material-closed joints (bonds) of two solderable metals. There are different forms of soldered joints. Wire-to-wire joints as parallel, cross or hook joints as well as soldered joints with twisted wires. Parallel and cross joints are mechanically connected by the solder only and, therefore, can be more easily detached.

The joint is heated above the melting-point temperature of the solder by means of the soldering iron and bonded with soldering tin added. Then the soldered joint must cool down with no displacement of the wires.

Groove welded joints, also called butt welds, are weldments that are commonly used when joining similar pipes together. They can also be used to join pipes to valves, fittings, and flanges for a secure attachment. (Fig 13)

Fig 13



For piping of certain thickness, the pipe may be cut at a sloping right angle before being welded.

A flange is a method of connecting pipes, valves, pumps and other equipment to form a piping system. It also provides easy access for cleaning, inspection, or modification.

Flanges are usually welded or screwed. Flanged joints are made by bolting together two flange with a gasket between them to provide a seal. (Fig 14)

When two pipes are joined together by making grooves (narrow cuts or depression) at the end of pipes with the help of sockets or couplings, such joints are called grooved joints

Due to the ease of assembly of the grooved joints, the labour cost is less. The piping system can be easily uninstalled and reinstalled frequently for maintenance. These are mostly used for fire protection. (Fig 15)

Fig 14

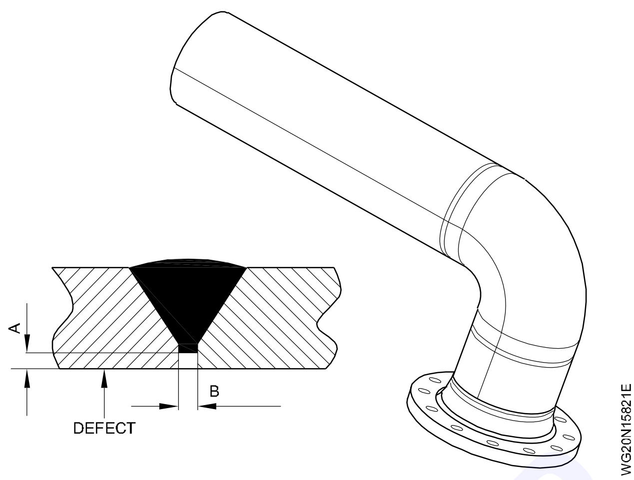
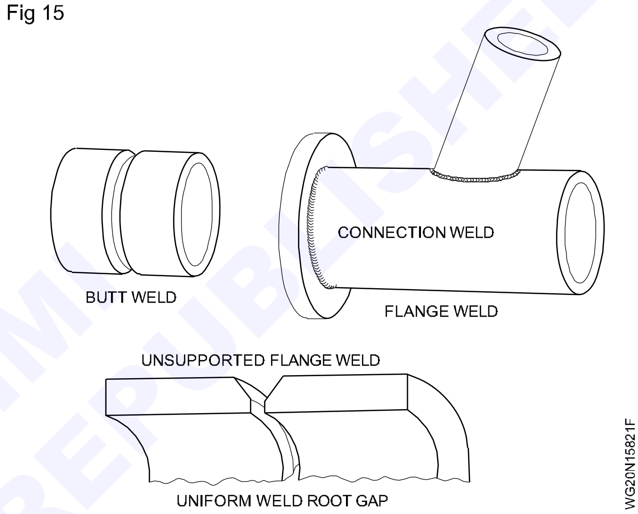


Fig 15



Edge preparation of plates & pipes

Objective: At the end of this lesson you shall be able to
- **decribe the edge preparation of plate & pipes**
- **name the different types of plates & pipes.**

GTAW/TIG welding is generally recommended for pipe to pipe or tube to tube joints. TIG welding with inert gas shielding produces the joints without any defect like gas porosity, oxide slag inclusions and hence the joints are of superior quality.

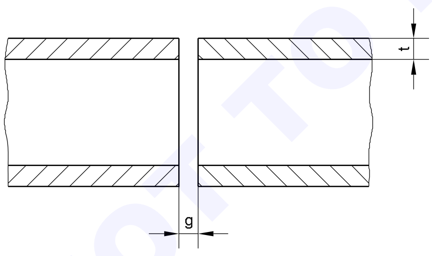
For MS/Carbon steel pipes and tubes, when welding is done with TIG process, the weld metal is free from hydrogen entrapment which usually occurs in normal oxy acetylene gas welding or manual metal arc welding processes. The hydrogen gas dissolved in the weld causes embrittlement during service. Hence TIG welding for MS pipes is always preferred for all pipe lines viz., gas pipe lines/liquid lines in all petroleum and power plant to convey high temperature and high pressure fluids (liquids & gases,steam etc.).

There are various pipe jointings like straight butt welds, fillet tee joints and pipe elbow joints to suit the piping layout of any process plant say petroleum or power generating plant.

Therefore it is mandatory to take utmost care in development of members of pipe joints so that the geometry will provide appropriate clearances for the joint fit up and the TIG welds so produced will be free from any defect and will offer highest joint efficiency as per the design standards.

Various configuration of the joints are well shown in practical Exercise book. (Figs 1, 2, 3 & 4)

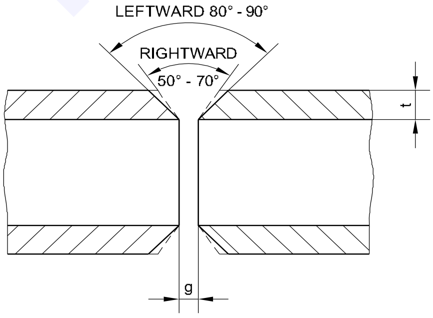
Fig 1



PIPE ENDS SQUARE

WG20N158511

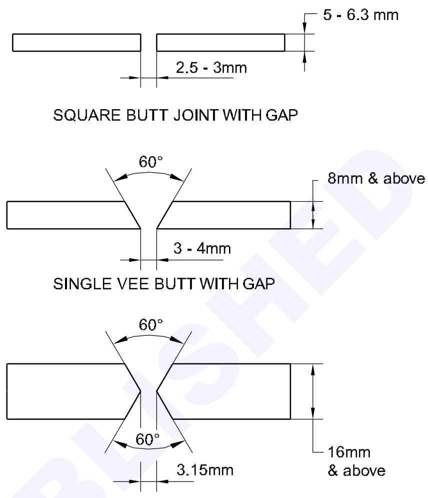
Fig 2



PIPE ENDS BEVELLED

WG20N158512

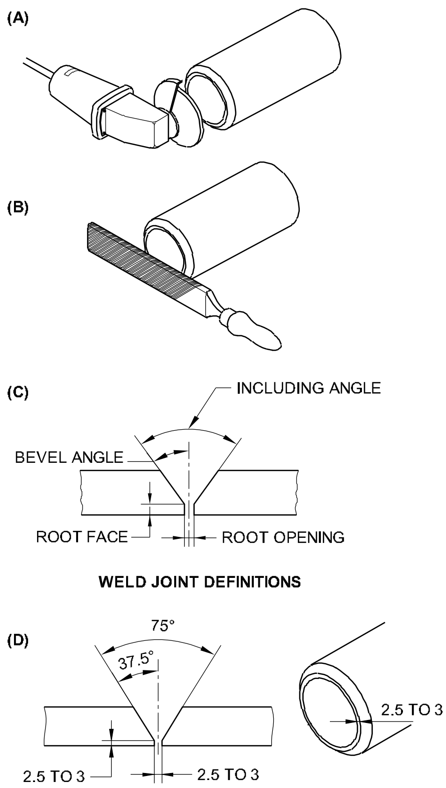
Fig 3



EDGE PREPARATION FOR RIGHTWARD WELDING

WG20N158513

Fig 4



WG20N158514

Fitting of joint plates for TIG Welding

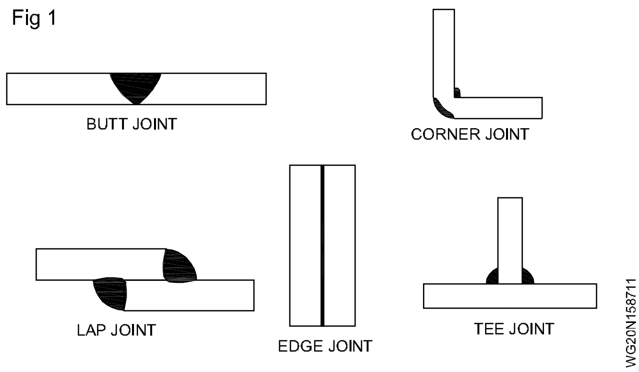
Objective: At the end of this lesson you shall be able to
- **to know about types of welding joints and breif description.**

The five basic weld joints include the butt joint, the lap joint, the tee joint, the corner joint, and the edge joint. The butt joint accurs when two members are placed sided-by-side or butted together. (Fig 11)

Butt joint

A butt weld is one of the simples and versatile types of weld joint design. The joint is formed simply by placing two pieces of metal end-to end.

Fig 1



Lap Joint Welding

Lap welding joints are essentially a modified version of the butt joint. They are formed when two pieces of metal are placed in an overlapping pattern on top of each other. They are most commonly used to joint two pieces with differing thicknesses together. Welds can be made on one or both sides.

Corner joint

Corner joint welding refers to instances in which two materials meet in the "Corner" to for and L-shape. You can use corner joints to construct sheet metal parts, including frames, boxes, and similar applications.

Tee Joint Welding

Tee welding joints are formed when two pieces intersect at a 90° angle. This results in the edges coming together in the center of a plate or component in a 'T' shape. Tee joints are considered to be a type of fillet weld, and they can also be formed when a tube or pipe is welded onto a base plate.

Edge Joint Welding

In an edge joint, the metal surfaces are placed together so that the edges are even. One or both plates may be formed by bending them at an angle. The purpose of a weld joint is to join parts together so that the stresses are distributed.

Advantages of root pass welding of pipes by TIG welding

Objective: At the end of this lesson you shall be able to
- **describe the advantages of root pass welding.**

Advantages of root run pipe welding in TIG

- Excellent control of weld penetration.
- Produces high purity and defect free weld.
- Little post weld cleaning is required compared with other welding process.
- It does not require cleaning after weld because does not produce slag, spatter, frames.
- Increase the weld depth to the desired thickness and yielding necessary strength.

Types of weld defects, causes and remedy in GTAW process

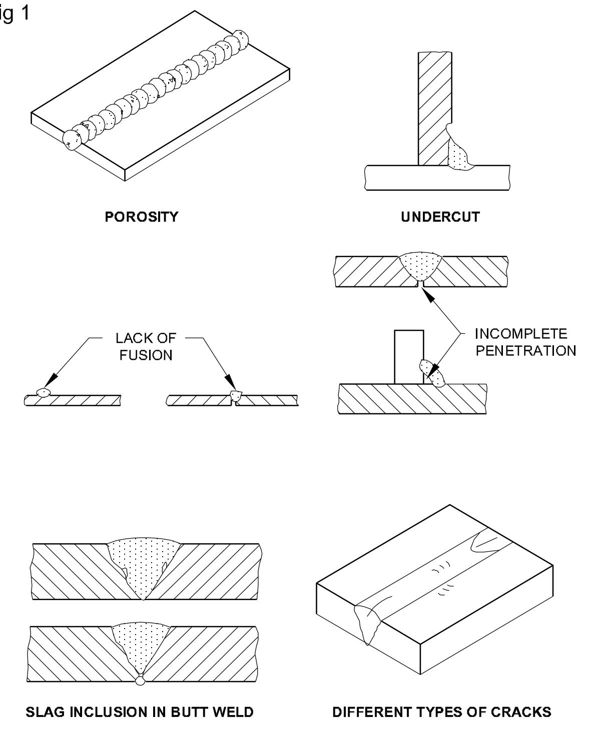
Objective: At the end of this lesson you shall be able to
- **state the different type of defects in GTAW**
- **state the causes and remedies of GTAW defects.**

The following Table 1 relates to the cause and prevention of the more common defects encountered in welds made by the TIG welding process. (Fig 1)

Table 1

Defect	Appearance	Cause	Remedy
Porosity	Pin holes in the weld.	Insufficient shielding gas. Bore of gas nozzle too small arc length too long. Surplus degreasing agent.	Satisfactory supply gas. Correct ceramic shield. Remove all degreasing agents and dry. Shorten arc length.
Undercut	Irregular grooves or channels	Incorrect welding technique. Current too high. Incorrect welding speed.	Correct current. Correct rod manipulation. Clear weld surface. at the toes of the weld.
Lack on fusion. (side root or inter run)	Surface on to which weld is deposited has not been melted. Not always visible. Usually	Incorrect current level. Incorrect filler rod manipulation. Unclean plates surfaces. detected by bend test or by non-destructive techniques (e.g.ultrasonic flaw detection).	Correct current. Use correct rod manipulation. Clean plate surfaces.
Lack of Penetration	Notch or gap at the root of a weld.	Incorrect preparation and set up. Incorrect current level. Welding speed too fast.	Use the correct preparation and set up. Correct current. Correct weld speed.
Inclusions	Usually internally and only detected by suitable testing techniques. Normally oxide or tungsten inclusions.	Oxide inclusions. Inadequate cleaning of parent material before welding. Contamination onsurface of filler rod. Inadequate protection of underside of a weld.Loss of gas shield.	Clean all metal surfaces. Ensure a satisfactory supply of shielding gas. Excluide draughts.
Cracking	Cracks can occur in the weld metals and in the parent metal alongside the weld. They may not be visible on the surface and may only be detected by the use of suitable testing techniques.	The type of crack and therefore its cause will depend on the material being welded. The correct diagnosis of the cause of a crack frequently calls for expert knowledge.	Use correct welding procedure. Pre-heating and post heat treatm-ent. Use correct preparation Set up current. Use correct filler rod. Always adhere strictly to the procedure specified when welding materials that are susceptible to cracking. Always ensure the correct type of filler is used and the correct amount of filler metal is added.

Fig 1


POROSITY
UNDERCUT
LACK OF FUSION
INCOMPLETE PENETRATION
SLAG INCLUSION IN BUTT WELD
DIFFERENT TYPES OF CRACKS
WG20N158911

Purging: Importance, Method of giving

Objective: At the end of this lesson you shall be able to
- **explain the importance of purging**
- **describe the methods of purging.**

Purging is an important part of a good calibration procedure and should always be practised when handling dangerous gases. Purging ensures that you have control over which gases are in your gas delivery system, and therefore which gases are being exposed to internal components, sensors or other equipment. It also helps to prevent unwanted reactions from taking place, which can greatly increase the service life of related components.

There are several main reasons for purging

Removing resident gases from a system before introduction of a new gas or gas mixture which may react.

Removing impurities from a system delivering a pure gas sensitive gas mixture.

Removing dangerous or damaging gas from a system after use.

Purging methods

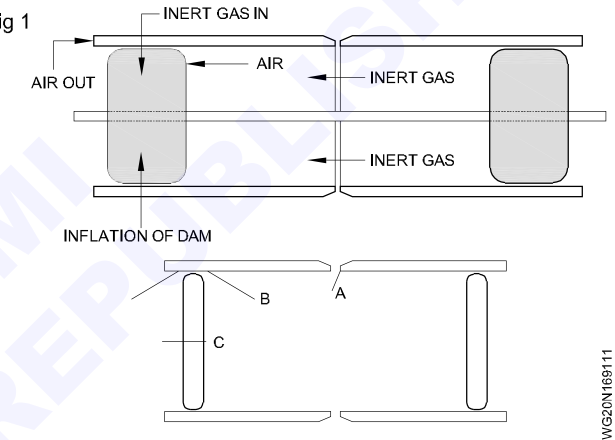
Weld purging is a process where oxygen is evacuated from a pipe, tank, or chamber using a noble gas such as argon or nitrogen. This process prevents oxygen from entering the weld pool, which can cause poor quality and loss of corrosion resistance.

Following methods are used for purging

The most common method is to remove gas from the weld zone is to flush it way with an inert gas (Argon, Helium, etc,). The weld zone can be contained to prevent fresh gas from entering once the contained volume has been purged.

Another method of purging is to enclose the metal parts completely in a vacuum chamber and evacuate it, prior to backfilling with inert gas for the welding process. (Fig 1)

Fig 1



Weldability of metals

Objective: At the end of this lesson you shall be able to
- **explain the effects of weldable quality on ferrous and non-ferrous metals.**

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 and Post heating, distortion and methods of control, Arc welding - Principles, application- Types of fluxes, welding head, power source and Parameter setting

Objective: At the end of this lesson you shall be able to
- **explain the necessity of heat treatment in welding**
- **describe different methods of heat treatment applied in welding**
- **state the purpose of preheating**
- **state the purpose of post heating.**

Different methods of heat treatment

Direct preheating, Indirect preheating, Local preheating

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

Table 1

Preheating of various metals

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

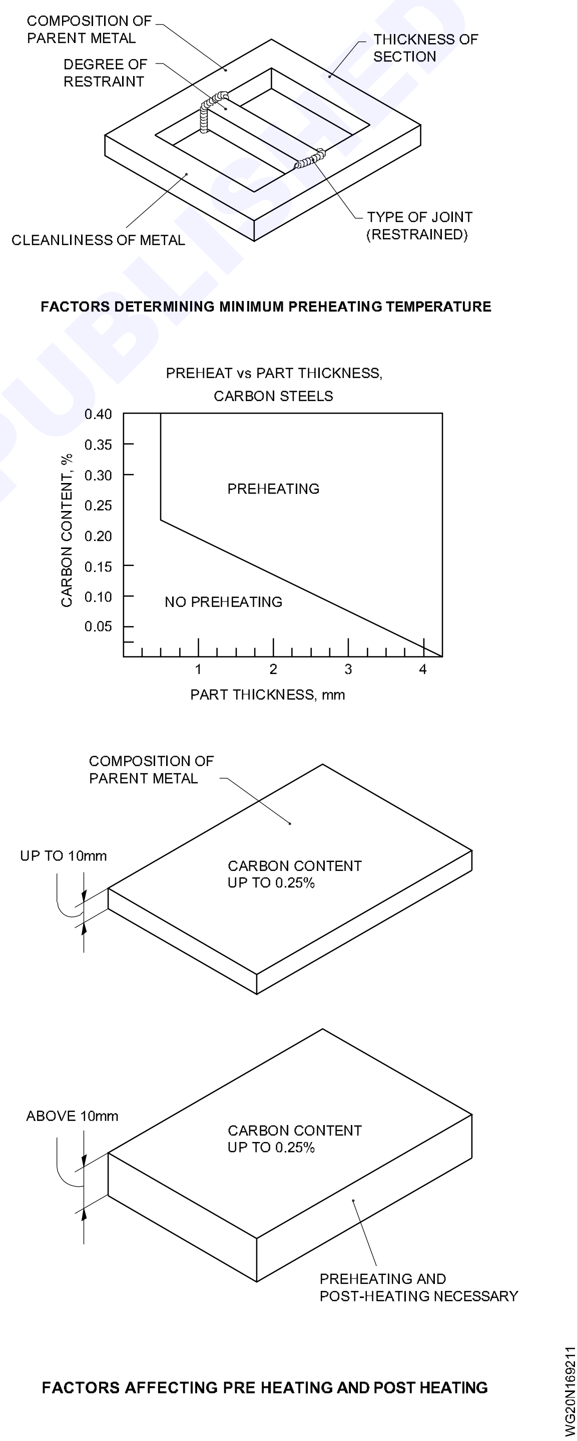
The preheating reduces the rate of cooling after welding. This is necessary to prevent the weld metal from cracking in restrained/rigid joints. Also some of the non-ferrous metals like copper, brass, aluminium, etc. expand more due to heating and ferrous metals like cast iron, medium and high carbon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

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

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

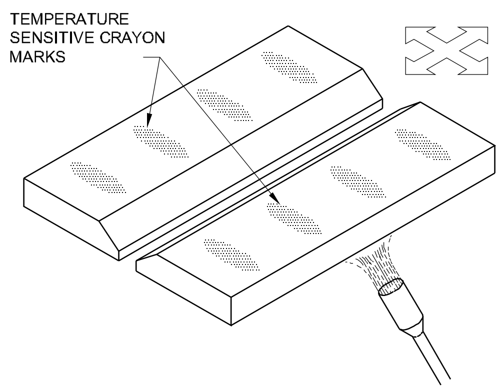
Do not allow the temperature to drop below the minimum preheating temperature between each weld run.

Fig 1



The preheating temperature can be checked by temperature indicating crayons. (Fig 2)

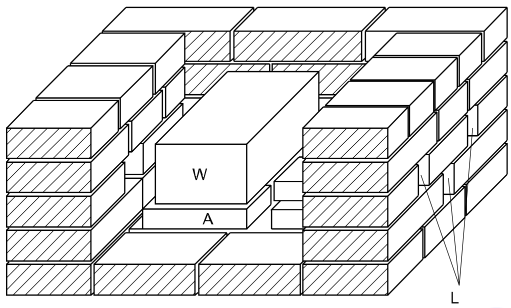
Fig 2



PREHEAT PLATES TO 200°C USING TORCH OR FURNACE AND USE OF CRAYONS

If the job and area to be preheated are large, then it is done in a preheating furnace (Fig 3).

Fig 3

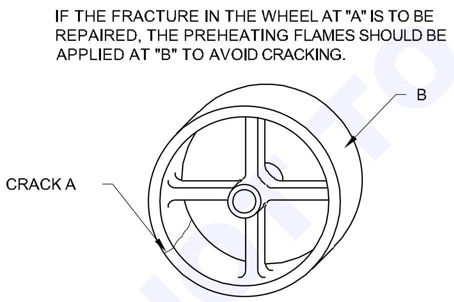


A - SUPPORTING BRICKS, W - WELDED JOB, L - AIR VENTS

TEMPORARY BRICK FURNACE FOR REPAIR WORK

If it is small localised preheating is applied to the joint area only. This is called local preheating. (Fig 4)

Fig 4



TECHNIQUE OF LOCAL PREHEATING

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

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

– the rate of heating

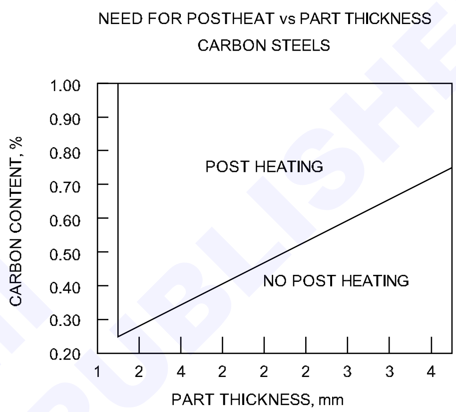
– temperature to which the part is to be post-heated

– holding time in the furnace

– the rate of cooling.

Post heating of carbon steels depends on the thickness of the base metal and its carbon content. (Fig.5)

Fig 5



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

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

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

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

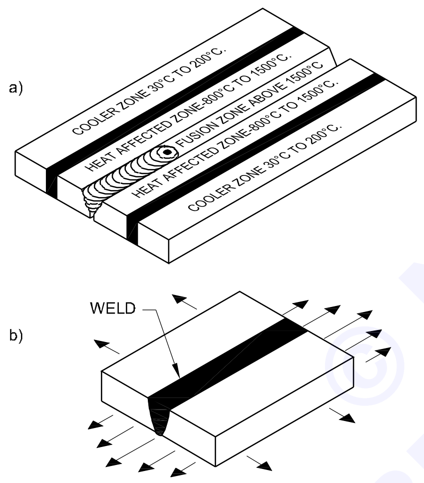
To avoid the above problems a welded job is usually either normalised or annealed or stress-relieved.

Distortion and its 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.**

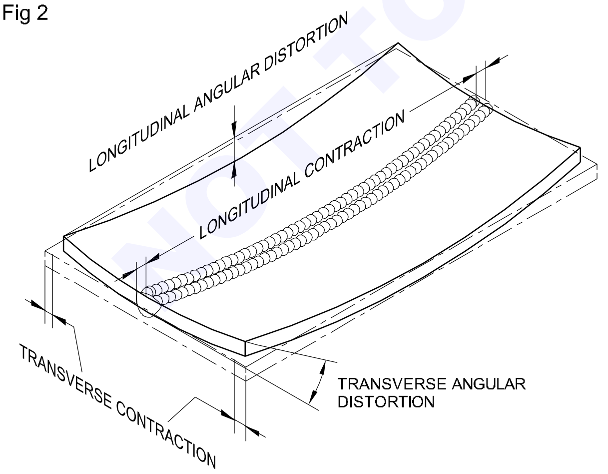
Causes of distortion: In arc welding, the temperature at different areas of the joint are different. (Fig 1a). The expansions in these areas are also different depending on the temperature (Fig 1b). In the same way after welding, different areas of the joint contract differently, But in a solid body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

Fig 1



EXPANSION OF A PLATE DURING WELDING (MILD STEEL)

Fig 2



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

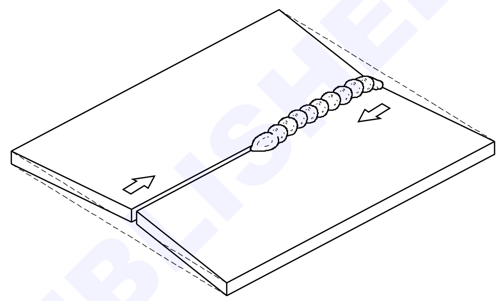
Types of distortion

The 3 types of distortion are:

- longitudinal distortion
- transverse distortion
- angular distortion.

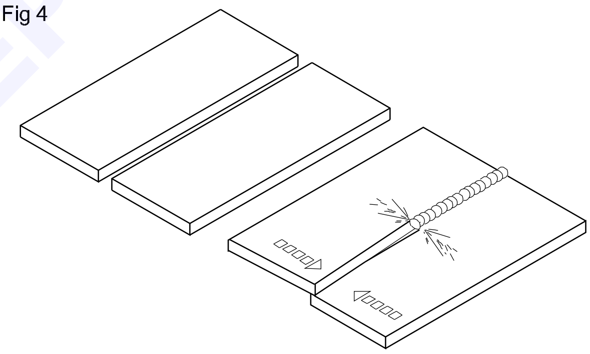
The figures (3,4,5) illustrate the different types of distortion.

Fig 3



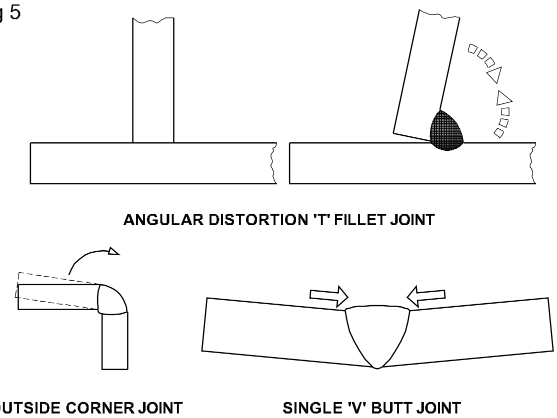
LONGITUDINAL DISTORTION

Fig 4



TRANSVERSE DISTORTION

Fig 5



Factors affecting distortion

Design

Parent metal

Joint preparation and set up

Assembly procedure

Welding process

Deposition technique

Welding sequence

Unbalanced heating about the neutral axis

Restraint imposed

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

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

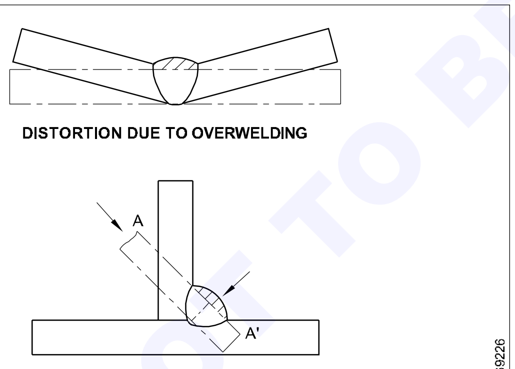
- Reducing the effective shrinkage force.
- Making the shrinkage forces to reduce distortion.
- Balancing the shrinkage force with another shrinkage force.

Methods of reducing the effective shrinkage forces

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

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

Fig 6

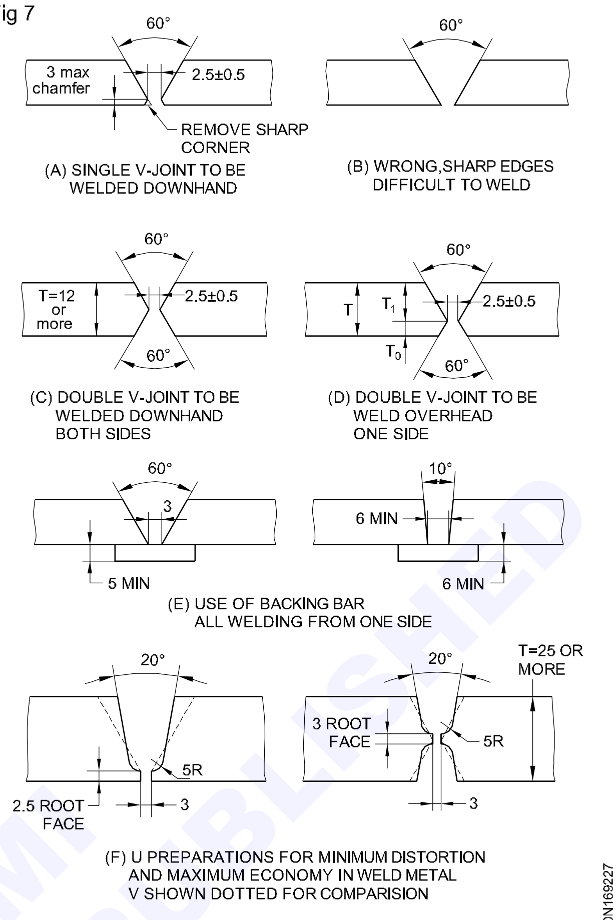


EXCESS WELD METAL ABOVE THE LINE A A' OF CONVENTIONAL FILLET WELD

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

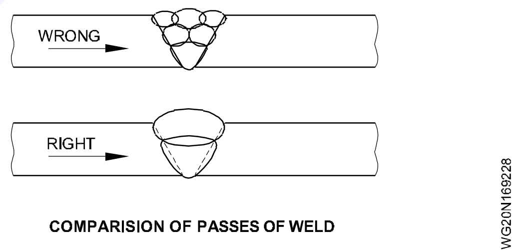
Use of few passes: Use of fewer passes with large dia. electrodes reduces distortion in the lateral direction. (Fig8)

Fig 7



PREPARATION OF PLATES FOR BUTT WELDING

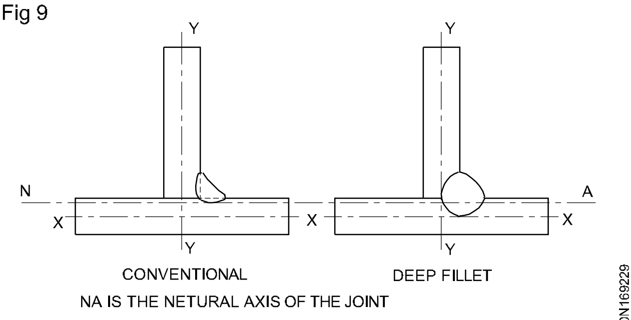
Fig 8



COMPARISION OF PASSES OF WELD

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

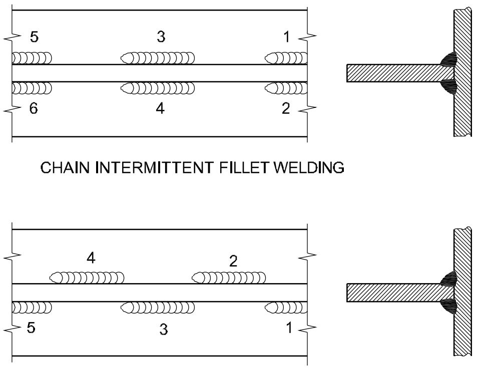
Fig 9



DEEP PENETRATION FILLET WELD

Use of intermittent welds: Minimize the amount of weld metal with the help of intermittent welds instead of continuous welds. This can be used with fillet welds only. (Fig 10)

Fig 10

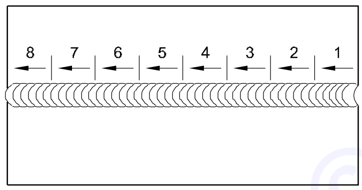


STAGGERED INTERMITTENT FILLET WELDING

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

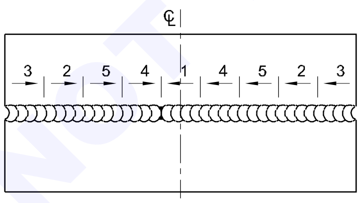


BACK STEP WELDING METHOD

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)

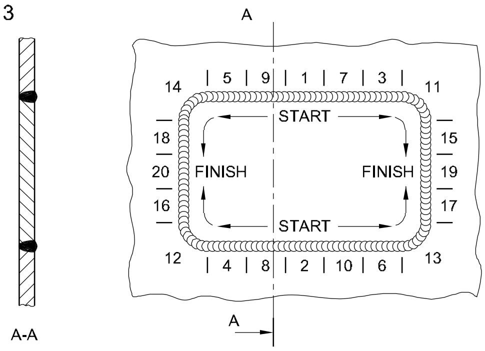
Fig 12



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



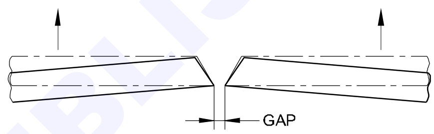
AS USED TO MINIMIZE LOCKED UP STRESSES IN TIED JOINT

SKIP WELDING

Methods used for making the shrinkage forces work to reduce distortion

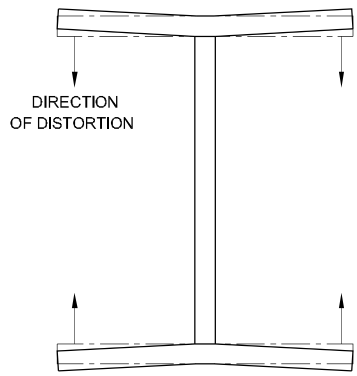
Locating parts out of position: Distortion may be allowed for by pre-setting the plates in the opposite way so that the weld pulls them to the desired shape. When the weld shrinks it will pull the plate to its correct position (Fig 14 & 15)

Fig 14



PRE-SETTING TO COMPENSATE FOR ANGULAR DISTORTION

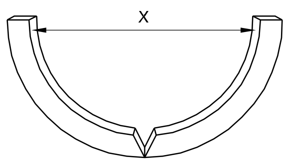
Fig 15



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

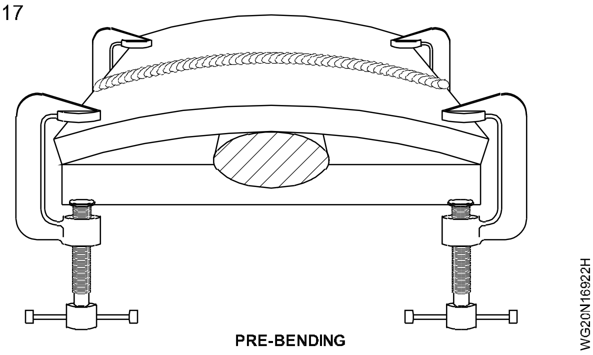


X = DIAMETER + SHRINKAGE ALLOWANCE

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

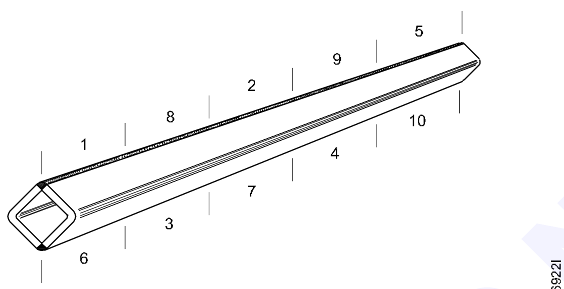


PRE-BENDING

Methods of balancing of one shrinkage force with another shrinkage force

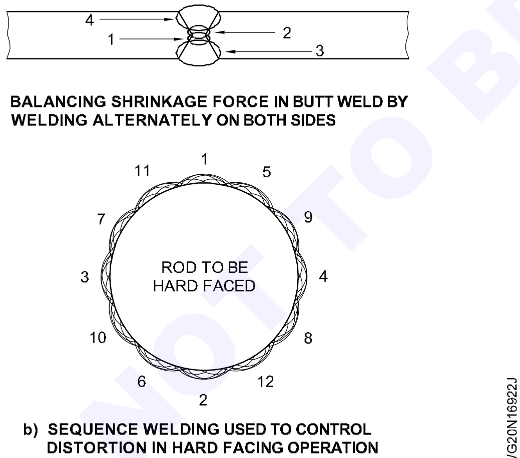
Use of proper welding sequence: This places the weld metal at different points about the structure. In this method, welds are made from each side alternately so that when a second run of weld metal shrinks it will counteract the shrinkage forces of the first weld. (Figs 18, 19 a and 19b)

Fig 18



AS USED WHEN FABRICATING SQUARE SECTIONS FROM ANGLES OR CHANNELS

Fig 19

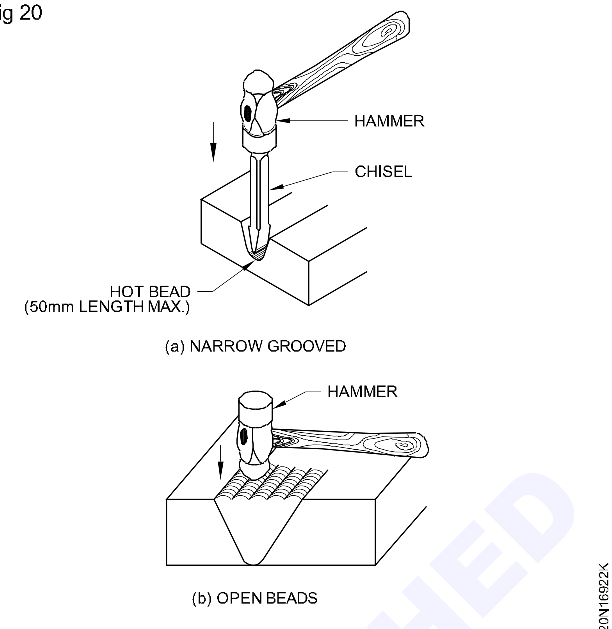


a) BALANCING SHRINKAGE FORCE IN BUTT WELD BY WELDING ALTERNATELY ON BOTH SIDES

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.

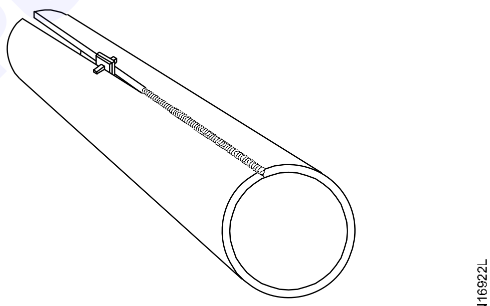
Fig 20



PEENING

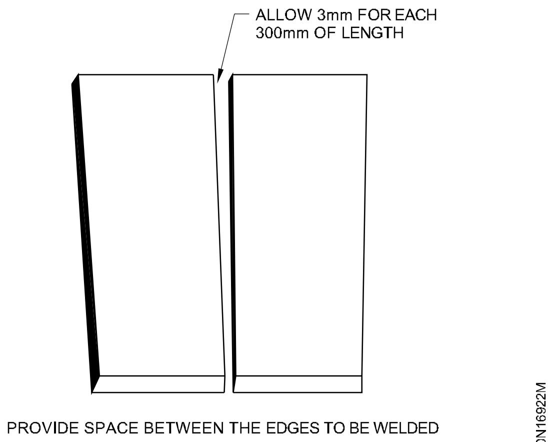
Divergence allowance: As there is a tendency of the plates to extend & converge along the seam during welding, this technique is used to diverge the plates from the point where welding commences by placing a wedge or an alignment clamp between the plates ahead of the weld. (Fig 21& 22)

Fig 21



DIVERGENCE ALLOWANCE

Fig 22



DIVERGING ALLOWANCE

The spacing allowances are as follows.

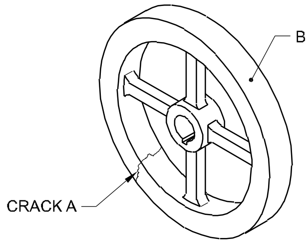
3mm/m for (mild steel) Ferrous metals

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



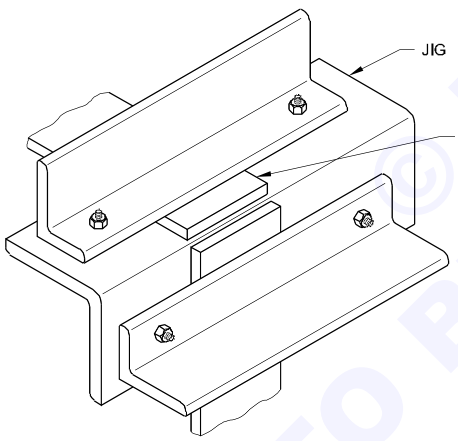
IF THE FRACTURE IN THE WHEEL AT 'A' IS TO BE REPAIRED. THE PREHEATING FLAME SHOULD BE APPLIED AT 'B' TO AVOID CRACKING.

TECHNIQUE OF LOCAL PREHEATING

WG20N16922N

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

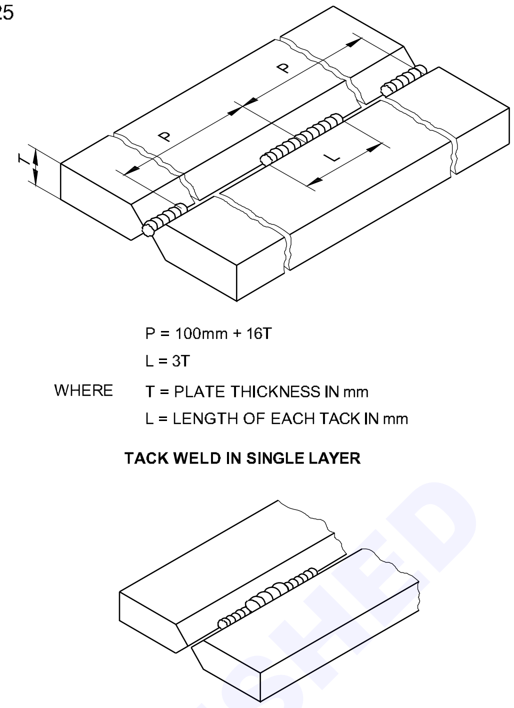
WG20N16922O

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}.

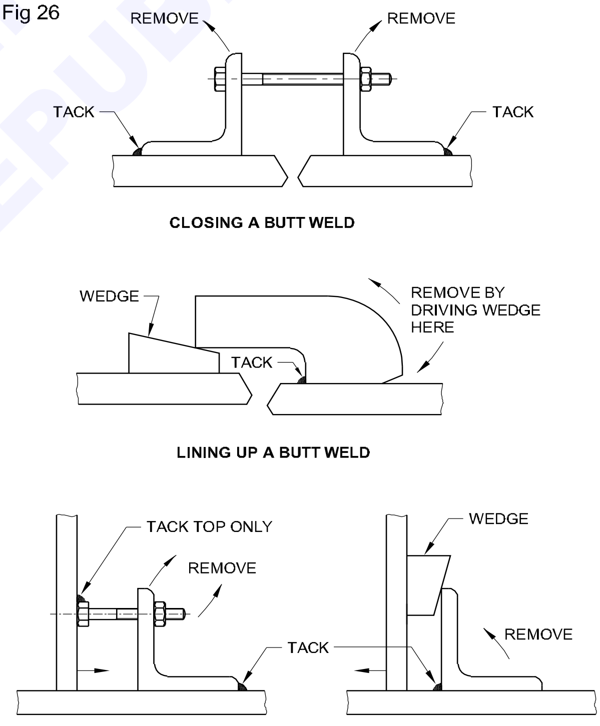
Fig 25



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

WG20N16922P

Fig 26



TACK WELDING ERECTION CLEATS AND AIDS TO ASSEMBLY

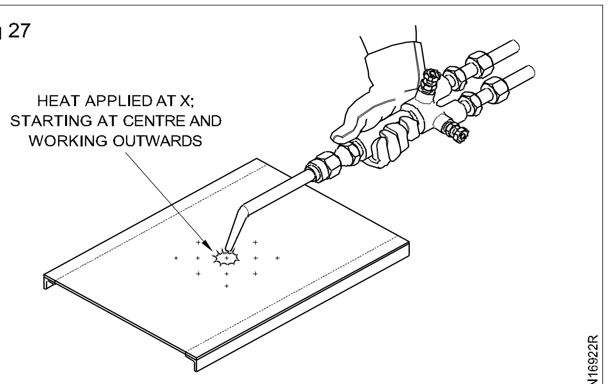
WG20N16922Q

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.

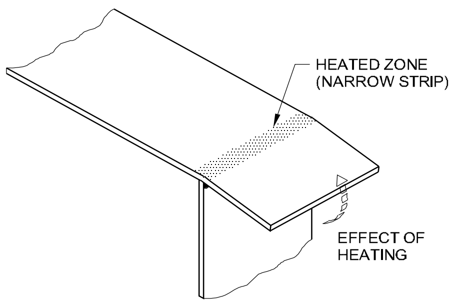
Fig 27



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.

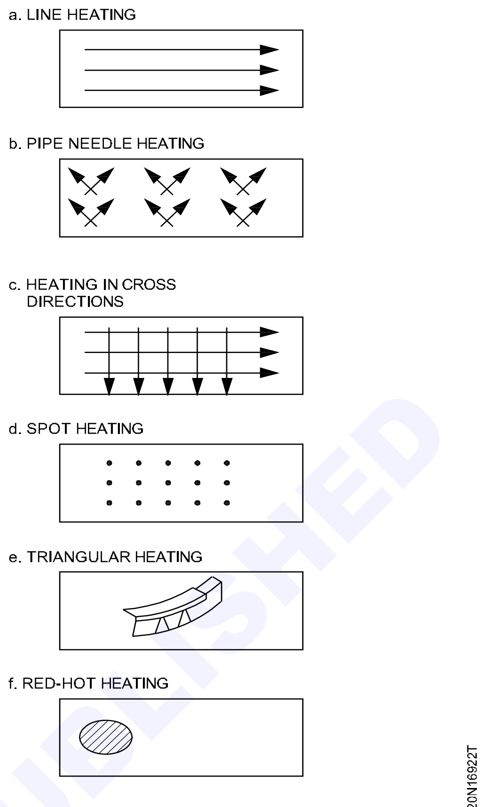
In checker board (cross-directions) heating, (Fig 29c) heat is applied along a pair of two lines crossing each other. This method is used to remove severe distortion.

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.

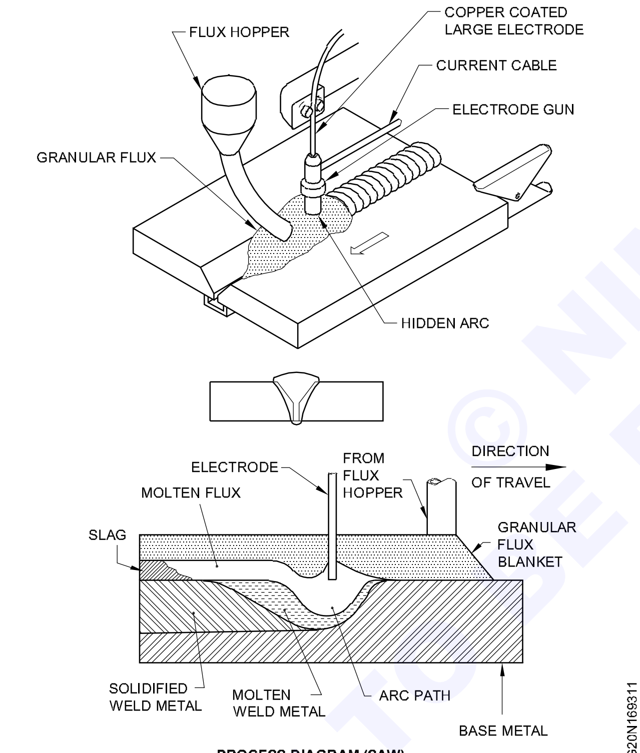
Vibration stress relieving: This technique reduces distortion by means of vibrating the weldments. The equipment consists of a variable speed vibrator, which is clamped to the work piece, and an electronic amplifier, by varying the speed of the vibrating motor, the frequency can be varied until a resonant 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.

Submerged Arc welding - Principles, application- Types of fluxes, welding head, power source and Parameter setting

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

Principles of submerged arc welding: Submerged arc welding is an arc welding process that uses an arc between a bare metal electrode and the weld pool. The arc and the molten metal are hidden by a blanket of granular flux on the workpieces. (Fig 1)

Fig 1



PROCESS DIAGRAM (SAW)

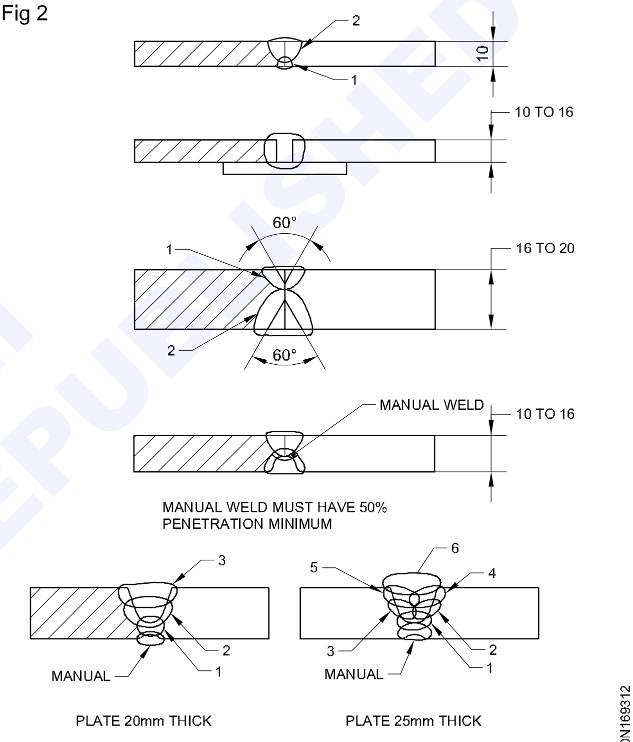
Metals which can be welded by SAW: In submerged arc welding, low and medium carbon steels, low alloy steels, high strength steels, quenched and tempered steel and stainless steel can be welded.

Metals weldable by saw

Base metal	Weldability
Wrought iron	Weldable
Low carbon steel	Weldable
Low alloy steel	Weldable
High and medium carbon	Possible but not popular
High alloy steel	Possible but not popular
Stainless steel	Weldable

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

Fig 2



TYPES OF BUTT WELDS

For plate thicknesses higher than 25mm a double Vee or single U or double "U" edge preparation is done Fig.3 shows fillet welds done by submerged arc welding.

The "T" and Lap joints shown in Fig.3 are tilted to 45^0 to weld them in flat position. If the thickness of plates are more than 16mm in T fillet joint then the edge of the vertical plate is bevelled by 45^0 and the joint is welded without a root gap.

Types of submerged arc welding process

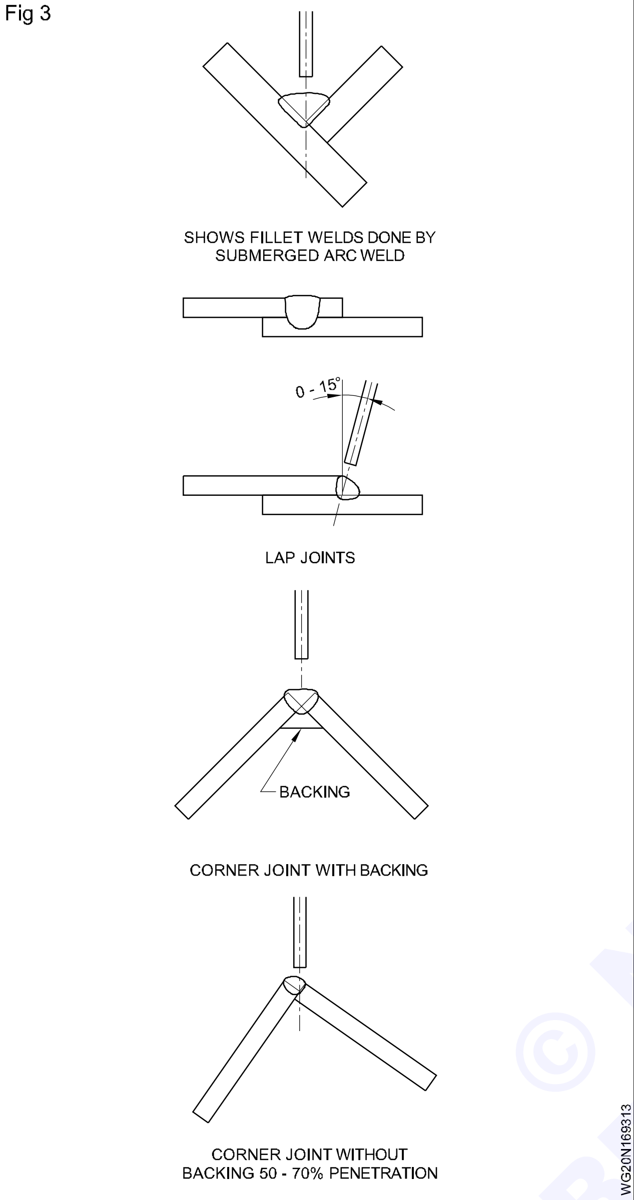
There are two types of SAW.

- Automatic
- Semi-automatic

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

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

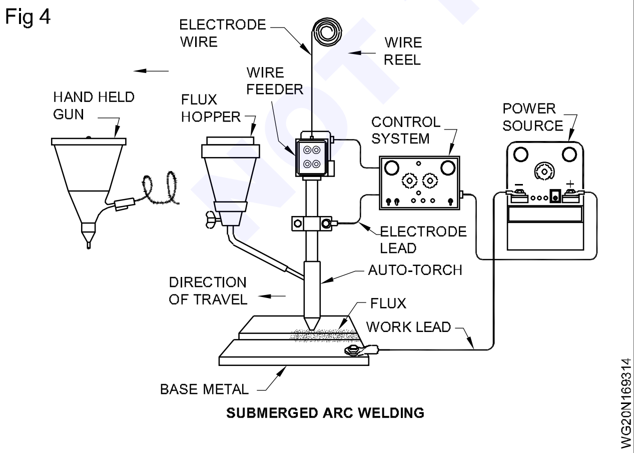
Fig 3



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

A wire feeder to drive the electrode to the work through the contact tube of the welding gun or welding head.

Fig 4



A welding power source to supply welding current to the electrode at the contact tube.

Arrangement for holding the flux and feeding it on the head of the arc.

A means of traversing the joint.

Fluxes: Fluxes used with submerged arc welding are granulated fusible mineral materials which are free from substances capable of producing large amount of gas during welding.

Flux when cool is non-conductive, but when molten it is highly conductive and allows high current.

The flux protects the weld pool from atmospheric contamination and influences deep penetration.

Electrode: Bare or lightly copper coated rods or wires are used as electrodes in SAW. These electrodes are available in coil or reel form.

Standard reels with diameters 2 to 8 mm are available.

Welding procedure (for striking the arc): The electrode momentarily contacts the work and is withdrawn slightly.

Arc start: Arc starting is difficult in submerged arc welding because of the flux cover. It is important to start the weld at a specific point on the joint.

Method of starting arc by using steel wool or iron powder: A rolled ball of steel wool 10 mm in dia. is placed at the required spot on the joint and the electrode wire is lowered on to it till it is lightly compressed. The flux is then applied and when the welding is commenced the steel wool or iron powder conducts the current from the wire to the workpiece, while at the same time it melts away rapidly as the arc is formed.

Clean the prepared workpiece and place it in position with provision for backing up. Fill the hopper with flux and insert the electrode ends into the welding head.

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

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

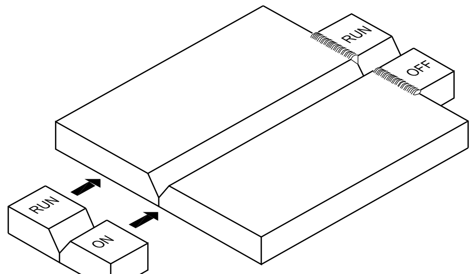
The entire welding zone is buried under a blanket of flux and longitudinaly it travels along the seam.

Use 'run on' and ' run off ' pieces for starting and ending to avoid formation of crater and beginning and ending faults. (Fig 5)

Advantages of SAW

– High quality weld metal
– High deposition rate and speed
– Smooth, uniform finished weld
– No spatter
– Little or no smoke
– No arc flash
– High utilization of electrode wire
– No need for protective clothing

Fig 5



ATTACHING EXTENSION PIECES

WG20N169315

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

Table 1

Submerged arc welding parameters for single electrode

(For fillet welds by automatic welding)

Weld size (mm)	5	6	8	10	12	16	20
Plate thickness (mm)	6	8	10	12	16	20	25
Electrode size (mm)	3.2	4	5	5	5	5	5
Current (amp) DC	520	620	720	800	870	920	970
Volts	30	32	34	36	38	39	40
Welding speed (m/min.)	1.4	1	0.7	0.56	0.36	0.25	0.20
Electrode req'd (Kg/m)	0.10	0.18	0.28	0.40	0.70	1.1	1.6
Flux req'd (Kg/m)	0.05 - 0.09	0.75 - 0.12	0.14 - 0.18	0.18 - 0.27	0.33 - 0.45	0.53 - 0.75	0.83 - 1.2
Total time (hr/m of weld)	0.012	0.016	0.0024	0.03	0.047	0.67	0.09

Table 2

Submerged arc welding parameters for single electrode

(For Butt welds by Automatic welding)

Plate thickness (mm)	6		10		12		16		20	
Pass	1	2	1	2	1	2	1	2	1	2
Electrode size (mm)	5		5		5		5		5	
Current (amp) DC+	600	750	650	800	750	850	750	850	800	900
Volts	31	33	33	35	35	36	35	36	36	37
Welding speed (m/min)	1.8	1.8	1.2	1.2	0.9	0.9	0.6	0.6	0.5	0.5
Electrode consumed (Kg/m)	0.13		0.23		0.35		0.56		0.63	
Flux consumed (Kg/m)	0.14 – 0.16		0.19 – 0.25		0.3 – 0.4		0.5 – 0.65		0.55 – 0.72	
Total time (hr/m of weld)	0.019		0.028		0.038		0.059		0.06	

Plasma welding principles, Equipment, power source, parameter settings, Advantages & limitations, Plasma cutting principles and advantages

Objective: At the end of this lesson you shall be able to
- **state the types of plasma arc welding**
- **state the equipments**
- **state the applications**
- **plasma arc cutting.**

Plasma Arc Welding is welding process in which plasma producing gas (Argon, Nitrogen, Helium, and Hydrogen) is ionized by the heat of an electric arc and passed through a small welding torch orifice. A shielding gas protects the plasma arc from atmospheric contamiantion in welding or cutting. A non-consumable Tungsten electrode is used in Plasma Arc Welding and additional metal is added to the weld with a filler rod.

Plasma Arc welding uses the keyhole method to obtain a full penetration and can be done manually or automatically. The works of temperature obtained in this process is about 20000ºC to 30,000ºC.

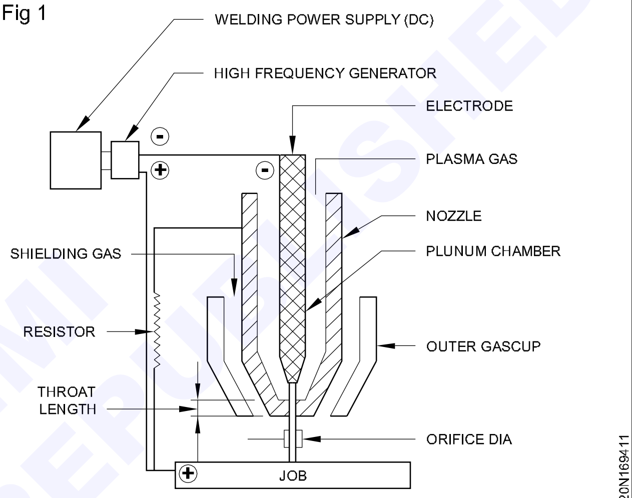
It is divided in to two basic types. They are:

1 Transferred arc

2 Non-transferred arc

Transferred arc process (Fig 1): The arc is formed between the electrode(-) and the work piece (+). In other words, arc is transferred from the electrode to the work piece. A transferred arc possesses high energy density and plasma jet velocity. For this reason it is employed to cut and melt metals. Besides carbon steels this proocess can cut stainless steel and nonferrous metals also where oxyacetylene torch does not succeed. Transferred arc can also be used for welding at high arc travel speeds.

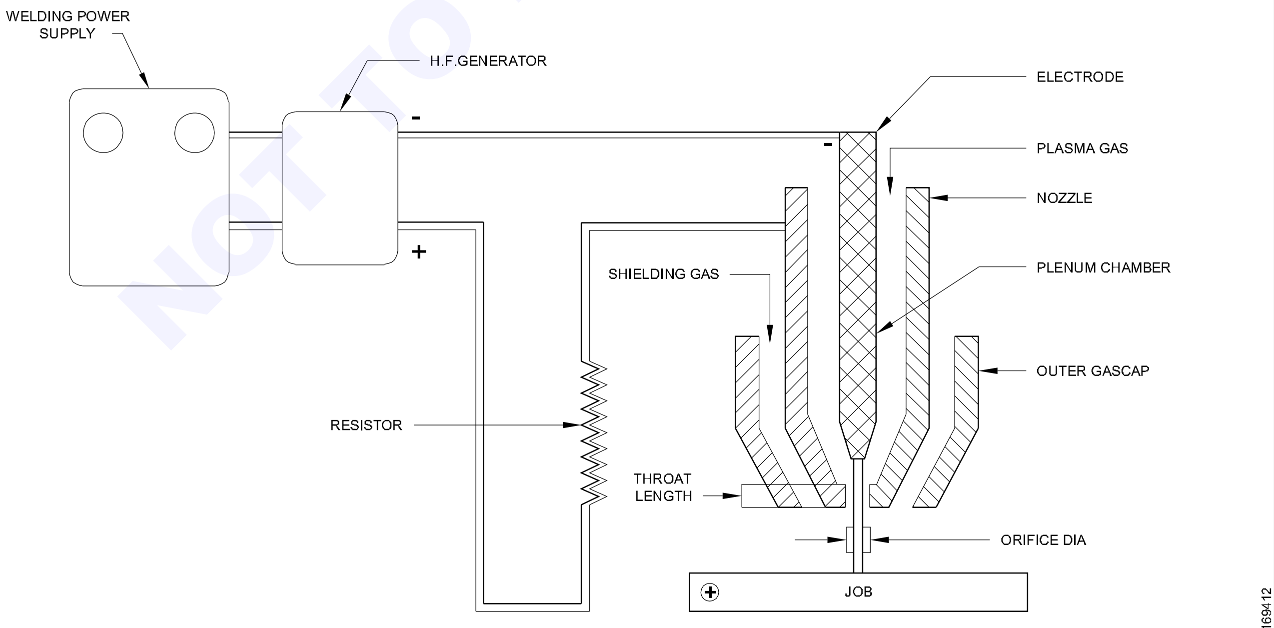
Fig 1



PLASMA ARC WELDING (TRANSFORMED ARC)

Non-transferred arc process (Fig 2)

Fig 2



PLASMA ARC WELDING (NON-TRANSFORMED ARC)

The arc is formed between the electrode(-) and the water cooled constricting nozzle(+). Arc plama comes out of the nozzle as a flame. The arc is independent of the work piece and the work piece does not form a part of the electrical circuit. Just as an arc flame, it can be moved from one place to another and can be better controlled. The non transferred arc plasma possesses comparatively less energy density as compared to a transferred arc plasma and it is employed for welding and in applications involving ceramics or metal plating (spraying).

Equipments

1 DC power source

2 Welding control console (Contain flow meter)

3 Recirculating water cooler

4 Plasma welding torch (up to 500 amps capacity)

5 Gas cylinders and a gas supply

6 Gas pressure regulator

7 Gas hoses and hose connections

8 Water cooled power cables

Gases for plasma welding

- Argon for carbon steel, titanium, zirconium, etc
- Hydrogen increase heat Argon + (5-15%) Hydrogen for stainless steel, Nickel alloys, Copper alloys

Plasma process techniques

1 Microplasma

- very low welding currents (0,1-15 Amps)
- very stable needle-like stiff arc & minimises arc wander and distortions
- for welding thin materials (down to 0,1 mm thick), wire and mesh sections

2 Medium current plasma

- higher welding currents (15-200 Amps)
- similar to TIG but arc is stiffer & deeper penetration
- more control on arc penetration.

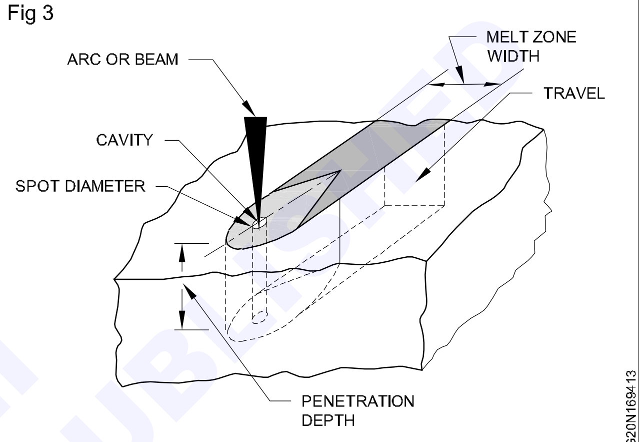
Microplasma and medium current plasma advantages

- energy concentration is greater & higher welding speed
- energy concentration is greater & lower current isneeded to produce a given weld & less distortions
- improved arc stability
- arc column has greater directional stability
- narrow bead & less distortions
- less need for fixturing
- variations in torch stand-off distance have little effect on bead width or heat concentration & positional weld is much easy
- tungsten electrode is recessed & no tungsten contami nation, less time for repointing, greater tolerance to surface contamination (including coatings).

Microplasma and medium current plasma limitations (Fig 3)

- narrow constricted arc & little tolerance for joint misalignment
- manual torches are heavy and bulky & difficult to manipulate
- for consistent quality, constricting nozzle must be well maintained

Fig 3



PLASMA PROCESS TECHNIQUE

3 Keyhole plasma welding (Fig 4)

- welding currents over 100 Amps
- for welding thick materials (up to 10 mm)

Keyhole plasma welding advantage

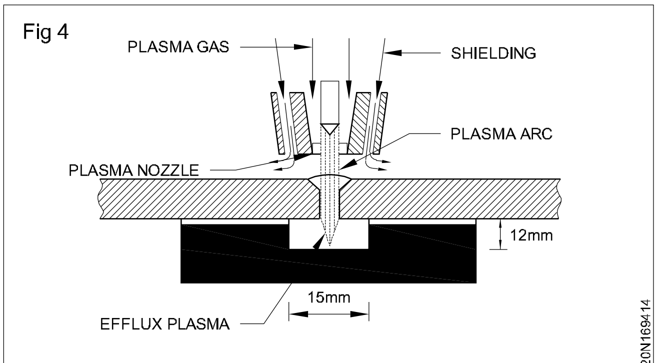
- Plasma stream helps remove gases and impurities.
- Narrow fusion zone reduces transverse residual stresses and distortions.
- Square butt joints are generally used and reduced time preparation.
- Single pass welds and reduced weld time

Keyhole plasma welding limitations

- more process variables and narrow operating windows
- fit-up is critical
- increased operator skill, particularly on thicker materials Ù high accuracy for positioning
- except for aluminium alloys, keyhole welding is restricted to downhand position
- for consistent operation, plasma torch must be well maintained

Application of the plasma process

Three operating modes possible by varying current bore diameter and gas flow rate



KEYHOLE PLASMA WELDING

- **Micro plasma:** 0.05 to 15 amps – used for welding thin sheet down to 0.1mm eg SS bellows and wire mesh, welding of surgical instruments, repair of gas turbine engine blades, electronic components and micro-switches etc.
- **Medium current:** 15 to 200 amps – used as alternative to conventional TIG for improved penetration and greater tolerance to surface contamination. Generally mechanised due to bulkiness of torch.
- **Keyhole plasma:** over 100 amps – By increasing current and plasma gas flow a very powerful beam is possible which can achieve full penetration in 10 mm stainless steel.During welding the hole progressively cuts through the metal with the molten weld pool flowing behind to form the weld bead.

Limitations of plasma arc welding

1 PAW requires relatively expensive and complex equipment as compared to GTAW; proper torch maintenance is critical

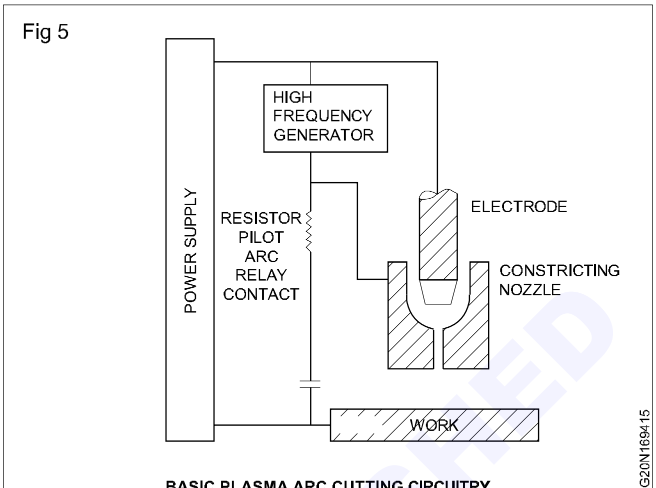
2 Welding procedures tend to be more complex and less tolerant to variations in fit-up, etc.

Cutting processes - plasma arc cutting

Plasma arc cutting process, was introduced in the industry in the mid 1950s. The process is used to cut all metals and non-metals. The common oxy-fuel cutting process (based on a chemical process) is suitable for cutting carbon steel and low alloy steel cutting only. Materials such as copper, aluminium and stainless steels were earlier separated by sawing, drilling or sometimes by power flame cutting. These materials are now cut using a plasma torch, at faster rates and more economically. The Plasma cutting process is basically a thermal cutting process, free of any chemical reaction, that means, without oxidation. In plasma arc cutting an extremely high temperature and high velocity constricted arc is utilized.

Principle of operation

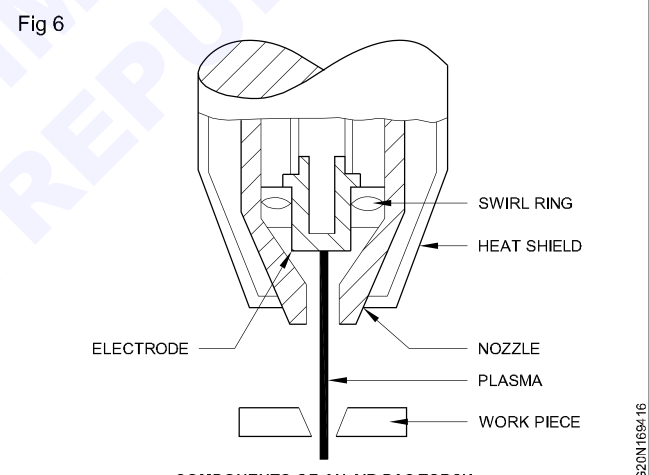
Plasma arc cutting is a process resulting from ionizing a column of gas (argon, nitrogen, helium, air, hydrogen or their mixtures) with extreme heat of an electric arc. The ionized gas along with the arc is forced through a very small nozzle orifice, resulting into a plasma stream of high velocity (speed up to 600 m/sec) and high temperature (up to 20000°K). When this high speed is reached, high temperature plasma stream and electric arc strike the workpiece, and ions in the plasma recombine into gas atoms and liberate a great amount of latent heat. This heat melts the workpiece, vaporizes part of the material and the balance is blasted away in the form of molten metal through the heat (Fig 5).



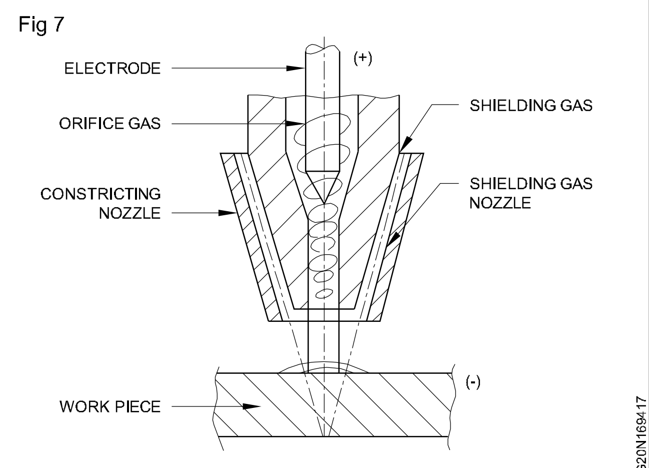
BASIC PLASMA ARC CUTTING CIRCUITRY

Plasma cutting system (Fig 6,7,8)

Plasma cutting requires a cutting torch, a control unit, a power supply, one or more cutting gases and a supply of clean cooling water (in case water-cooled torch is used).

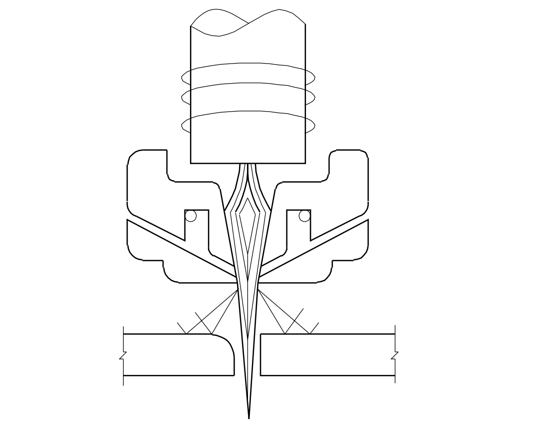


COMPONENTS OF AN AIR-PAC TORCH



DUAL FLOW PLASMA ARC CUTTING

Fig 8



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.

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

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.

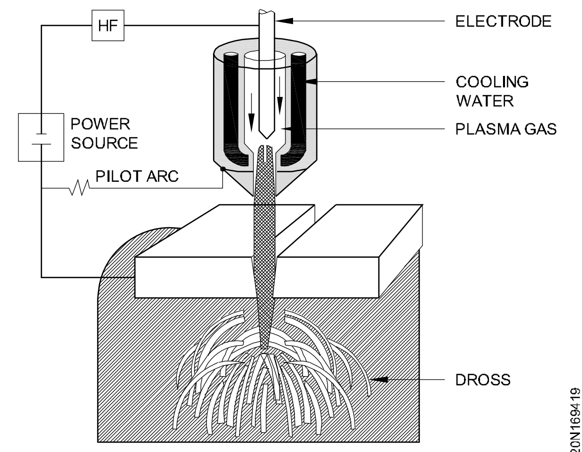
vi Cutting speed is high.

vii Cutting is possible in all positions and locations (underwater also).

Gases for plasma cutting (Fig 9)

- 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
- shielding gas - optional
- applications : stainless steels, aluminium and thin sheet carbon steel.

Fig 9



GASES FOR PLASMA CUTTING

Inspection & testing of weldments - Visual inspection methods - Inspection kits - universal gauge, Fillet gauge, etc

Objective: At the end of this lesson you shall be able to
- **explain the necessity of inspection and testing of weld**
- **describe the different stages of visual inspection**
- **explain the check points of visual inspection**
- **state types of testing of welds.**

Necessity of inspection: The purpose of inspection is to locate and determine the type of weld fault, strength and quality of joint and quality of workmanship.

Types of tests

– Non-destructive test (NDT)

– Destructive test

– Semi destructive test

Determining the quality of the weld without destroying the weld is called a non-destructive test (NDT). The job can be used after the test. The test to be carried out on welded specimens by cutting the job and destroying it is called destructive test. The job cannot be used after the test.

Sometimes the quality of a welded joint is tested by grinding, drilling, etching, filing etc. for finding machinability, microstructure etc. These tests are called semi-destructive tests. The tested job can be used after the test by rewelding the small area damaged during the test.

Visual inspection (non-destructive test): Visual inspection is observing the weld externally using simple hand tools and gauges to know whether there is any external weld defects. This is one of the important inspection methods without much expense. This method of inspection needs a magnifying glass, a steel rule, try square and weld gauges. Visual inspection is made in three stages namely:

– before welding

– during welding

– after welding

Visual inspection before welding

(The operator must be familiar with the type of work, electrode and welding machine)

The following factors are to be ensured.

The material to be welded is of weldable quality.

The edges have been properly prepared for welding as per thickness of the plate.

Proper cleaning of the base metal.

Setting of proper root gap.

Proper procedure to be followed to control distortion.

Proper selection of blow pipe nozzle and filler rod, flux and flame.

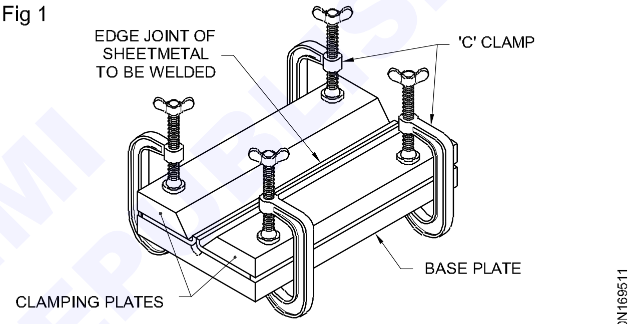
Polarity of the electrodes in the case of DC welding current.

Whether the cable connections are tight.

Current setting according to the size of the electrode and position of welding.

Whether any jigs and fixtures are necessary to ensure proper alignment. (Fig 1)

Fig 1



CLAMPING PIECES BETWEEN HEAVY BLOCKS WILL KEEP THEM STRAIGHT.

Proper facilities should exist for storing and drying of the electrodes.

Visual inspection during welding

The following points are to be checked.

Studying the sequence of weld deposit.

Examining whether each weld is cleaned adequately before making the next run in multi-run welding.

The following factors are to be ensured.

Visual inspection kits and gauges

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 miirors, magnifying glasses, microscopes (or) video-cameras.

Visual testing requirements

The requirements for visual testing 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.

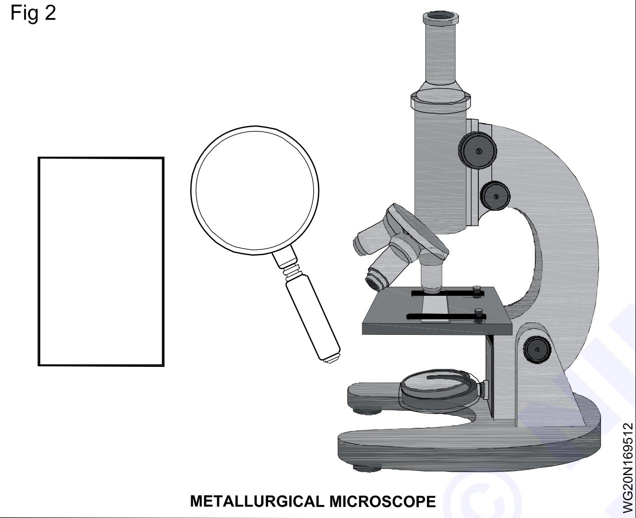
Unfilled craters and contour of the welded parts.

Surface porosity and general condition of the component.

Optical aids used in visual inspection (Fig 2)

Mirrors, magnifying glasses, universal and filled gauge etc.,

Fig 2



METALLURGICAL MICROSCOPE

Welding gauges: 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 3)
- AWS type weld measurement gauge (Fig 4)

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 3)

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 4)

Fig 3

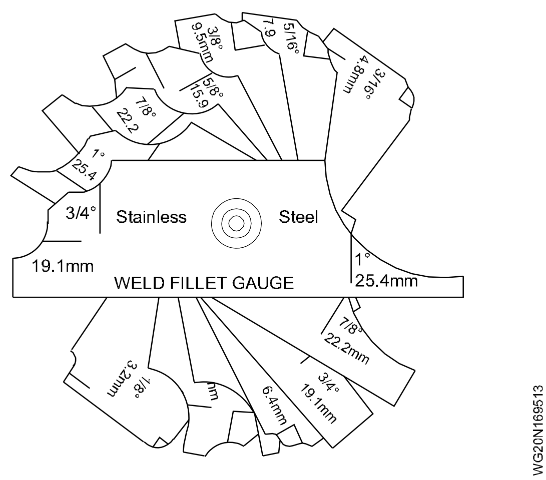
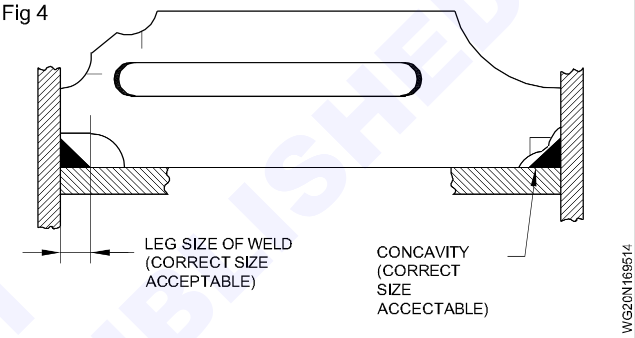
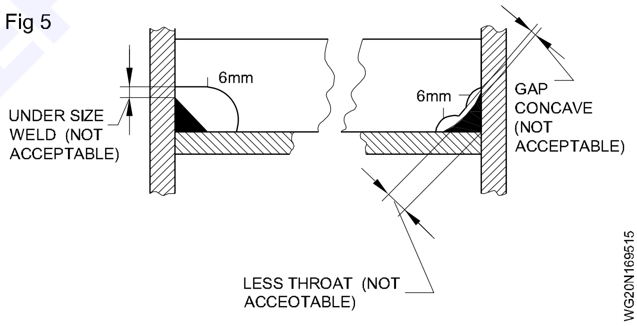


Fig 4



If one of the leg sizes is short then welding size is undersized, and this is not acceptable, (Fig 5)

Fig 5



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.

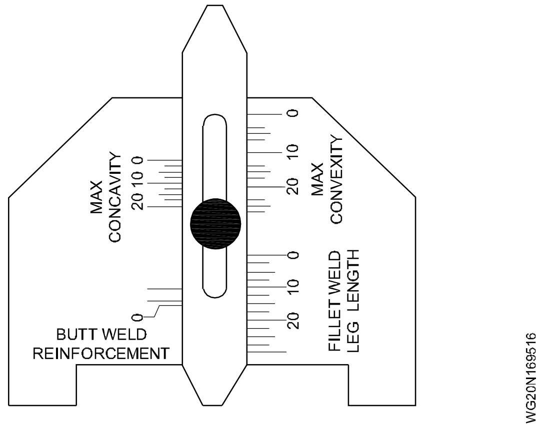
4 Acceptable reinforcement height on butt weld

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 6) Is tightened suitably to determine the measurement .

Fig 6

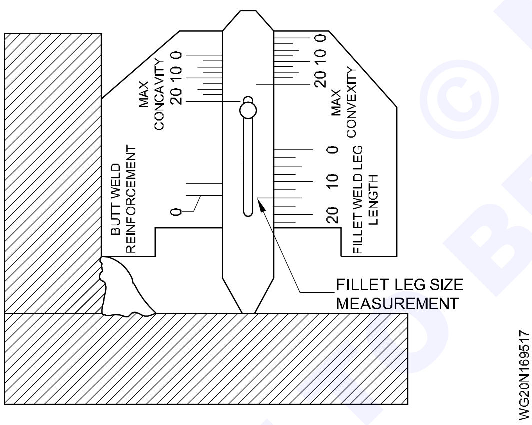


1 **Leg size of fillet weld:** To determine the fillet weld leg size the slot is placed against the toe of the weld as shown in (Fig 7)

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 7



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 8)

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 9.

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 9.

Fig 8

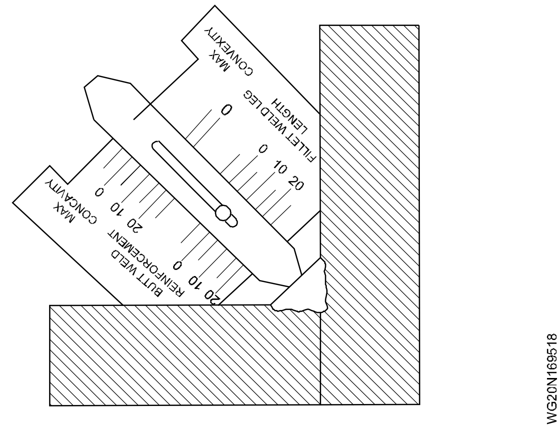
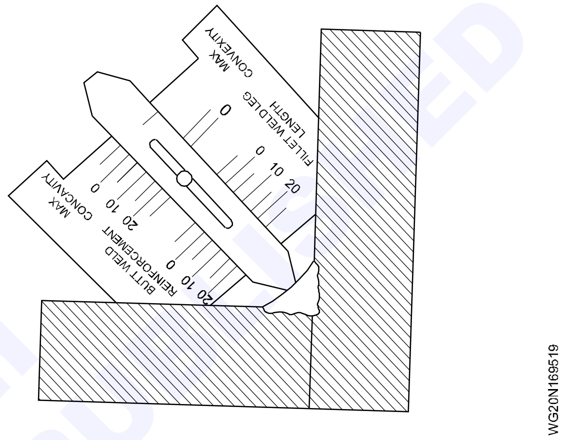


Fig 9



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 be scated on either size of butt weld as shown in Fig 10, 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. (Figs 11, 12, 13, 14 & 15)

Fig 10

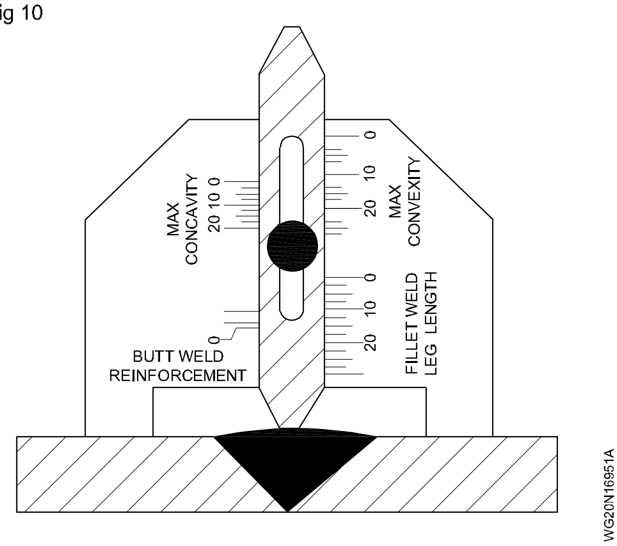
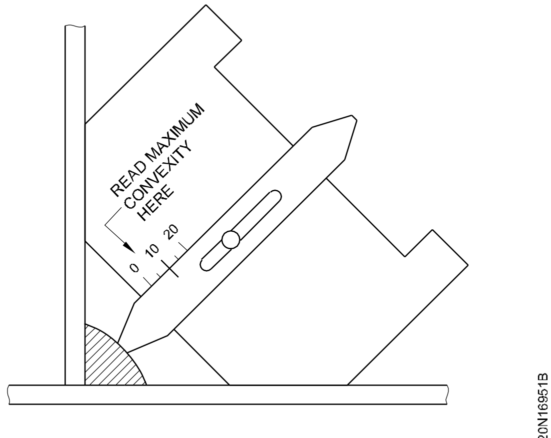
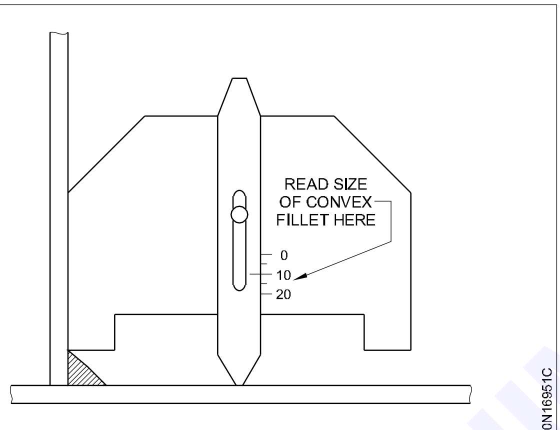


Fig 11



TO CHECK THE MAXIMUM PERMISSIBLE CONVEXITY

Fig 12



TO MEASURE THE SIZE OF A FILLET WELD

Fig 13

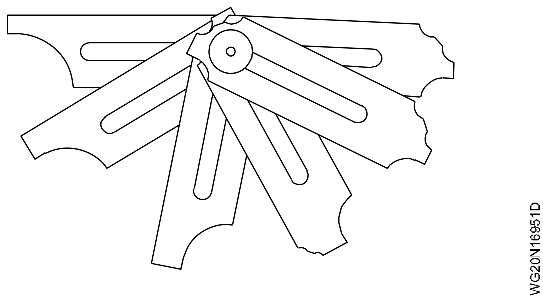


Fig 14

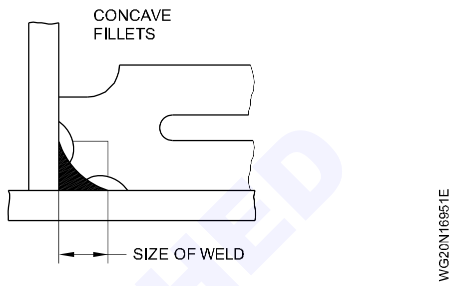
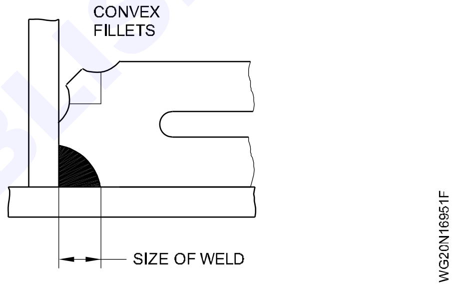


Fig 15



Non-destructive Testing methods, PT, MPT, UT & RT

Objective: At the end of this lesson you shall be able to
- **explain the non distructive testing method**
- **describe the types of NDT and its uses.**

Methods of non-destructive tests

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
- 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.

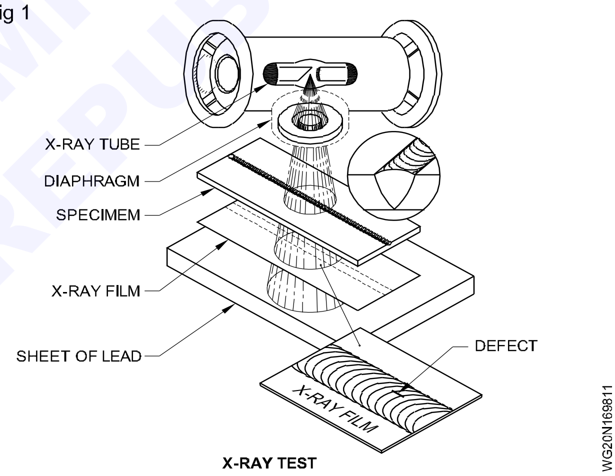
An ordinary physician's stethoscope and a hammer may be used to magnify and identify the sound.

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



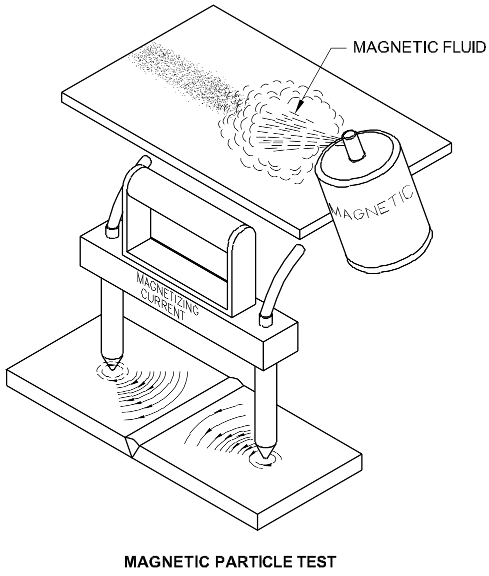
X-RAY TEST

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.

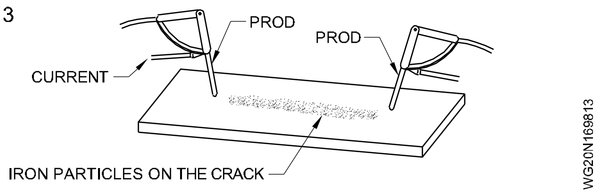
A liquid containing iron powder is first sprayed over the joint to be tested. When this test piece is magnetised, the iron particles will gather at the edges of the defect (crack or flaw) and can be seen as dark hair line marks with naked eyes. (Figs 2 & 3)

Fig 2



MAGNETIC PARTICLE TEST

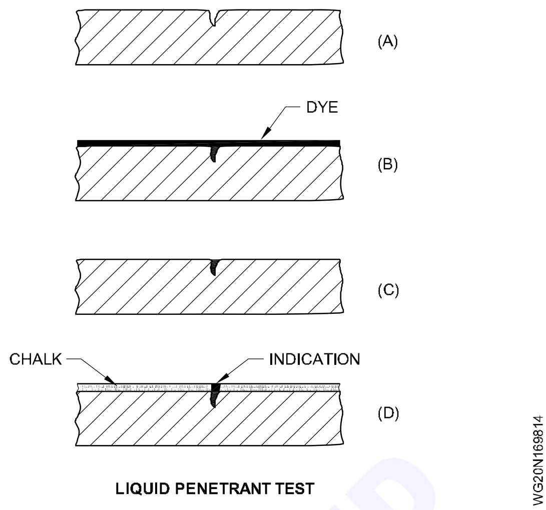
Fig 3



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.

A liquid developer (white in colour) is then sprayed on the weld. The coloured dye comes out in the shape of surface defects into the white developer coating. The defect can be seen in normal light with naked eyes. (Fig 4)

Fig 4



LIQUID PENETRANT TEST

Impact test: Impact means application of a sudden force on an object. In an impact test of a weld, a test specimen is prepared from a test plate. This is further machined to have a V notch. The test specimen with 10 mm square cross-section is used for charpy V impact test and one with 11 mm diameter circular cross-section is used for the izod impact test.

The impact test is used to determine the impact value of welds and base metals in welded products to be used at low temperatures up to - 40^0 C which are subjected to severe dynamic loading.

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

Destructive testing - Bend test & tensile test

Objective: At the end of this lesson you shall be able to
- **explain the necessity for destructive tests**
- **explain the different methods of destructive test of weldments**
- **explain the advantages and limitations of workshop and laboratory tests**
- **identify the specimen for destructive tests.**

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

– workshop tests

– laboratory tests

Workshop tests - These are the tests that can be performed in the workshop.

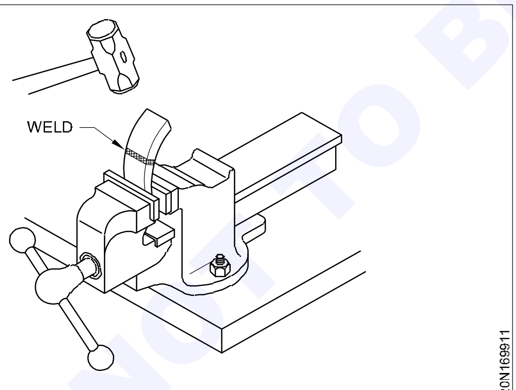
– Nick break test

– Free bend test in a vice

– Fillet fracture test (by using a bending bar

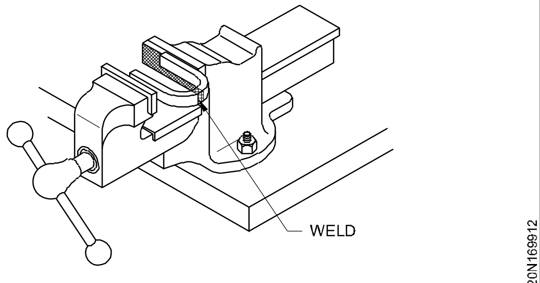
Free bend test: The welded joints are fixed on a vice and bent by applying forces by hammer/bending bar to determine the defect in the weld done by a trainee in a workshop. (Figs 1&2) The workshop tests are usually used to break open the weld in a workshop using a vice and hammer for visual inspection.

Fig 1



THIS IS ONE WAY THE INITIAL BEND CAN BE MADE

Fig 2



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

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

Examination of fractured weld: The fractured weld may exhibit and show the following internal defects.

– Lack of fusion

– Incomplete penetration

– Slag inclusions

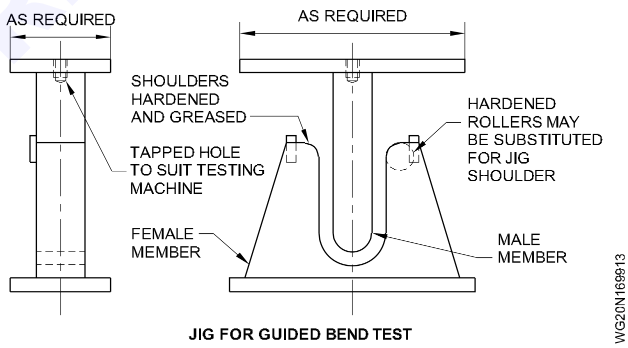
– Blow-holes or porous weld

Laboratory tests

The laboratory tests conducted on welds are the:

Guided bend test: A guided bend test is one in which the specimen as in Fig 3.

Fig 3



JIG FOR GUIDED BEND TEST

There are two types of specimens prepared for this - one for face bend and the other for root bend. (Fig 4) This test measures the ductility of the weld metal in a butt joint in a plate. This test shows most weld faults quite accurately and it is very fast. A sample specimen can be tested on destruction to determine (a) the physical condition of the weld and thus check on the weld procedure and (b) the welder's capability.

Impact test: Impact means application of a sudden force on an object. In an impact test of a weld, a test specimen (Fig 4) is prepared from a test plate. This is further machined to have a V notch as in Fig 5. The test specimen with 10 mm square cross-section is used for charpy V impact test and one with 11 mm diameter circular cross-section is used for the izod impact test. Fig 6 shows an impact testing machine.

Fig 4

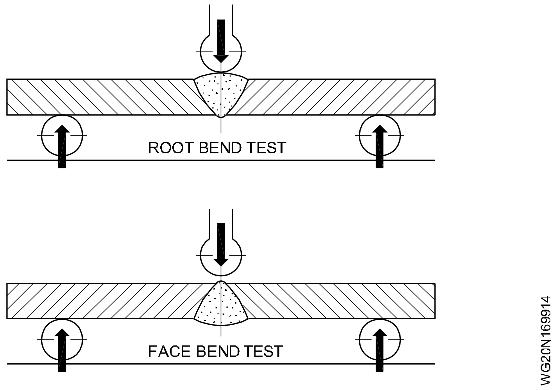
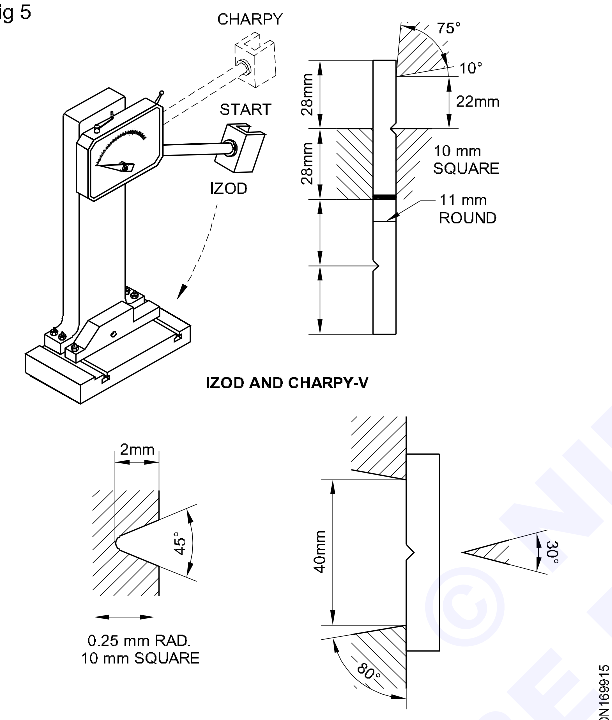
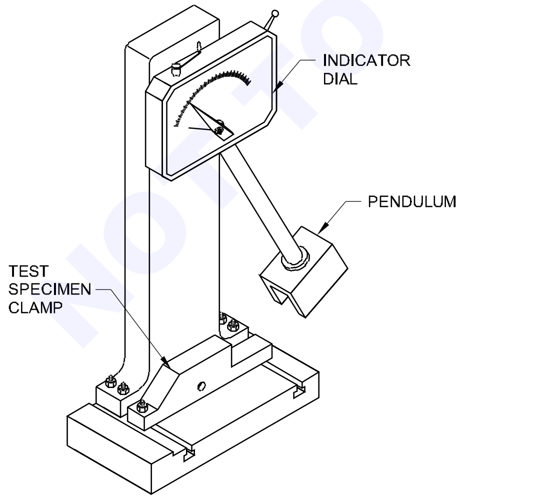


Fig 5



IZOD AND CHARPY - V MACHINE AND SPECIMENS IMPACT TEST

Fig 6



A CHARPY IMPACT TESTING MACHINE

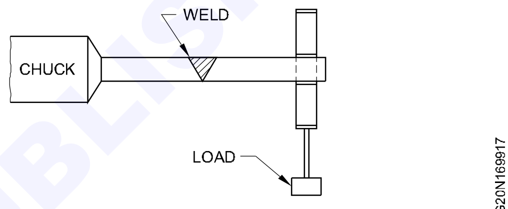
IN THIS TESTER THE PENDULUM IS LIFTEDAND DROPED AGAINST THE TEST SPECIMEN WHICH IS HELD IN THE CLAMP. THE IMPACT FORCE IS REGISTERED BY THE DIAL INDICATOR.

The impact test is used to determine the impact value of welds and base metals in welded products to be used at low temperatures up to - 40^0 C which are subjected to severe dynamic loading.

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

The resistance to fatigue of a welded joint is tested by fixing the welded specimen in a chuck and rotated at a particular speed with a load hung at the other end as shown in Fig 7. Fatigue tests are extremely useful while testing welded shafts, cranks and other rotating parts which are subjected to varying alternating loads.

Fig 7 ILLUSTRATING PRINCIPLE OF WOHLER TEST

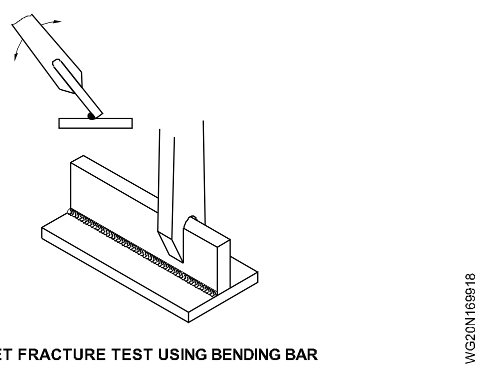


FATIGUE TEST

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

Examination of fractured weld: The fractured weld may exhibit and show the following internal defects. (Figs 8,9,10, and 11)

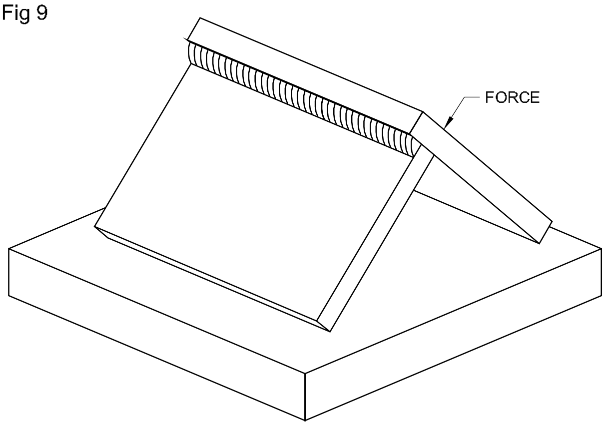
Fig 8



FILLET FRACTURE TEST USING BENDING BAR

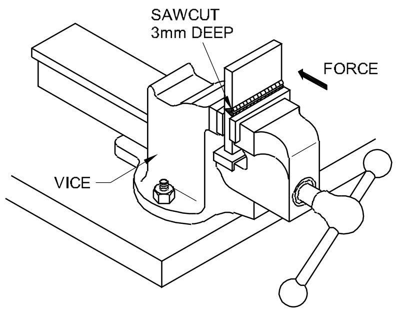
– Lack of fusion
– Incomplete penetration
– Slag inclusions
– Blow-holes or porous weld

Fig 9



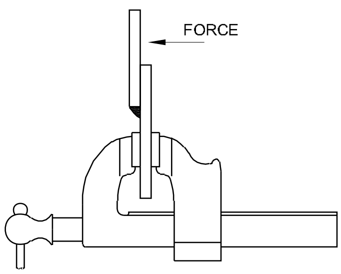
FILLET FRACTURE TEST USING HAMMER

Fig 10



FRACTURE TEST ON BUTT JOINT

Fig 11



FRACTURE TEST ON LAP FILLET

Laboratory tests

The laboratory tests conducted on welds are the:

- tensile test
- guided bend test
- impact test
- fatigue test.

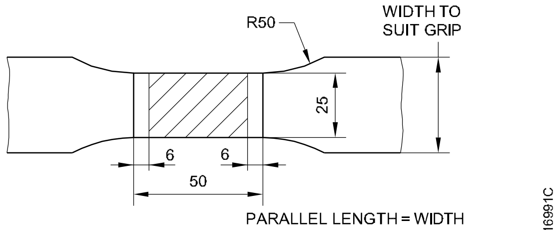
Tensile test: A tensile test is conducted to know the tensile strength and ductility (i.e. elongation) of a weld.

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

They are

- transverse tensile test specimen (Fig 12)

Fig 12

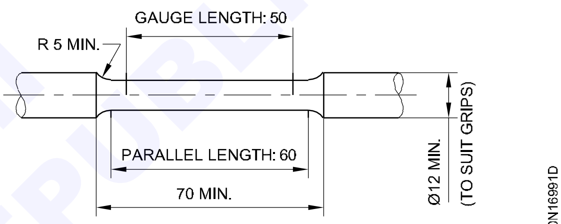


DIMENSIONS OF TRANSVERSE TENSILE TEST SPECIMEN

- all-weld metal tensile specimen. (Figs 13 and 14)

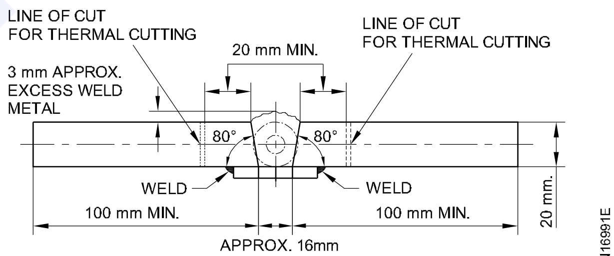
The tensile test gives the values of the tensile strength of the weld and the percentage of elongation of the weld. This reveals the suitability of a joint welded with certain electrodes and base metals for a particular service condition.

Fig 13



ALL-WELD METAL TENSION SPECIMEN

Fig 14



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