WELDER

TRADE THEORY

NSQF LEVEL - 4

HANDBOOK FOR CRAFTS INSTRUCTOR TRAINING SCHEME

Directorate General of Training

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

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A Comprehensive Training Program
under Crafts Instructor Training Scheme (CITS)
for Instructors

HANDBOOK ON TECHNICAL INSTRUCTOR TRAINING MODULES

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भारत सरकार
कौशल विकास एवं उद्यमिता मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
AND ENTREPRENEURSHIP

सत्यमेव जयते

Foreword

In today's rapidly evolving world, the role of skilled craftsmen and women is more crucial than ever. The Craft Instructor Training Scheme (CITS) stands at the forefront of this transformation, shaping the educators who will train the next generation of artisans and technicians. This book aims to provide an in-depth understanding of the subject, exploring its significance, methodologies, and impact on vocational training.

The Craft Instructor Training Scheme was established with the objective of enhancing the quality of instruction in industrial training institutes and other vocational training institutions. By equipping instructors with advanced skills and knowledge, the scheme ensures that they are well-prepared to impart high-quality training to their students. This, in turn, contributes to the creation of a highly skilled workforce capable of meeting the demands of modern industry.

The initial chapters provide the importance of specialized instructor training. Following this, detailed chapters delve into the curriculum covering advanced techniques, safety protocols, and instructional strategies. Each section is designed to offer both theoretical insights and practical applications, ensuring a well-rounded understanding of the subject.

The book offers recommendations for overcoming obstacles and enhancing the effectiveness of the program, with the ultimate goal of producing highly skilled instructors capable of shaping the future workforce.

This book is intended for a diverse audience, including current and aspiring instructors, vocational training administrators, policymakers, and industry stakeholders. It serves as a valuable resource for understanding the intricacies of the subject and its pivotal role in vocational education.

I extend my heartfelt gratitude to all contributors who have shared their experiences and expertise, enriching this book with their valuable insights. Special thanks to the contribution of the development team, reviewers and NIMI that have supported this endeavor, providing essential data and resources.

It is my sincere hope that this book will inspire and guide readers in their efforts to enhance vocational training, ultimately contributing to the development of a skilled and competent workforce.

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DIRECTORATE GENERAL OF TRAINING

FOREWORD

The Craftsmen Training Scheme (CTS) implemented by the Directorate General of Training (DGT) provides skill training to the youth and ensures a steady flow of skilled manpower for the industry. It aims to raise quantitatively and qualitatively the industrial production by systematic training, and to reduce unemployment among the youth by providing them with employable skills.

The Craft Instructor Training Scheme (CITS) is an indispensable part of the Craftsmen Training Scheme (CTS). It offers comprehensive training both in 'skills' and in 'training methodology' to the instructor trainees to make them conversant with techniques of transferring hands-on skills.

I congratulate NIMI for taking the initiative of preparation of the course content for CITS. This will help institutionalize the mechanism for imparting training to the trainers all across the ecosystem. I also extend my gratitude to the Instructors and Officials of National Skill Training Institutes (NSTIs) and the DGT for their invaluable contribution in preparation of the CITS course content.

As we navigate the complexities of a rapidly changing world and the technological disruptions, the significance of CTS and CITS has increased manifold. It not only empowers individuals with practical skills but also lays the foundation for a prosperous future. I am confident that this book will serve as a guiding light to all instructor trainees for skill development and nation-building.

(Trishaljit Sethi)

PREFACE

The Craft Instructor Training Scheme is an indispensable module of the Craftsmen Training Scheme, which has been an integral part of the Indian skill development industry since its inception. This program aims to equip instructors with the necessary skills and teaching methodology to effectively transfer hands-on skills to trainees and promote a holistic learning experience. The first Craft Instructor Training Institute was established in 1948, followed by six more institutes across India in 1960. Today, these institutes, including the National Skill Training Institute (formerly Central Training Institute for Instructors), offer the CITS course, which is mandated by the Directorate General of Training (DGT).

The Craft Instructor training program is designed to develop skilled manpower for industries. The course aims to offer instructors an opportunity to improve their instructional skills, engage learners effectively, offer impactful mentoring, and make efficient use of resources, leading to a more skilled workforce in various industries. The program emphasizes collaborative and innovative approaches to teaching, resulting in high-quality course delivery. Overall, the Craft Instructor Training Scheme is a pivotal program that helps instructors grow in their careers and make a significant contribution to society. This program is essential for developing skilled manpower and promoting a robust learning environment that benefits both trainees and instructors alike.

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following experts to bring out this Instructional material **(Trade Theory)** for **CITS Welder (NSQF Level - 4)** under the **Capital Goods & Manufacturing** Sector for **Instructors**.

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

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

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

ABOUT THE TEXT BOOK

The Vocational Instructor Training Program is a comprehensive initiative designed to equip aspiring students with the necessary skills and knowledge to effectively teach in vocational education settings. This program encompasses a range of pedagogical strategies, instructional techniques, and subject-specific content tailored to the diverse vocational fields. Participants engage in coursework that covers curriculum development, assessment methods, classroom management, and the integration of industry-relevant technologies. Practical experience and hands-on training are emphasized, allowing participants to apply theoretical concepts in real-world teaching environments. Through collaborative learning experiences and mentorship opportunities, aspiring vocational instructors develop the confidence and competence to facilitate engaging and impactful learning experiences for their students. This training program aims to cultivate a new generation of educators who are not only proficient in their respective vocational fields but also adept at fostering the success and employability of their students in today's competitive workforce.

This text book covers communication, self-management, information and communication technology, entrepreneurial and green skills. It has been developed as per the learning outcome-based curriculum.

G C Rama Murthy,
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CONTENT

◆MODULE 1 : Induction Training & Welding Safety Process◆

Lesson 1 - 3 : Importance of welding in industry

Objectives

At the end of this lesson you shall be able to

- realise and state the importance of welding in industry
- state the advantages of welding over other methods of joining metals.

In industries, welding is extensively used either in fabrication works or in repair and maintenance Jobs. Welding as a means of fabrication imparts great flexibility in the design of jobs. Welded structures are comparatively simple in design and cheaper as well as the use of patterns etc is eliminated. In welding a considerable saving is obtained in production cost. Abrupt changes or improvement in the design of a job may be made easily, directly and immediately by welding where as to bring any change in a casting design involves lot of Complicacies. The cost of material used in welded structures is also lower because the materials often used are of standard forms and sizes and of advantage strength. Less machining is required on welded structures. In condition of weight also the welded structures are lighter than cast ones. The rate of labour cost is also reduced because fewer man hours of production are involved in welding. In repairing works also welding is the cheapest and quickest way of meeting the requirement of joining metal parts together.

As already mentioned, welding is used in every phase off all types of metal Industries; however it is more extensively used in following industries.

i Air Craft manufacturing.

ii Automobiles.

iii Ship building industries.

iv Structural work in bridges and buildings.

v Oil industries.

vi High speed rail road cars..

vii Mining equipments.

ix Manufacturing of furnaces and boilers.

x Military war equipment.

xi Steel-mill equipment

xii Machine tool industry.

xii Die and tool manufacturing.

xiv Repairing and construction of mild steel structures

Advantages of welding

1 Welding equipment is not very costly.

2 Weld is as strong as the base metal.

3 Freedom in design is possible in welding.

4 Similar and dissimilar metals can be welded easily.

5 Welding can be automatic and mechanised.

6 Portable welding equipment is available and can be taken to the site easily.

7 Both pressure and fusion welding are applicable on different Jobs.

8 With modern welding techniques all alloys can be welded with good finish.

Disadvantages of welding

Although disadvantages of welding are minimum in Comparison to advantages but still some of disadvantages. are listed below:

1 The ultra-violet rays and Infrared says of welding arc are too much harmful for the eyes.

2 The flames and gases are harmful for the human being.

3 There are more stress and distortion in the Jobs done by welding.

4 For having good weld, the operator must be a skilled one otherwise the Job once spoiled cannot be rectified.

5 Welded Joint must be stress relieved.

Course Objective

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

- state and understand course Objective in the CITS training program.

Sl No.	Course Objective (At the end of the theory we shall be able to)	Remark
1	Importance of Welding in Industry	
2	Safety precautions in SMAW, OAW and OAGC	
3	Introduction of Arc, Gas and other welding process ,Oxy-Acetylene gas cutting, faults in cutting.	
4	Basic electricity, Heat and temperature ,Principle of arc welding,	
	Types of weld joints. Edge preparation.	
5	AC welding Transformer, DC welding Motor generator set, Welding Rectifier and inverter type welding machines.	
6	Arc length, Welding position. Polarity.	
7	Arc blow, Distortion, Arc Welding defects.	
8	Common gases used in Gas welding and cutting. Chemistry of Oxy-Acetylene flame. Types of Oxy- Acetylene flame .	
9	Calcium carbide. Acetylene, Purifier, Hydraulic back pressure valve and Flash back arrestor.	
10	Oxygen, Oxygen and Acetylene gas cylinders, Colour coding, safe handling and storage, regulator, Gas welding and cutting blow pipe.	
11	Gas welding techniques, filler rods, fluxes, defects, causes and remedies	
12	Classification ,Aluminum, Copper - types- properties and welding methods.	
13	Brass - types - properties Stainless steel - types- weld decay	
14	Development drawings for pipe Elbow joint. ‘T’ Joint. ‘Y’ Joints.	
15	Electrode types, functions of flux, Coding of electrode as per IS and AWS.	
16	Brazing, filler rods and fluxes, necessity of cleaning, brazing parameters.	
17	Pipe & plate pipe welding. Pipe schedule.	
18	Pipe welding procedure uphill , downhill and horizontal welding Pipe welding position 1G, 2G, 5G & 6G	
19	Procedure for welding heavy wall pipes in 5G & 6G position welding	
20	Importance of pre heating, post heating, inter pass temperature.	

21	Welding symbols as per BIS & AWS, Reading of assembly drawings	
22	Cast iron -types- properties and uses. Welding methods of cast iron.	
23	Requirement for qualification codes Qualification, Different tests Writing procedure for WPS and PQR	
24	Safety GTAW & GMAW. Introduction to CO2 welding equipment accessories.	
25	Modes of metal transfer, Welding parameters for GMAW M.S and Alloy steels, related Tables, Data.	
26	Welding wires used in CO2 welding, Shielding gases, Edge preparation, weld defects, causes and remedy in GMAW	
27	Flux cored arc welding, types coding as per AWS and specification - Trouble shooting in MIG welding .	
28	Introduction to GTAW, GTAW torches, Tungsten electrode. Pulsed TIG welding	
29	Filler metals for GTAW Types & Specifications as per BIS & AWS.	
30	Advantages of root pass welding of pipes by TIG welding Square wave concept.	
31	Types of weld defects, causes and remedy in GTAW process Purging.	
32	Submerged Arc welding - Principles, application-Types of fluxes.	
33	Micro plasma welding principles, Plasma cutting principles and advantages	
34	Friction welding process: principles, Principles Friction Stir welding	
35	Laser, Electron beam,Electro slag, Electro gas, Thermit welding etc. Water jet cutting & laser cutting	
36	Resistance welding processes, Spot, seam projection , Flash butt etc,	
37	Robot Welding, Mechanical Testing, Hardness testing, Impact testing Tensile testing	
38	NDT- DPT,MPT , UT , RT X-Rays, Eddy current testing .	

Topic - safety precautions in shielding metal arc welding (SMAW)

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

- identify the safety apparels and accessories used in arc welding
- select the safety apparels and accessories to protect from burns and injuries
- learn how to protect yourself and others from the effect of harmful arc rays and toxic fumes
- select the shielding glass for eye and face protection.

Introduction: Welding and cutting of metal involve intense heat and inflammable gas. Welding heat and the sources employed to produce it can be potentially hazardous. Therefore, to protect person from injury and to protect workshop, Equipment's against fire

Types of safety

1 Personal safety.

2 Work shop safety.

3 Machinery safety.

Personal safety in SMAW-During ac welding operation, the following protecting clothing made of leather are used to protect the welder's body from on arc flash, heat, sparks and Spatters.

i Apron is used to protect the front body of a welder.

ii Gloves are used to protect the hand of a welder. Protect from electric shock. arc flash, Heat sparks and spatter.

iii Gloves must not be used to pickup hot job as the heat make them stiff, hard and difficult to use later.

iv Sleeves used to protect the arms of welder.

v Safety Shoes used to protect the feet of a welder from metal spatters.

vi Leg guard used to protect the legs and ankles of a welder.

Vii Helmet is used to protect the head and d hair of a welder.

viii Use of appropriate eye Shield or face protection form danger arc rays

Workshop safety in SMAW

i The welding shop should be well ventilated to protect the welders from fumes and suffocation. Make sure that the exhaust system functions effectively an Confined spaces where fumes are dangerous and may cause unconsciousness. A respirator also should be readily available to the welder so that can used it When need.

ii Never store flammable materials near the welding Shop

iii Tankers are container should never be welded unless these are free from any explosive materials or Vapours.

iv The movable screens should be available so that other may be saved from ray's effect.

v Display posters reading "Do Not L00K AT THE ELECTRIC ARC"

vi Fire-fight fighting Extinguishers should be kept within the welding shop.

vii Store the scrap pieces in a Container.

viii Natural Light, water and transport facilities must be available in the welding shop.

ix First Aid box must be ready in the welding Shop

x Arc Welding booth should not be pained in such a colour which can reflect the lights.

Machine safety in SMAW

i Do not keep the machine in open space.

ii In DC welding generator do not put the strong switch on delta position directly. keep the switch on start position first. Run it for a few second and put the switch in delta position.

iii Do not disconnect the cooling fan of welding generator.

iv Maintain the Cooling all level in the oil cooled welding transformer set and periodically drain the cooing oil from the transformer and purify and then refill the transformer.

v Fix the input cable from the main to the machine and the electrode and earth Cables firmly.

vi Replace the carbon brushes of the DC. welding generate Whenever necessary

vi Do not clean any welding machine with water.

vii The dust and other impurities are to be removed by compressed dry air only.

ix Operate all the control knobs and handles gently.

x Avoid loose Connection at the mains power Supply, fuses switch board.

xi Switch off the mains power supply when welding has been completed

Accessories safety in SMAW

i Do not touch live, wires or objects that may carry or conducts electrical Current.

ii Ensure the welding and Earth cables are of Standard ampere range.

iii The Cables are to be joined only by sockets.

iv Use the right Capacity electrode holder and clamp.

v Ensure that cables are in good condition and fully insulated.

vi Avoid direct contact of electrode holders with work table or job or earth. Clamp.

vii Use a properly insulated electric holder.

vii Avoid over running of the trolley wheel etc on the welding or return cable.

viii Do no undertake any maintenance on Welding machine they are disconnected from main Supply unless.

ix Have all electrical Equipment inspected by a qualified electrician and defect should be eliminated before the become serious.

xi Do not touch or handle any equipments of machine about which you have no idea.

Safety precautions in oxy acetylene gas welding and cutting

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

- state various improper practices, while working in gas cylinders
- state different precautions to be taken for the gas cylinders.
- describe the safety precautions to be followed by handling gas cutting equipment
- explain the safety precautions to be followed by the operator
- state the safety required during gas cutting operation.

In Gas welding the welders must follow certain safety precautions, while handling plants in order to prevent accidents to other and himself the following precautions will help the Gas welder to avoid accidents to a great extent.

General safety in gas welding and cutting

i Never use oil or grease in any part or assembly of a gas welding plant as if may cause an explosion.

ii All inflammable materials should be kept away from the welding area.

iii Always wear goggles with proper filter lens during welding.

iv Wear fire resistant clothes, asbestos, gloves and Apron while welding.

v Never wear nylon or greasy clothes while Welding.

vi Rectify the leakages noticed immediately, even a small leakage can lead to serious accident.

vii Always keep fire extinguishing device handy and in working order

viii While leaving the work area, make sure that the palace is free from any fire.

ix Always use spark lighter for igniting blow pipe.

x "NO SMOKING" notices should be placed near the cylinder or Generator.

xi Never clean the nozzle or tip with iron or steel wire. A Special set of drills is available for this purpose. In the absence of the nestle cleaning drills a copper or brass wire may be used.

Safety concerning gas cylinders in gas welding and cutting

i Do not roll Gas- cylinder for shifting. Always use a trolley to carry cylinders.

ii Do not drop the Gas cylinders.

iii Close the cylinder valves when not in use or empty.

iv Keep the empty cylinder and full cylinder separately.

v Always open the cylinder valve slowly and not more than one and half turns.

vi Use always the correct size spindle key.

vii Stand aside when checking the cylinders.

viii Do not remove the spindle key from the cylinders during welding. It will help to close the cylinders quickly in case of an emergency.

ix Always keep the cylinders in upright positions. Keeping in view safely easy and handling.

x Always check the cylinders valves to clean the valves s socket before attaching the regulator.

xi Never attempt to transfer D.A. from one cylinder to another.

xii When returning empty DA cylinders make sure that the valves are closed to avoid evaporation of acetone.

xiii Never open or close the cylinder valve with hammer.

Accessories safety in gas welding and cutting

i Use only the type of hose recommended for use in gas welding.

ii Use only black coloured hoses for oxygen and maroon coloured ones for Acetylene gas.

iii Avoid damage to the hose pipes caused by rubbing against hard or sharp edges.

iv Ensure that the hoses do not cross the gangways.

v Do not add bits of hoses together to make up the length

vi Blow out the hose pipes before correcting to the blow pipe to remove dust or dirt.

vii Protect the regulators from water, dust oil etc.

vii Never attempt to inter Charge oxygen and acetylene regulators while fitting as it Can damage the threads.

viii Always remember the oxygen connection is right hand thread and acetylene be Connection have left hand threads.

ix In the event of backfire shut both the blow piper valves (oxygen first) quickly and dip the blow pipe in the water.

xi While exhausting the flame, Shut off the acetylene valve first and then the oxygen to avoid backfire.

xii Check the leakage before using oxy-acetylene welding equipment.

xiii While igniting the flame point the blow pipe nozzle in a safe direction.

xiv Use the spark lighter to ignite the flame avoid hazards.

xv Toxic and poisonous flames given out during welding of some materials should be collected and clear as to be prevented from inhaling.

xvi Containers used for the storage of Flammable materials should not be welded without through cleaning as otherwise the containers may explode.

xvii Periodical checking of gauges of the regulators should be conducted to assure that their readings are correct.

xviii Pressure adjusting screw (Regulator Knob) should be turned slowly.

xix Never try to repair regulators.

xx Soapy water should be used for detecting leaks.

Safety during cutting gas welding and cutting

i Sparks from cutting and gouging can travel a considerable distance. Hence Such work should be carried out in a safe place away from all risk of Causing fire.

ii Fire Extinguishers and Sand should be readily available.

iii When cutting inside boilers or others confined places, gas cylinders should always be placed outside.

iv Cutting should never be done on concrete floor because a portion of concrete may get cracked. Asbestos mates or steel sheets should be used to protect the floor cutting.

Fire and fire fighting equipments

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

- state the types of fire
- describe the fire fighting equipments
- describe the list of general fire equipments.

Introduction

Fire fighting equipment is a range of tools and appliances that are designed to extinguish fires.

When used correctly, this equipment will protect the operator from harm.

Class A Fires: "Ordinary" Fires

Class A fires are the most common of the 5 different classes of fires. They occur when common combustible materials like wood, paper, fabric, trash, and light plastics catch fire. These accidental fires are ubiquitous across a variety of industries, so it's recommended to have adequate protection against "ordinary" fires in addition to other condition-specific fires.

Despite being "ordinary", don't rule this class of fire as low-risk. If there's an abundance of fuel present, these fires can intensify quickly. It's best to put out a Class A fire quickly before it spreads using water or monoammonium phosphate.

Class B Fires: Liquids & Gases

Class B fires involve flammable liquids and gases, especially fuels like petroleum or petroleum-based products such as gasoline, paint, and kerosene. Other gases that are highly flammable are propane and butane, which are common causes of Class B fires. The best way to deal with these types of fires is by smothering them or removing oxygen using foam or CO_2 fire suppression equipment.

Be aware that Class B fires do not include grease fires or cooking fires, which belong to their own class.

Class C Fires: Electrical Fires

Electrical fires fall under Class C and are common in facilities that make heavy use of electrical equipment, but they can occur in a wide range of industries. For example, data centers might be an obvious risk area for Class C fires. They must have safeguards in place to deal with electrical fires.

Construction sites are another common Class C fire risk: electrical power tools or appliances used for cooking can cause sparks to ignite combustible materials and intensify rapidly. Old buildings with bad wiring or space heaters present more concerns.

Electrical fires require non-conductive materials to extinguish the flame, so water alone is not a good solution. Facilities with sensitive equipment may prefer clean agent suppression because it won't leave residue or damage electrical equipment.

Class D Fires: Metallic Fires

Class D fires are not as common as the other classes, but they do require special attention because they can be especially difficult to extinguish. Metallic fires involve flammable materials like titanium, aluminum, magnesium, and potassium — all commonly occurring in laboratories.

Class D fires cannot be addressed with water, as this can exacerbate the fire and be potentially dangerous. Dry powder agents are the best solution for smothering the flames and limiting damage to property or people.

Class F Fires: Grease Fires or Cooking Fires

Class F fires involve flammable liquids, similar to Class B fires, but are specifically related to food service and the restaurant industry. These common fires start from the combustion of liquid cooking materials including grease, oils, and vegetable and animal fats.

Because they can spread quickly and be difficult to manage, Class K fires are some of the most dangerous. Water can make the situation worse, but smothering the flames or using a wet agent fire extinguisher is effective.

Types of fire fighting equipmnts

FOR CLASS A - ABC/powder, water, water mist, foam

FOR CLASS B - ABC/powder, CO2, water mist, clean agent

FOR CLASS C - ABC/powder, CO2, water mist, clean agent

FOR CLASS D - Dry powder agent

FOR CLASS F - Wet chemical, water mist.

Fire Fighting Equipment's

a Water filled bucket

b Sand filled bucket

c Canvas sheet

d Fire extinguisher- C.T.C Extinguisher, Soda, Acid Extinguisher.

This is a fire extinguisher, which is used to extinguish the fire. They hang it in the proper place in the workshop. in this gas and chemicals are filled according to the fire. From which the fire is extinguisher.

C.T.C Fire Extinguisher

Foam Extinguisher

Soda Acid Extinguishe

List of general equipments

1 Fire Extinguishers

2 Fire Alarm Systems

3 Smoke detector

4 Heat Detector

5 Fire Hydrant System

6 Fire Suppression System

7 Fire doors

8 Emergency and Safety Sign

9 Fire First Aid Kits

10 Fire Buckets

11 Fire fighter gloves

Lesson 4&5 : Introduction of Arc, Gas and another welding process and their application

Objectives

At the end of this lesson you shall be able to

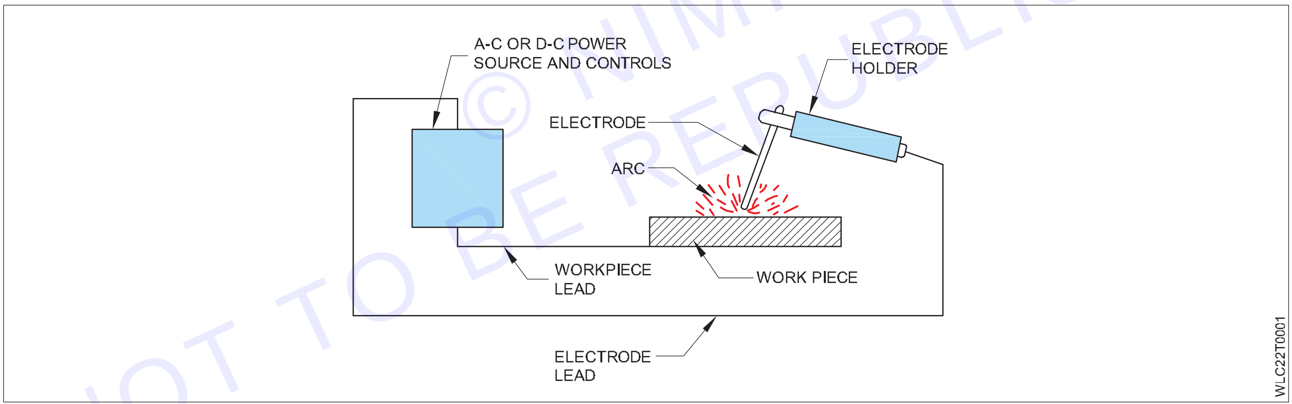
- explain the function arc welding definition, application
- explain the function gas welding definition, application
- explain the function MIG welding definition, application
- explain the function TIG welding definition, application
- explain the function Submerged arc welding definition, application.

1 **Arc welding -** This is process of welding of welding in which the heat energy is obtained from electricity. An electric arc is maintained between the end of a coated metal electrode and work piece.

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. Provide AC and DC welding supply for arc welding.

Application –Arc welding used for welding all ferrous and non- ferrous metal.



2 **Gas welding -** In the Gas welding process, the welding heat is obtained from the combustion of Acetylene Gas 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 intensity.

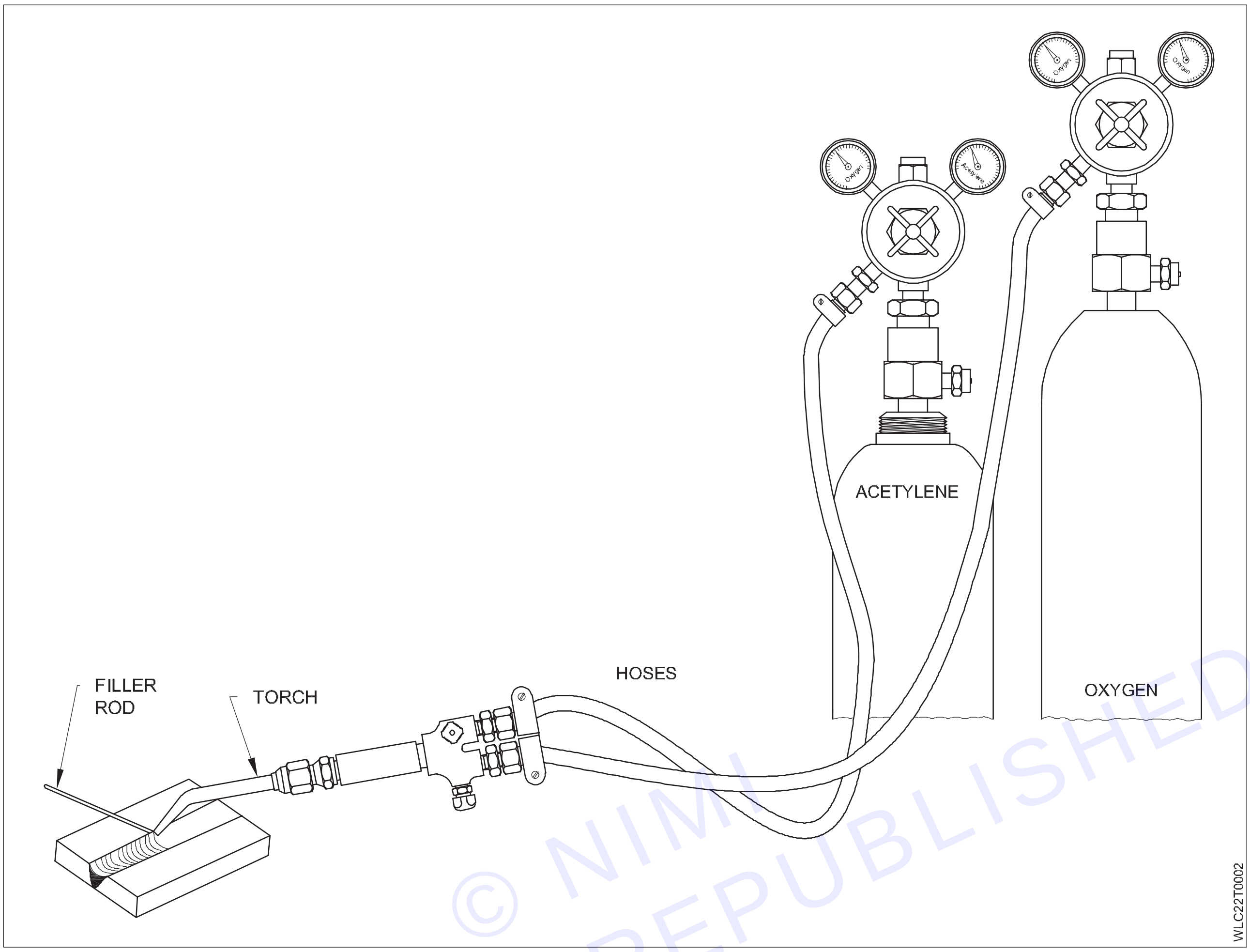
Oxy –acetylene plant : An oxy –acetylene plant can classified into –

a) High pressure plant b) Low pressure plant.

A high pressure plant used the acetylene cylinder and oxygen cylinder.

A low pressure plant used the a low pressure acetylene generator and a high pressure oxygen cylinder.

Application –oxy –acetylene used for ferrous and non-ferrous metals, generally below 3mm thickness



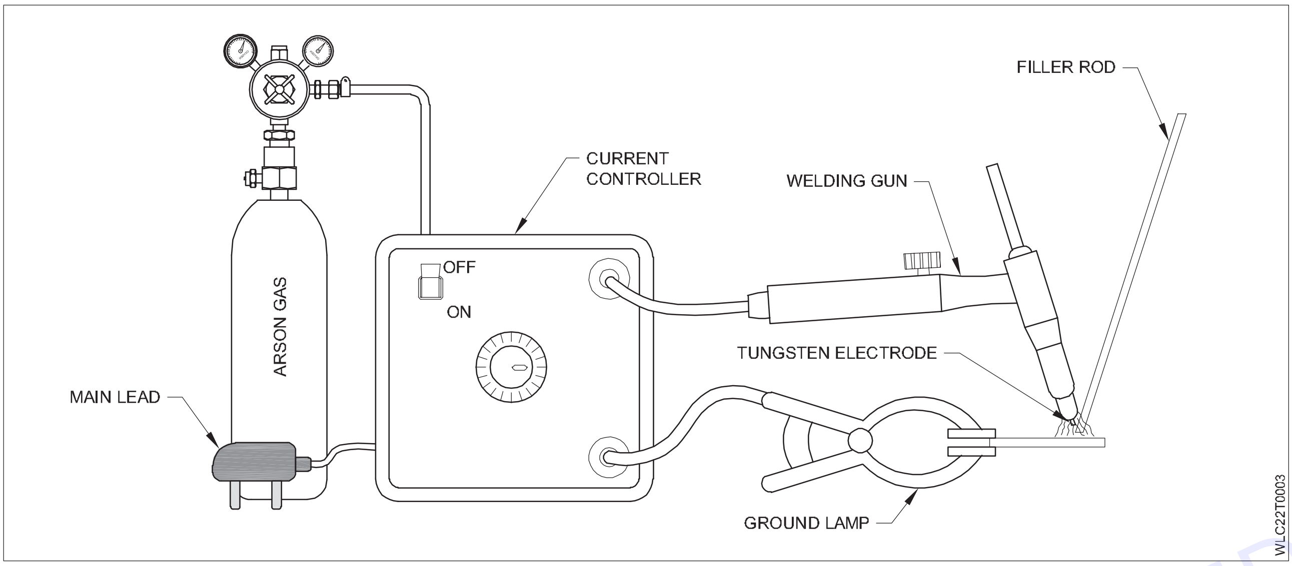
3 **MIG/GMAW –**In this process the arc is formed between a continuous, automatically fed, metallic consumable electrode and welding job in an atmosphere of inert gas, and hence this is called metal inert gas arc welding (MIG) process.

When the inert gas replaced by carbon dioxide then it is called CO2 arc welding or metal active gas (MAG) arc welding.

Application – Ferrous metal welding

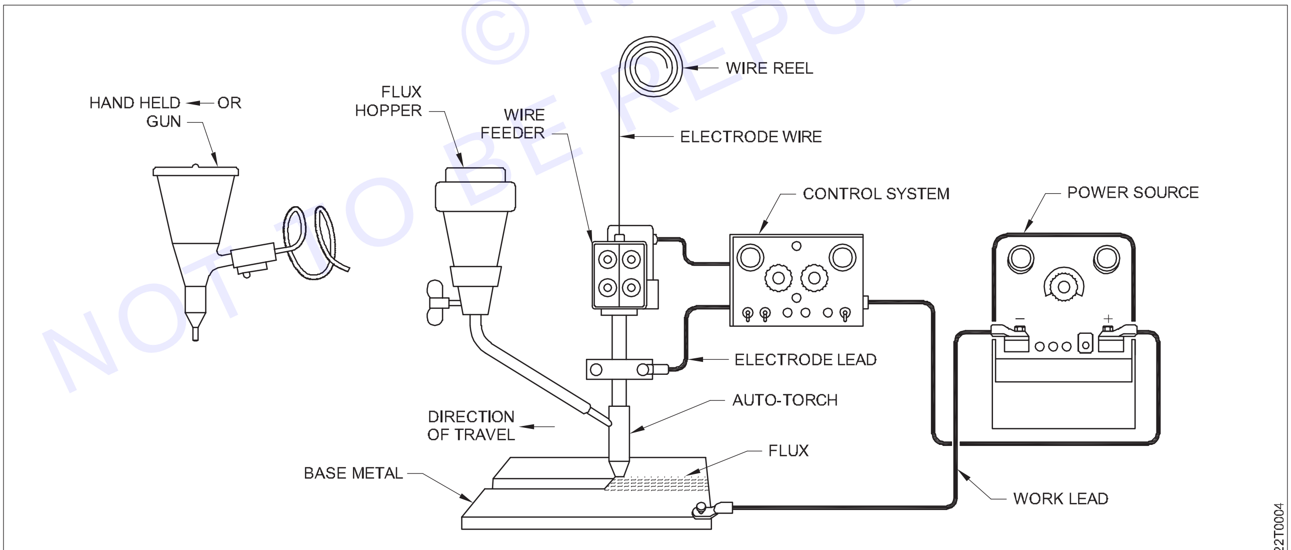
4 **TIG WELDING -** In this case the arc is formed between the tungsten electrode and the welding job in an atmosphere of an inert gas (argon or helium). A separate filler rod is used to add the filler rod.

Application – ferrous &nonferrous metal welding



5 **Submerged arc welding (SAW) -**In this process Arc is formed between a continuous , automatically fed, metallic consumable electrode and the welding job under a heap of powdered /granulated flux. The arc is totally invisible submerged in the flux.

Application – Ferrous metal thicker plates welding



SUBMERGED ARC WELDING

Oxy-acetylene gas cutting of metal - cut ability, cutting parameters

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

- explain of the oxy-acetylene cutting equipment
- describe the principal oxy-acetylene cutting
- describe the cutting parameter and metal cut ability.

Introduction

Oxy-Acetylene Gas Cutting is a widely used method for cutting metals, offering versatility and efficiency in various industrial applications. It involves the use of a mixture of oxygen and acetylene gases, which are ignited to create a high - temperature flame capable of melting and severing metal

Principle of gas cutting

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

Cutting torch

Different that regulator blow pipe it has an additional level for oxygen cutting

i Cutting tips is made with orifice in the centre surrounded by smaller five holes

ii Different types of cutting tips also available

Parameters

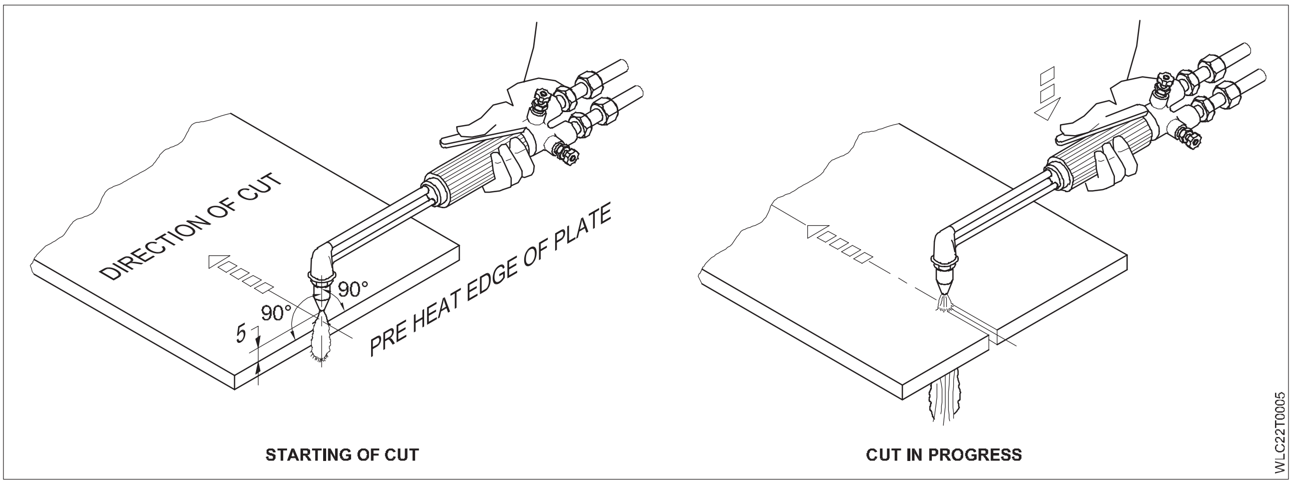
Cutting nozzle size-m	Thickness of plate.mm	Cutting oxygen Pressure kgf/cm²
0.8	3-6	1.0-1.4
1.2	6-19	1.4-2.1
1.6	19-100	2.1-4.2
2.0	100-150	4.2-4.6
2.4	150-200	4.6-4.9
2.8	200-250	4.9-5.5
3.2	250-300	5.5-5.6

Application

- Low cost equipment
- Basic equipment suitable for cutting, gauging and other jobs such as welding and heating.
- Portable, suitable for site work.
- Manual and mechanized operations.
- Mild and low alloy steels (but not aluminum or stainless steel).
- Wide range of thickness (typically from 1- 1000mm).

Common defects

- Extremely slow cutting speed
- Tip too close the job



Oxy-Acetylene Gas Cutting of Metals: Cut Ability

Oxy-Acetylene Gas Cutting is a versatile method used to cut a wide range of metals efficiently. The process involves using a combination of oxygen and acetylene gases to generate a high-temperature flame, capable of melting and severing metal. Here's an overview of the cut ability of oxy-acetylene gas cutting:

1 **Metal Types:**

2 Oxy-acetylene cutting is effective for cutting various types of metals, including:

- **Carbon Steel:** Commonly used in fabrication and construction industries.
- **Stainless Steel:** Known for its corrosion resistance, often used in food processing, aerospace, and automotive applications.
- **Aluminum:** Lightweight metal used in aerospace, transportation, and construction industries.
- **Cast Iron:** Widely used in machinery, automotive parts, and pipelines.

3 **Thickness:** Oxy-acetylene cutting can handle a wide range of metal thicknesses, from thin sheets to thick plates. While it is effective for cutting thin materials, its ability to cut thick metals, particularly those over 50 mm thick, is one of its notable advantages over other cutting methods.

4 **Versatility:** The versatility of oxy-acetylene cutting allows for straight cuts, bevel cuts, and shapes with ease. It's commonly used for cutting metal plates, pipes, structural shapes, and intricate designs.

5 **Edge Quality:** Oxy-acetylene cutting can produce relatively clean edges, especially when performed by skilled operators using the appropriate cutting parameters. However, the quality of the cut edge may vary depending on factors such as the material type, thickness, cutting speed, and torch angle.

6 **Cost-Effectiveness:** Compared to other cutting methods such as plasma cutting or laser cutting, oxy-acetylene cutting equipment is generally more affordable and accessible. This makes it a cost-effective option, particularly for small-scale operations or when cutting thick materials where other methods may be less efficient.

7 **Portability:** Oxy-acetylene cutting equipment is portable and can be used in various locations, including remote job sites or areas with limited access to electricity. This portability adds to its versatility and makes it suitable for a wide range of applications.

8 **Heat Affected Zone (HAZ):** Like any thermal cutting process, oxy-acetylene cutting creates a heat-affected zone along the cut edge. While this zone is relatively small compared to some other cutting methods, it's essential to consider its impact, particularly on heat-sensitive materials or when maintaining tight tolerances.

Overall, oxy-acetylene gas cutting offers excellent cut ability across different metal types and thicknesses, making it a preferred choice for many industrial applications requiring efficient and versatile metal cutting solutions.

Oxy-Acetylene Gas Cutting: Parameters and Faults

Oxy-Acetylene Gas Cutting is a widely used method for cutting metals, offering versatility and efficiency. To achieve optimal results, it's essential to understand the key parameters involved in the process and be aware of common faults that may occur. Here's an overview:

Cutting Parameters

1 **Gas Pressures:** Proper adjustment of oxygen and acetylene pressures is critical for effective cutting. The oxygen pressure typically ranges from 20 to 70 psi, while the acetylene pressure ranges from 5 to 15 psi. Higher pressures can lead to faster cutting speeds, but excessive pressure may cause overheating and rough cuts.

2 **Cutting Speed:** The speed at which the torch moves along the cutting path is crucial. Too slow can result in excessive heat buildup and slag accumulation, while too fast may lead to incomplete cuts or poor edge quality. Finding the right balance is essential for achieving clean and precise cuts.

3 **Tip Size:** The size and type of cutting tip used in the torch affect the width of the cut and the amount of heat delivered to the work piece. Selecting the appropriate tip size for the material thickness and desired cut quality is essential for achieving optimal results.

4 **Preheating:** Preheating the metal before cutting can improve efficiency, especially for thicker materials. Proper preheating reduces the time required to achieve full penetration and minimizes distortion along the cut edge. The preheating flame should be adjusted based on the material type and thickness.

5 **Torch Angle:** Maintaining the correct angle of the torch relative to the work piece is essential for achieving clean and accurate cuts. Improper torch angle can result in uneven heat distribution, leading to angularity errors or poor cut quality.

Common faults in cutting

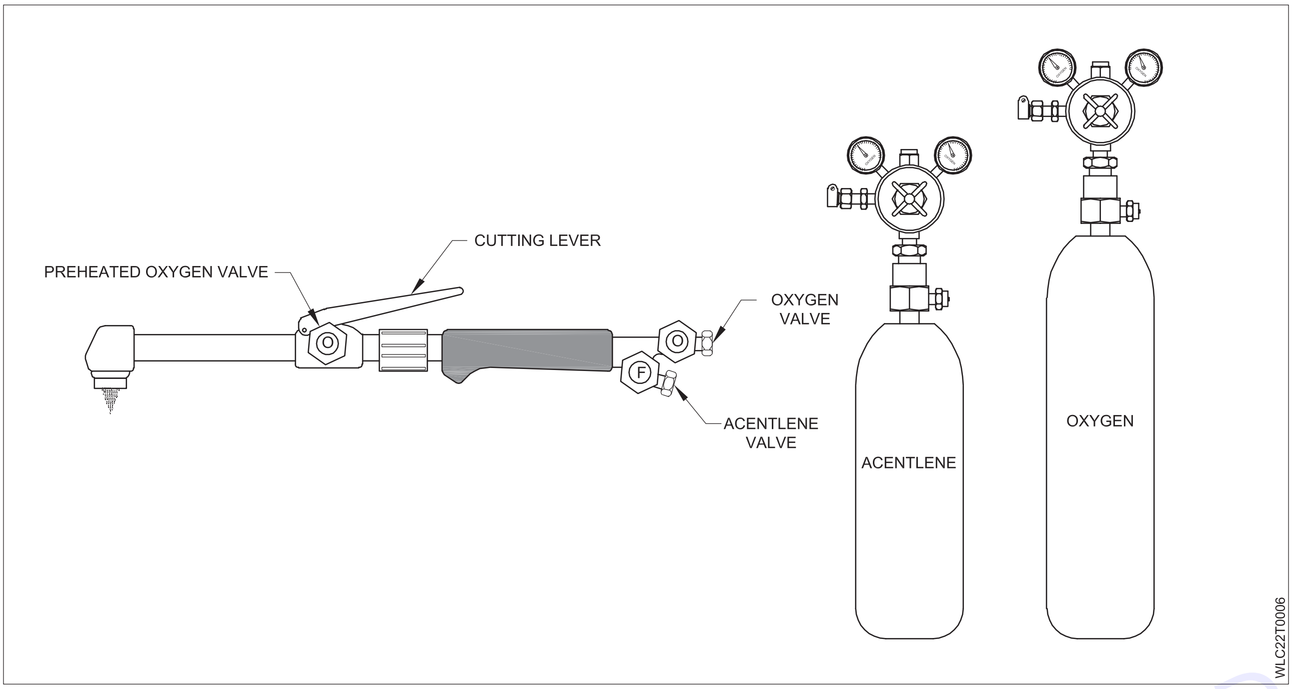
1 **Slag Inclusions:** Excessive slag buildup along the cut edge is a common issue caused by improper cutting parameters or torch manipulation. Slag inclusions can weaken the integrity of the cut and require additional finishing operations to remove.

2 **Incomplete Penetration:** Insufficient heat or incorrect cutting parameters may result in incomplete penetration of the metal, leading to a jagged or uneven cut surface. Proper preheating and adjustment of cutting parameters can help prevent this issue.

3 **Warping and Distortion:** Overheating or uneven heating of the work piece can cause warping and distortion along the cut edge, compromising dimensional accuracy and surface finish. Proper preheating and control of cutting parameters can help minimize this issue.

4 **Backfires and Flashbacks:** These are safety hazards that occur when the flame travels back into the torch or hoses. They can be caused by improper gas pressures, leaks, or blockages in the equipment. Regular maintenance and inspection of equipment are essential for preventing backfires and flashbacks.

By understanding and controlling these parameters while being aware of common faults, operators can achieve high-quality cuts consistently in oxy-acetylene gas cutting operations. Regular training, proper equipment maintenance, and adherence to safety protocols are crucial for successful cutting outcomes.



Oxy acetylene gas cutting flames

The oxy-acetylene gas cutting flame is a type of flame produced by the combustion of oxygen and acetylene gases in a cutting torch. This flame is used in the process of oxy-fuel cutting, a method employed to cut or shape metal materials. The oxy-acetylene flame is characterized by its high temperature and its ability to rapidly melt and sever metals.

There are typically three zones in an oxy-acetylene flame:

1 **Inner cone:** This is the central, hottest part of the flame. It appears as a small, pointed blue flame and is where the majority of the cutting action occurs. The temperature in this zone can reach around 6,300°F (3,480°C).

2 **Outer cone:** Surrounding the inner cone is the outer cone, which is less intense and appears as a larger, lighter blue flame. This zone provides the preheating necessary for the metal to be cut. Its temperature is lower than that of the inner cone but still high enough to facilitate the cutting process.

3 **Feather or neutral flame:** Beyond the outer cone is the feather or neutral flame. This part of the flame is used for preheating the metal surface prior to cutting. It has a lower temperature and is often used to control the heat input into the work piece.

The oxy-acetylene gas cutting flame is versatile and widely used in various industries such as metal fabrication, automotive, shipbuilding, and construction due to its ability to cut through thick metals quickly and efficiently. However, it requires proper training and safety precautions due to the high temperatures involved and the potential hazards associated with handling flammable gases.

Faults in gas cutting

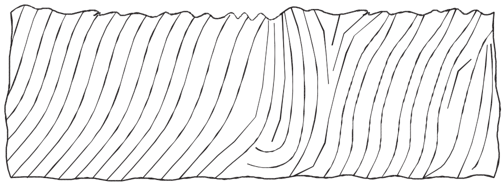
Objectives: At the end of this lesson you shall be able to

- explain the principle of gas cutting
- state common Faults in gas cutting.

Common faults in cutting

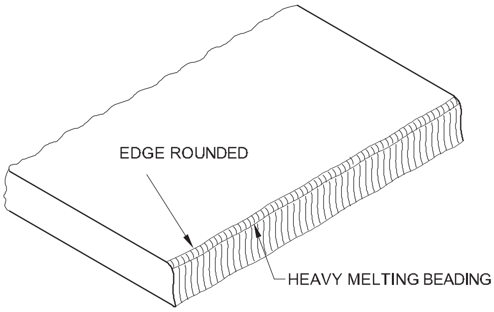
The tip is too high off the steel. The top edge is heated or rounded, the cut face is not smooth, and often the face is slightly beveled where preheat effectiveness is partially lost due to the tip being held so high. The cutting speed must be reduced because of the danger of losing the cut. (Fig 1)

Fig 1



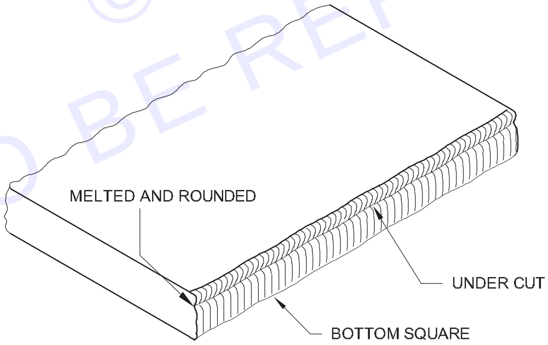
Extremely slow cutting speed. Pressure marks on the cut face indicate too much oxygen for the cutting conditions. Either the tip is too big, the cutting oxygen pressure is too high, or the speed is too slow as shown by the rounded or beaded top edge. On reducing the cutting oxygen volume to the correct proportions for the thickness of the cut, the pressure marks will recede toward the bottom edge until they finally disappear. (Fig 2)

Fig 2



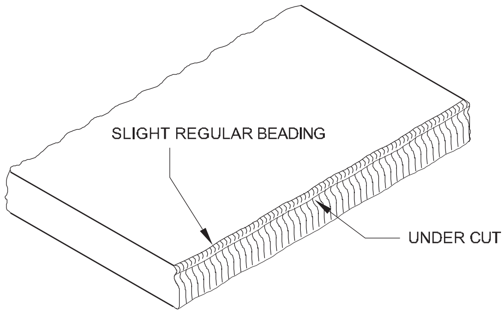
Tip too close to the steel. The cut shows grooves and deep drag lines, caused an unstable cutting action. Part of the preheat cones burned inside the kerf, where normal gas expansion affected the oxygen cutting stream. (Fig 3)

Fig 3



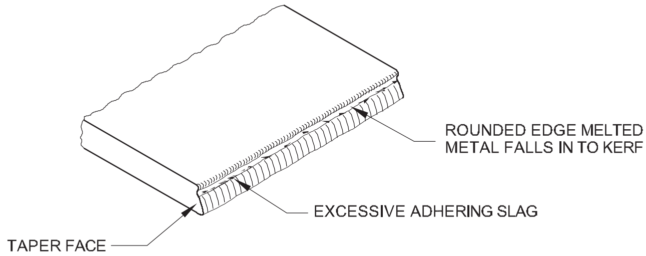
Too much cutting oxygen. The cut shows pressure marks caused by too much cutting oxygen. When more oxygen is supplied than can be consumed in oxidation, the remainder flow around the slags, creating gouges or pressure marks. (Fig 4)

Fig 4



Too much preheating. The cut shows a rounded top edge caused by too much preheat. Excess preheating does not increase the cutting speed, it only wastes gases. (Fig 5)

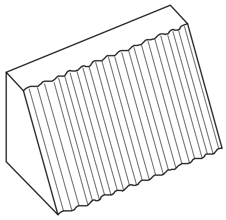
Fig 5



TOO MUCH PREHEATING

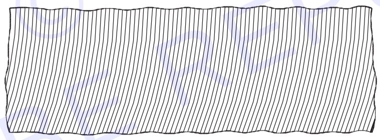
Poor quality bevel cut. The most common fault is gouging, caused by either excessive speed or inadequate preheat flames. Another fault is a rounded top edge caused by too much preheat, indicating excessive gas consumption. (Fig 6)

Fig 6



Slightly too fast a cutting speed. The drag lines on this cut incline backwards, but a drop cut' is still attained. The top edge is good; the cut face is smooth and slag-free. This quality is satisfactory for most production work. (Fig 7)

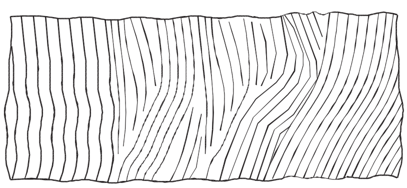
Fig 7



SLIGHTLY TOO FAST CUT

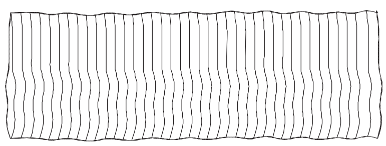
Slightly too slow a cutting speed. The cut is of high quality although there is some surface roughness caused by the vertical drag line. The top edge is usually slightly beaded. This quality is generally acceptable, but faster speeds are more desirable because the labour cost for this cut is too high. (Fig 8)

Fig 8



In a good cut, the edges are square, and the lines of cut are vertical. (Fig 9)

Fig 9



Lesson 6&7 : Basic electricity applicable to arc welding

Objectives

At the end of this lesson you shall be able to

- define simple basic electricity
- define electric circuits, voltage, current, resistance, electric arc
- state basic electricity applicable to arc welding

Introduction

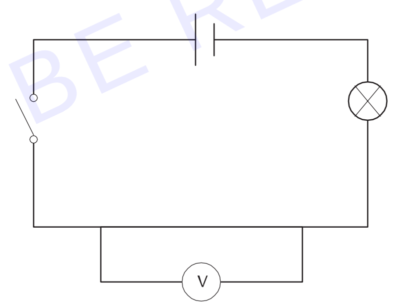
Arc welding is a versatile and widely used welding process that joins metals by melting them with the heat generated from an electric arc. Understanding the basic principles of electricity is crucial for anyone engaging in arc welding, as it forms the foundation for operating welding equipment safely and effectively.

Electricity is a kind of invisible energy which is capable of doing work such as –Burning of lamp.

Running of fan. Running of motor & machine, Producing heat, Creating an Arc. Electrical resistance of material. Electrons in motion is called current. The rate of flow of electrons is measure in amperes. The measuring instrument is called ampere meter, or ammeter.

1 Electric circuits

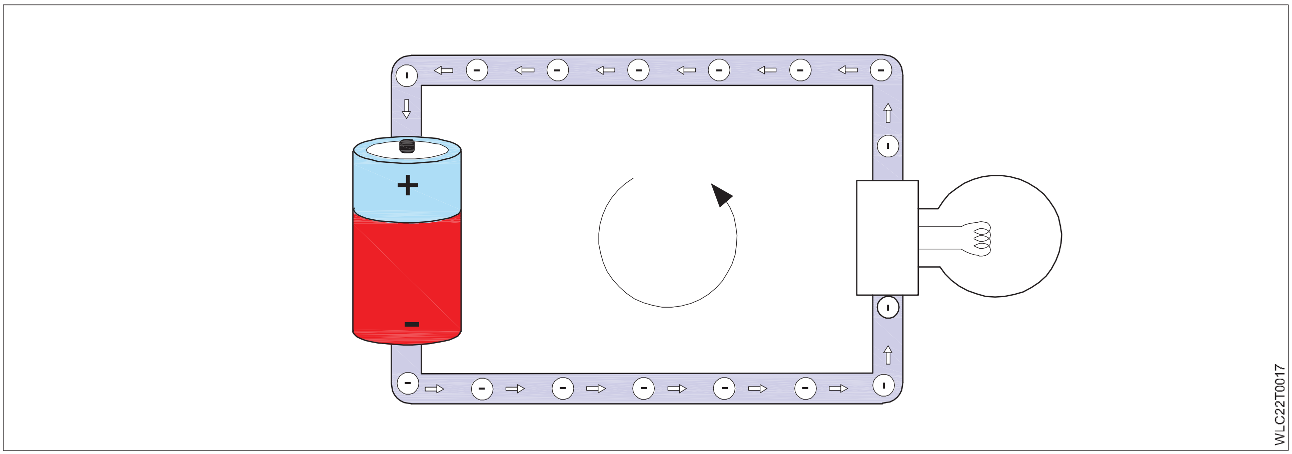
- Arc welding requires a closed electrical circuit consisting of a power source, welding electrode or wire, work piece, and ground clamp.
- The power source supplies the necessary voltage and current for welding, creating a flow of electricity through the circuit.



CURRENT ELECTRICITY

2 Static electricity

- This type electricity generate to by Friction.
- This type electricity not transfer one place to other place.so this not useable this type electricity.
- Current Electricity –Electrons motion is called current.
- This type current transfer one place to another place.



3 Voltage and Current

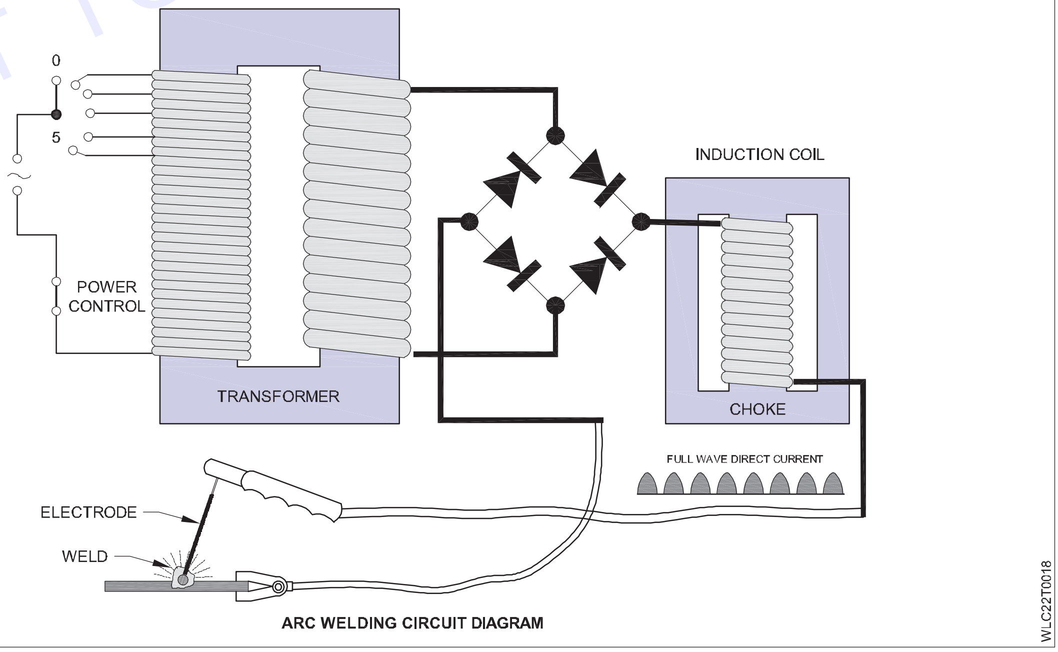
- Voltage (V) is the measure of electrical potential difference between two points in a circuit. It represents the force that pushes electric charges through a conductor.
- Current (I) is the flow of electric charge. It is measured in amperes (A) and determines the rate at which electric charge passes through a conductor.
- In arc welding, adjusting voltage and current settings is essential to control the heat input and penetration into the work piece.

4 Resistance

- Resistance (R) is the opposition to the flow of electric current in a circuit. It is measured in ohms (Ω).
- The resistance in the welding circuit plays a significant role in generating heat. The high resistance at the point where the electrode contacts the work piece leads to intense heat generation, forming the arc.

5 Electric Arc

- An electric arc is a discharge of electricity between two electrodes through ionized gas or plasma.
- In arc welding, the arc forms between the welding electrode and the work piece, creating temperatures high enough to melt the base metal and any filler material, resulting in a strong weld joint.



ARC WELDING CIRCUIT DIAGRAM

2 Basic electricity applicable to arc welding.

Use the external power to motor /chemical than generate the electricity. this external power generate to electromotive force (E.M.F)

In the welding process, the electrical energy is converting to heat energy. Used the electrical current melt the metal / heat them to red hot condition. So electrical is used to very large extent in many welding process.

Created a high temperature (3400°C- 4000C°) between electrode and work using the electric voltage and high current (All types of arc welding) All the resistance welding-Like spot welding, seam welding, friction welding.

Electron beam welding &Electro slag welding.

Heat and temperature and its terms related to welding

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

- differentiate between heat and temperature
- state the units of heat and temperature measurement
- differentiate between heat and temperature as applicable to welding
- convert centigrade to Fahrenheit.

Introduction to heat

1 **Heat–** Heat is a type of energy. Due to which we experience heat and cold. It is absorbed by molecular .any heat to object speed of the speed of the molecules increases. Object heat is cool down than molecules also decreases.

Units of heat

a **Calories–** Calories is the unit of heat in matric system/C.G.S System. The amount of heat required to raise the temperature of one gram of water is called a calories.

b **British Thermal Unit –**The unit of heat in the British system (F.P.S system) is the British Thermal Unit. The amount of heat used to Increase the temperature of pound water by one degree Fahrenheit is called British Thermal Unit. (B.Th.U). British Thermal Unit = 252 Calories.

c **Centigrade Heat Unit –** The amount of heat used to increase the temperature of a pound water by one degree of calcium (Centigrade) is call C.H.U.

1 C.H.U = 453.6 Calorie.

(B.TH.U)

d Kilo Calories – This is unit of M.K.S system. Raising the temperature 1degree centigrade of one kilogram of water the amount of heat required for is called 1°C kilocalorie.

1 kilo calories =1000 calories.

2 Temperature – It is effect of Heat. It detects the hotness and coolness of an object or body.

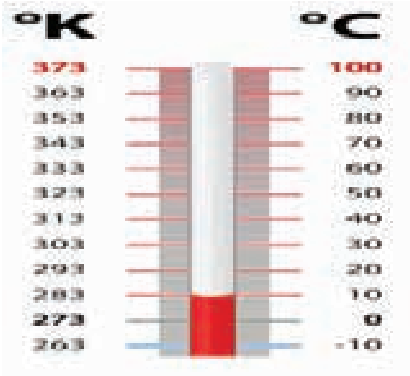
The instrument used to measure temperature is called Thermometer. It is filled with mercury. Different scales are used to measure temperature.

a Centigrade scale - It is also known as Celsius scale. The scale starts at 0°C. Ice has a melting point 0°C and water boiling point 100 °C.

b Fahrenheit Scale – It has a melting point of ice 32°F and 212°F boiling point. This scale is divided into 180 equal parts. Each part is call 1°F.This scale is used medical thermometer.

c Reaumur Scale – Reaumur scale unit (R°) are used to measure it. It has 0 to 80 marks. It has ice melting point 0°C and a boiling point of water at 80°R. Its every part called 1°R.

d **Kelvin Scale–**The degree is used to measure this scale K°. It range from 273.15° to 373.15°K



Formula and relation of centigrade , Fahrenheit , and Kelvin

Introduction

$$\frac{C}{100} = \frac{F-32}{180} = \frac{R}{80} = \frac{K-273.15}{100}$$

Principle of arc welding and characteristics of arc

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

- state the electric arc welding
- state the principal of arc welding
- state the characteristics of Arc.

Electric arc welding

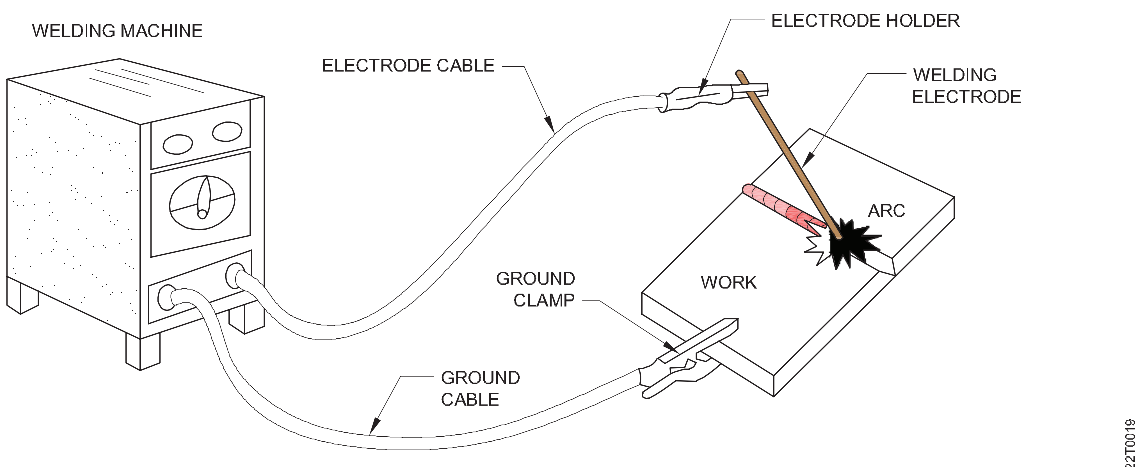
This is a process of welding in which the heat energy is obtained from electricity. When electric current passes through a medium material it generates heat.

An electric arc maintained between the end of a coated material electrode and work piece.

The Flux covering melts during welding and forms gas and slag the arc molten pool.

Flux also prevent the atmosphere contamination oxidation (oxygen & nitrogen)

The flux also provides a method of adding deoxidizer and alloying elements to the weld metal.

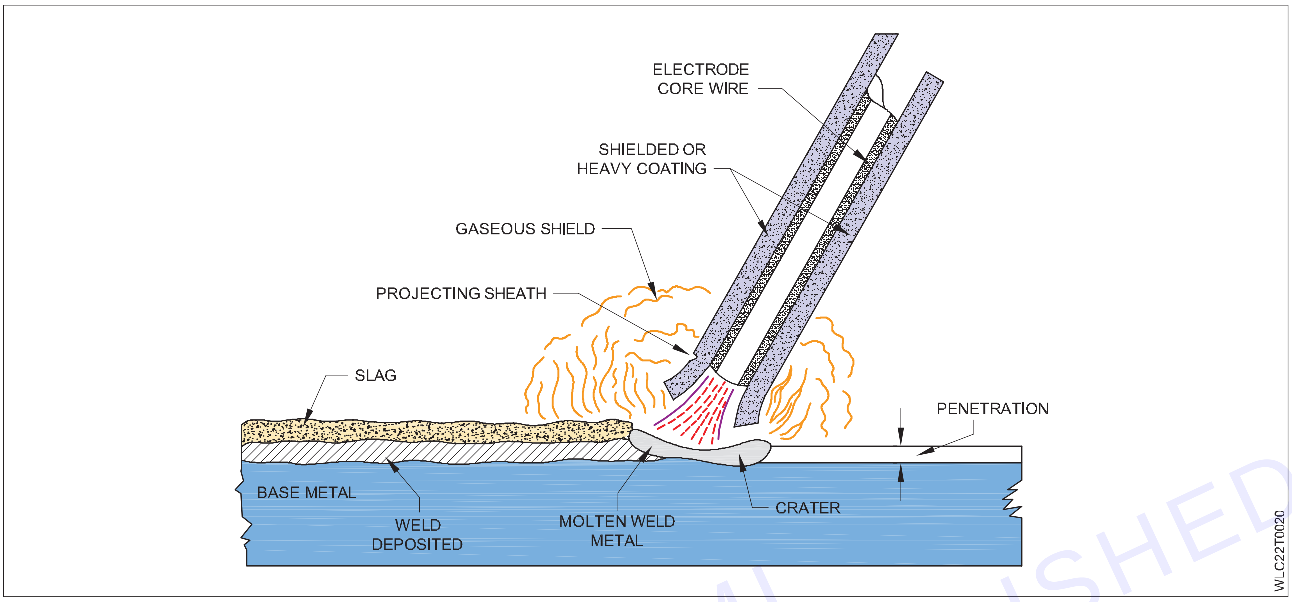


COMPONENTS OF AN ARC WELDING SYSTEM

Principle of Arc welding

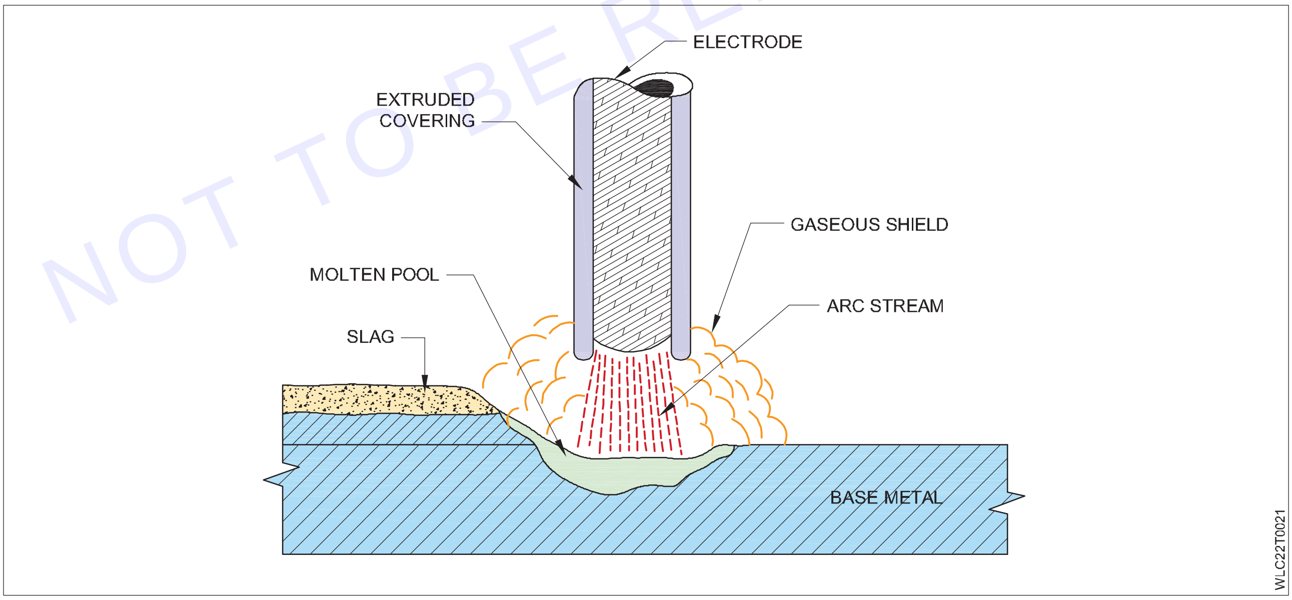
When high current passes through an air gap from one conductor to another, It produce very intense and concentrated heat in the from spark.

The temperature of this spark /arc is approx 3400° C to 4000°.Which can melt and fuse the metal very quickly to produce a homogeneous weld.



Characteristics of Arc

Welding power source construct and design deferent shape and size. Supply the current AC and DC both .and its voltage and amperage output are controlled.



Constant current characteristics

Constant Current power source is used with a coated electrode. This type power sources less variation in amperage and greater variation in arc voltage. Slightly increasing the arc length increase the arc voltage and decreases arc amperes.

Constants voltage characteristics: The voltage is always constant, the voltage is set while the amperage depend on the speed of wire feed in the welding gun.

Increasing the speed of the wire feed increases the amperage. And decreasing with decreasing.

Types of weld joint

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

- explain the basic welding joints
- explain of butt and fillet welds.

Introduction

Joints are prepared to weld metals at less cost. Joint obtain the required strength, lode and pressure. Weld can very easy, less time of weld, save the filler metal. Control the internal stresses.

Types of welding joint

1 Butt joint

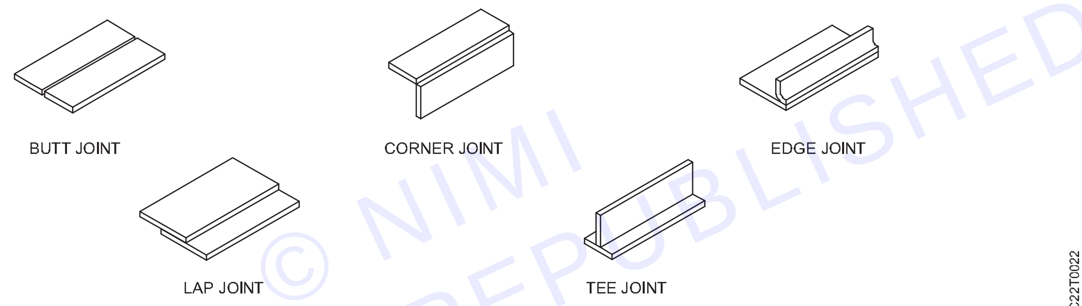
2 T-joint

3 Lap joint

4 Corner joint

5 Edge joint

Fig 1



FUNDAMENTAL TYPE OF JOINTS

1 **Butt joint:** Joint two members that meet at thin edge on the Same plane used in application where a Smooth weld face is required. Filler groove welded groove welding requires added expertise and expense.

Improper design welding risk distortion and residual Stresses

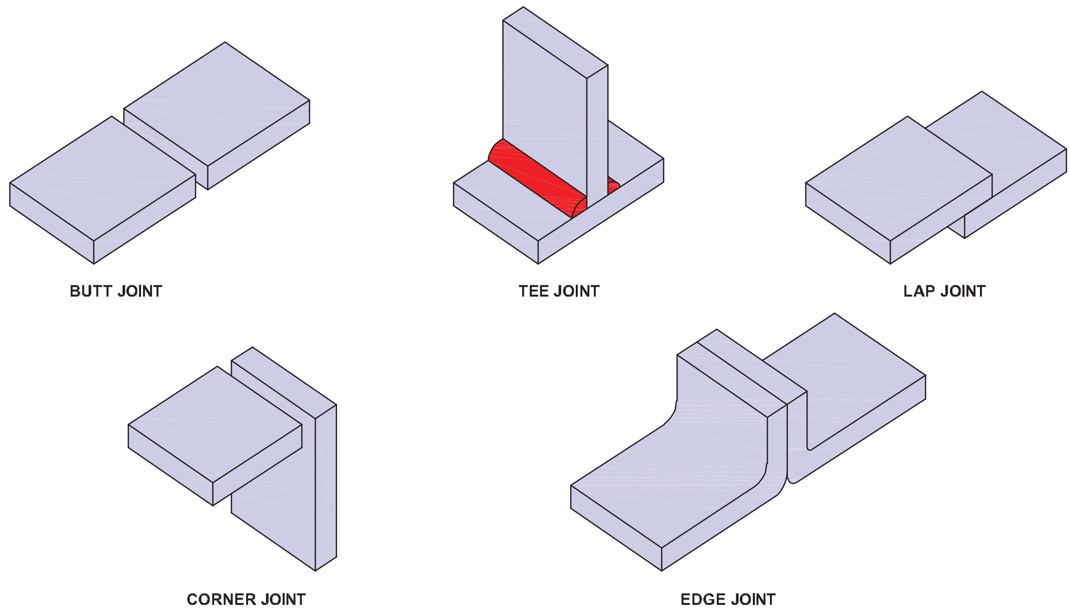
2 **T-joint :-**Joint two member that meet at a shaped angle good Mechanical properties, especially when welded from both side. Easily welded with little or no joint preparation. Usually fillet welded, although j-grooves are possible.

3 **Lap Joint :** Joint two member Raving overlapping surfaces. Good mechanical properties especially when welded from both sides. Usually fillet wedded thicker material required, more, over lap.

4 **Corner joint:** Joint two member that meet at an angle. Two main types open corner and closed corner. Easily welded with tittle or no joint preparation. Increase travels speed on light gauge material to avoid burn through.

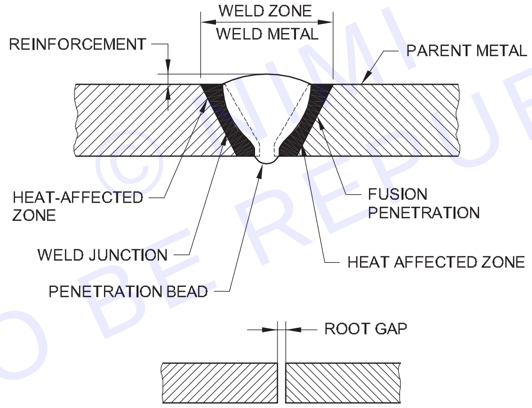
5 **Edge joint:** Joint two parallel member. , or, nearly parallel, not recommended if either member will be Subject impact on high stresses. Square groove is most common. But other groove conformation is possible. Very deep penetration is impossible.

Fig 2



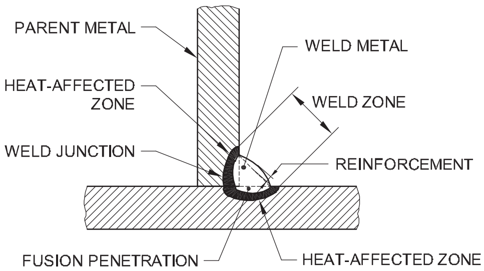
- **Root gap:** It is the distance between the parts to be joined. (Fig 3)

Fig 3



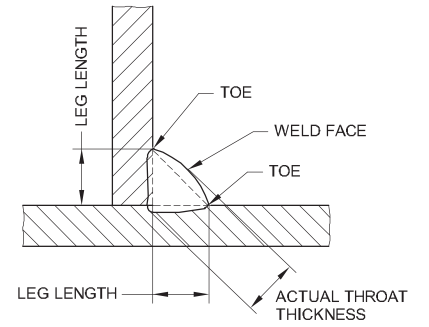
- **Heat affected zone:** Metallurgical properties have been changed by the welding heat adjacent to weld.(Fig 4)

Fig 4



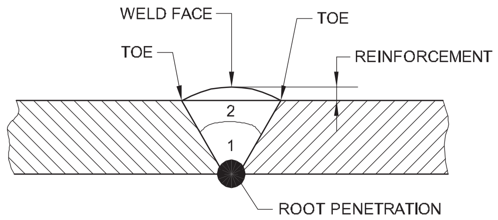
- **Leg length:** The distance between the junction of the metals and the point where the weld metal touches the base metal 'toe' (Fig 5)

Fig 5



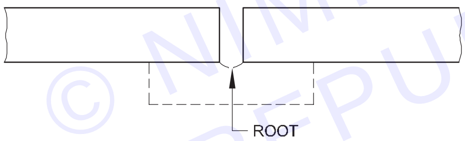
- **Reinforcement:** Metal deposited on the surface of the parent metal of the excess metal over the line joining the two toes. (Fig 6)

Fig 6



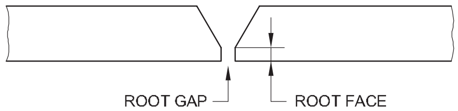
- **Root:** The parts to be joined that are nearest together. (Fig 7)

Fig 7



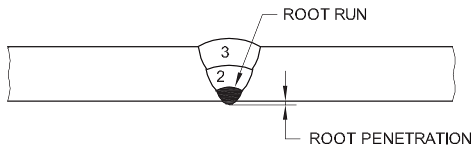
- **Root face:** The surface formed by squaring off the root edge of the fusion face to avoid a sharp edge at the root. (Fig 8)

Fig 8



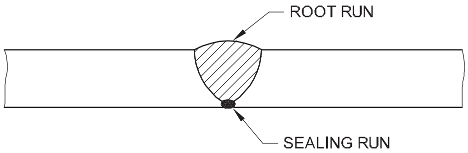
- **Root run:** The first run deposited in the root of a joint (Fig 9)

Fig 9



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

Fig 10



Edge Preparation

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

Definition

The term Edge preparation refers to the manner in which the edges of work pieces are prepared prior to welding in order to accommodate the weld metal, and . varies according to such factors as the type of metal thickness of plate and the method of welding to be employed.

Necessity of edge preparation

Edge preparation of plates is required before butt welding due to the following reasons:

1 To ensure full thickness of preparation.

2 To obtain full strength weld with minimum of weld metal.

3 To limit distortion due to welding.

4 To accommodate the weld metal.

5 To obtain welds free from defects.

Influencing factors

Joint to be prepared are largely influenced by the view point of economy. The preparation is done prior to welding in order to obtain the required strength. The following factors are to be taken into consideration for the edge preparation.

1 The welding process like SMAW, Oxy-Acetylene welding, MIG/MAG/Co_2 electro slag etc.

2 The type of metal to be joined, i.e. mild Steel, stainless steel, aluminium etc.

3 The thickness of metal to be joined.

4 Economic factor.

Method of edge preparation

The joining edges may be prepared foe welding by any one of the metliods mentained below.

i Flam cutting

ii Machine tool cutting

iii Machine Grinding or Hand grinding

iv Filing chipping.

Type of edge preparation

Deferent type of plate preparation have been designed which permit penetration of plates with minimum of weld metal

1 Flanged preparation: For Sheet metal up to 1/16 inch (1.6mm) thickness, the edges to be joined should be flanged, the upturned edges to joint Should be Flanged, the upturned edge being at right angles to the sheet and of a depth equal to about twice the thickness of the Sheet. Flanging may be performed by the special machines built for this purpose or the material could be held in a vice and hammer to the require shape. Such type of joint is known as Flanged joint.

2 Squire edge preparation: For material of thickness between 1/16 inch and 1/4 inch (16mm to 6mm) it is not necessary to flange or to bevel the edges; the latter are left Square, such joints are turned as Square Butt joint. and the preparation is known as square edge preparation square butt joints are of two types.

3 Closed square butt joint: It is used for plates up to 3 mm thick where full thickness penetration is not necessary

4 **Open square butt joint:** It is used for plates up to 6mm thickness and when full penetration is required. The root gap between the plates varies from one half thickness to one thickness of the plate.

When full penetration is required. The root gap between the plates varies from one half thickness to one thickness of the plate.

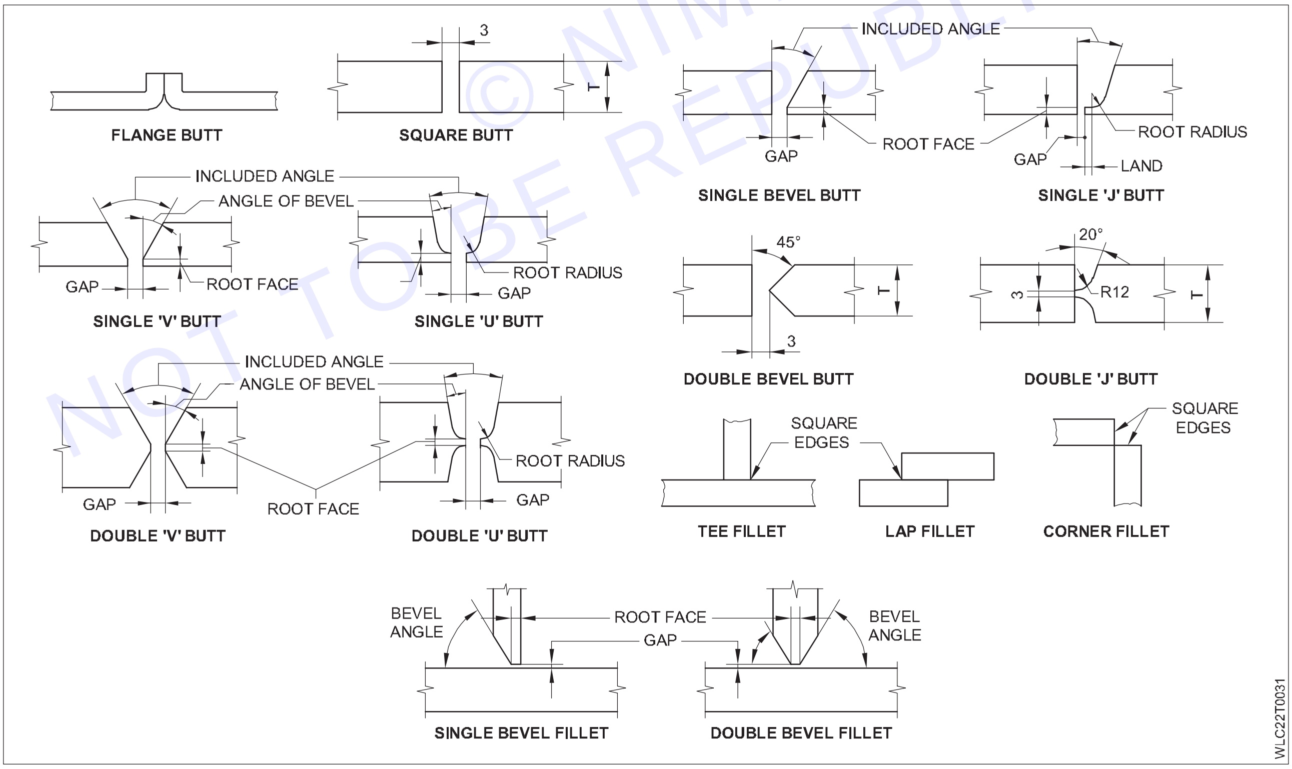
5 **Single 'v' preparation :** The next type is that turned 'single' 'V' preparation which consists in hovelling the edge of each plate so that a 'v' is formed when they are brought to gather. This is the most commonly. Used type of edge preparation for welding plates up to 12mm thickness, the root gap and root face are kept as 2 mm and the included angle of 70° such type of preparation is known as single 'V' Butt joint. This type of penetration is also used for welding of The pipes. The edge preparation is done either by machining or by flame cutting.

6 **Double 'V' preparation:** This type of preparation is used if the plates are more than 12 mm thick and are accessible for welding from both sides. Less weld metal is required to complete a double 'v' Butt joint. Heat distribution is equal from both sides and hence there is less distortion. This preparation the root gap, root face and included angle will be same as for single 'v' preparation.

7 **Single 'U' & double 'U' preparation:** This type of edge preparation is suitable for if the thickness of the plate is 15 mm or more the Double 'U' is used if the plates are accessible for welding from both sides. The 'U' type edge preparation required less weld metal than the 'V' type for the same thickness of plate. Double 'U' has the advantage of equaling heat input from both side and hence causes less distortion.

8 **Horizontal butt weld preparation:** This type of preparation is required for welding of two vertical plate by a horizontal weld. The upper plate is beveled to an angle of 45o And the lower to 15o .This difference in the angle of bevel is required to support the molten metal.

9 **Single bevel & single 'J' butt preparation:** These type of edge preparation are used for welding of plates at right angle to each other.



Lesson 8&9 : Arc welding power sources - AC welding transformer

Objectives

At the end of this lesson you shall be able to

- state the necessity of an AC arc welding machine
- state the working principal and parts of AC arc welding machine.

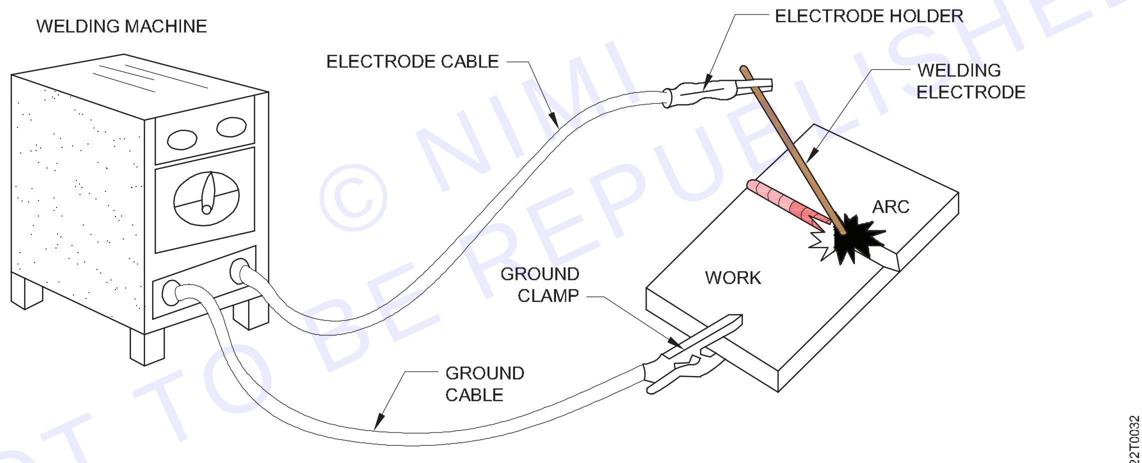
Introduction: AC welding transformer –This is type of AC welding machine which converts AC supply into AC welding supply.

It is a step down transformer.

Reduced the main supply voltage (220V or 440 volts)

To welding supply open circuit voltage (OCV). between 40 and 100volts

Increases the main supply low current to the required high output welding current in hundreds of amperes (300 -400 amps)



COMPONENTS OF AN ARC WELDING SYSTEM

AC transformer construction

It consists of an iron core made out of a special alloy thin iron sheet stamping.

Two coils of wire are wound over the iron core without any inter connection between them.

One coil, called primary winding, consists of a thin conductor and has more turn which receives energy from the mains.

The second coil, called secondary winding, consists of a thick conductor and less turns which supply energy for welding.

A current regulator is attached to the secondary output supply to adjust the amperes forwarding

Parts list

1 Body, Holder connector, Earth connector, Holder cable, Earth cable, handle for current setting, Primary coil, secondary coil,

Working Principle

Two welding cables are attached with the output terminals. One is for the electrode and the other is for earth or job.

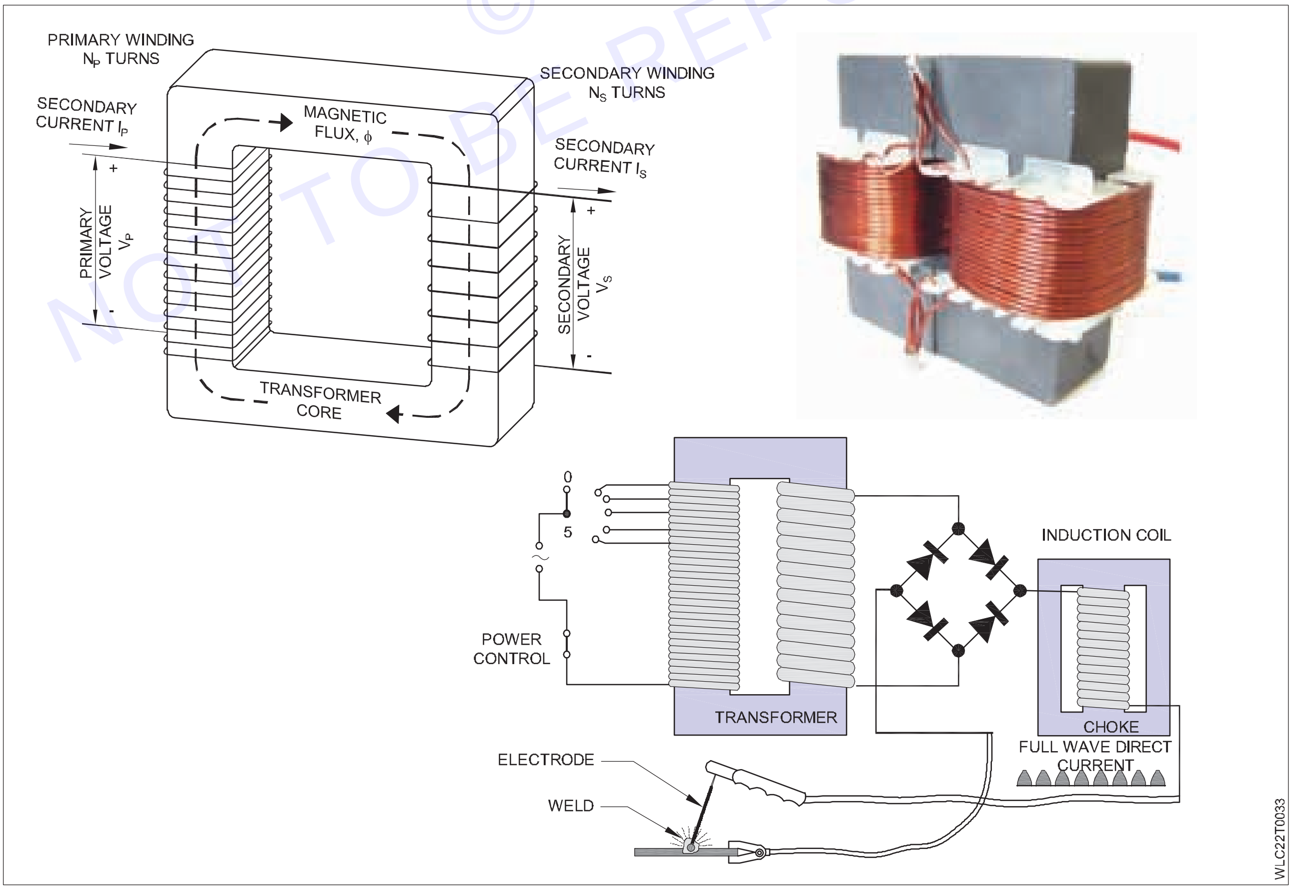
The transformer may be air – cooled or oil- cooled.

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.

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.

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



DC welding motor generator set

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

- explain, DC welding generator set
- explain the construction of DC generator set
- explain the working principle of DC welding motor generator set.

Introduction

Generate DC welding supply with the help of AC main supply. A DC welding generator produces direct current in either straight or reveres polarity. The current supply by DC generator is created by an armature rotating in the electrical field. And armature is rotated by AC electric motor.

Commutators convert to AC to DC current.

Generators are designed to rotate at speed1500, 1800, or 3600 rpm to give option current values.

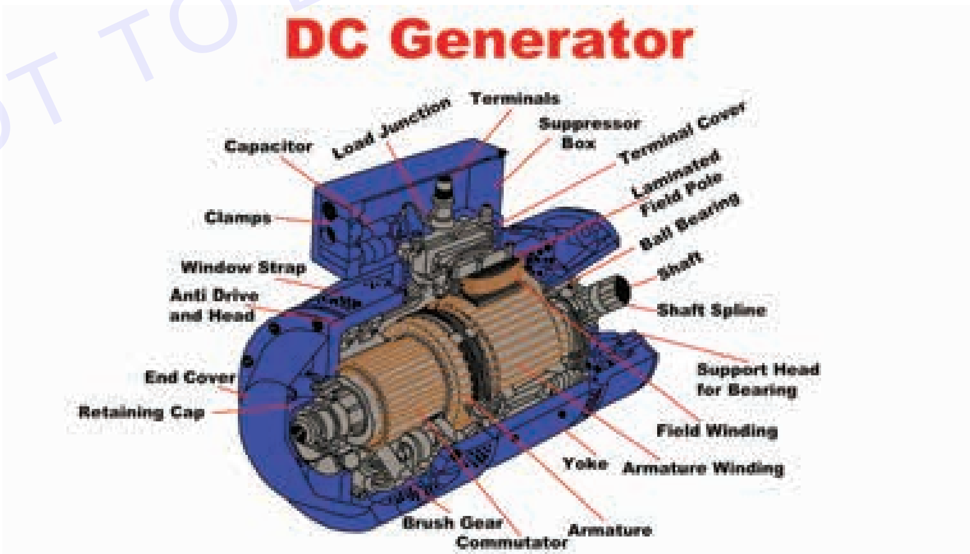
Generator supplies voltage usually in the range from 15 to 45 volts across the arc.

DC welding generator

Construction of DC generator

Main polies - These are connected to the body or yoke to produce magnetic line of force, also called Field coils.

Body/ yoke - It is the body of the generator which covers all the parts and helps in completing the magnetic circuit to the generate electricity.

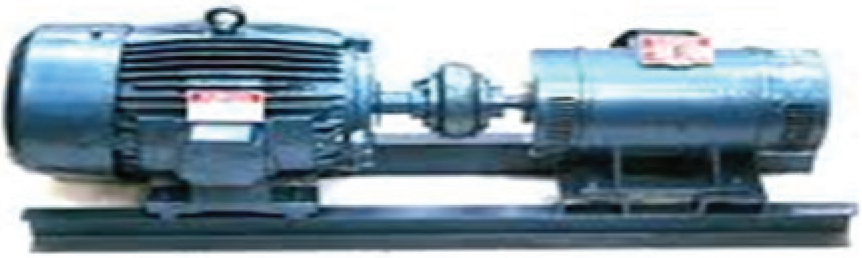


Armature - It is a laminated steel drum with longitudinal slots which accommodate copper conductors.

Commutators - It is made out of copper segments separated by mica insulation. It is also mounted on the shaft along with the armature and is connected to the armature conductors.

Carbon Brushes - These are mounted on the body to the have connected to the rotating commutator and are connected to the output terminals.

AC to DC Generator



Working principle of DC Generator

The armature is made to rotated with the help of a prime mover between the main poles, where a strong magnetic field exists.

The armature cuts the magnetic lines of force, generating EMF in the conductors. The commutator, being connected to the armature conductors, changes the generated alternative current into DC.

The generated DC is then taken to the generator terminal through the carbon brushes.

Note - Where the main supply electricity is available. Used as a prime AC motor.

Where main supply is not available, petrol or diesel engine may be used as a prime mover.

Diesel welding generator

Rectifier and inverter welding machine

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

- explain DC welding rectifier and inverter set
- explain the working principle of rectifier and inverter set.

Introduction to rectifier welding machine

A welding rectifier set is used to convert AC welding into DC welding supply. It consists of a step down transformer.

Welding current rectifier cell convert to AC to DC current.

The rectifier cell consists of a supporting plat made of steel or aluminum. Rectifier plate with a thin layer of nickel or Bismith, spreyed with selenium or silicon.

It is finally covered with an alloyed film of cadmium, Bismith and Tin.

Working principle of rectifier welding machine

The output of the step down transformer is connected to the rectifier unit.

The DC output is connected to positive to negative terminal from where it is taken for welding purposes. It can be designed to provide either AC or DC welding supply by operating a switch provided on the machine.

Introduction to inverters welding machine

It is a new type of welding power source.

It taken AC input to the machine and convert it to DC.

This is done with a rectifier.

It is converted back to DC but at a higher frequency.

It now allows us to use a smaller transformer; this is accomplished with the inverter.

The power is now rectified back to DC for welding. Inverter power sources are smaller than conventional power sources. But amperage range increases the efficiency of other welding machine.

For this reason it is very convenient for the welder.

And gives stability to his magnetic field. Inverter welding machine provide the current for shielded metal arc welding, Gas tungsten arc welding (TIG), Gas metal arc Gas metal arc welding (MIG), plasma arc cutting. They are used in all of these.

Inverter welding machine are light in weight and can be carried anywhere.

Working principle to inverter welding machine

The size of the iron Core is taken from the length of time the magnetic field is created by it.

Inverter welding by solid state electronic parts varies from 60 Cycle/second to several thousand cycles per second.

Due to which the transformer for 7Lbs works done equal to a transformer of 100Lbs pound.

Advantages and Disadvantages of AC and DC welding machine

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

- compare the advantages and disadvantages of AC welding
- compare the advantages and disadvantages of DC welding.

Advantages of A.C welding machines

i A low in initial cost due to simple and easy construction.

ii A low operating cost due to less power consumption.

iii No effect of arc blow during welding due to AC.

iv Low maintenance cost due to the absence of rotating

v Higher working efficiency.

vi Noiseless operation.

Disadvantages of AC welding

i It is not suitable for bare and light coated electrodes.

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

iii Welding of thin gauge sheet, cast iron and non –ferrous metals will be difficult.

iv It can only be used where electrical mains supply is available.

Advantages of D.C welding machines

i 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).

ii It can be used successfully to weld both ferrous and not –ferrous metals.

iii Bare wires and light coated electrodes can be easily used.

iv Positional welding is easy due to polarity advantage.

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

vi It can be used where sheet. Cast iron and non- ferrous metals successfully due to polarity advantage.

vii It is easy to strike and maintain a stable arc.

viii Remote control of current adjustment is possible.

Disadvantages of D.C welding machine

i A higher initial cost.

ii A higher operating cost.

iii A higher maintenances cost.

iv Traubel of arc blow during welding.

v A lower working efficiency.

vi Noisy operation in the case of a welding generator.

vii Occupies more space.

Lesson 10&11 : Topic- Arc length-types-effects of arc length

Objectives

At the end of this lesson you shall be able to

- define and identify the different types of arc lengths
- explain the effects and uses of different arc lengths

Arc length - It is the straight distance between the electrode tip and the job surface when the arc is formed. There are three

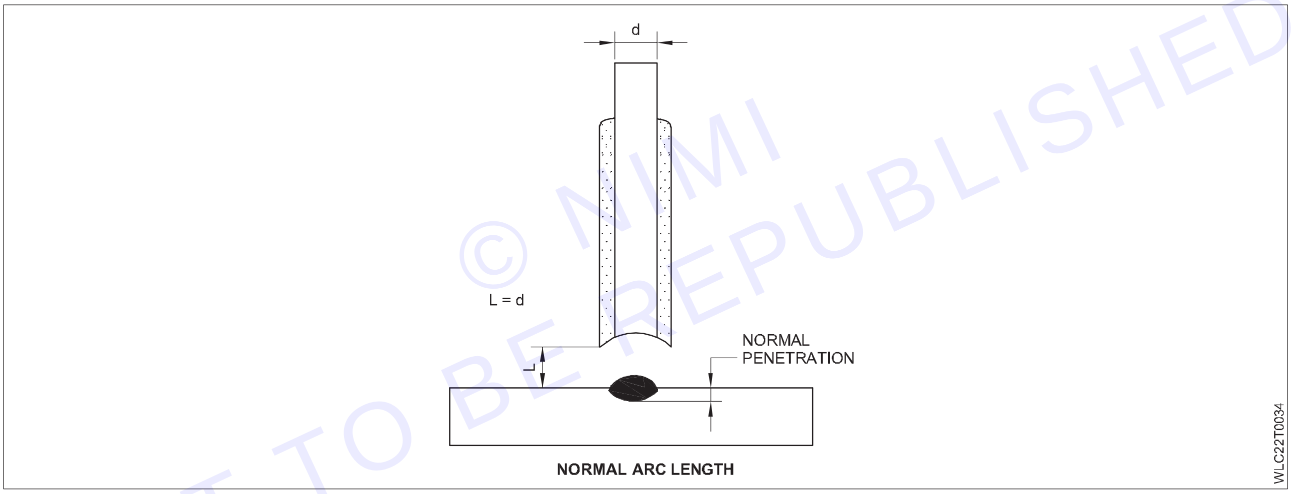
Types of arc length

1 Medium or normal arc length (Correct arc length)

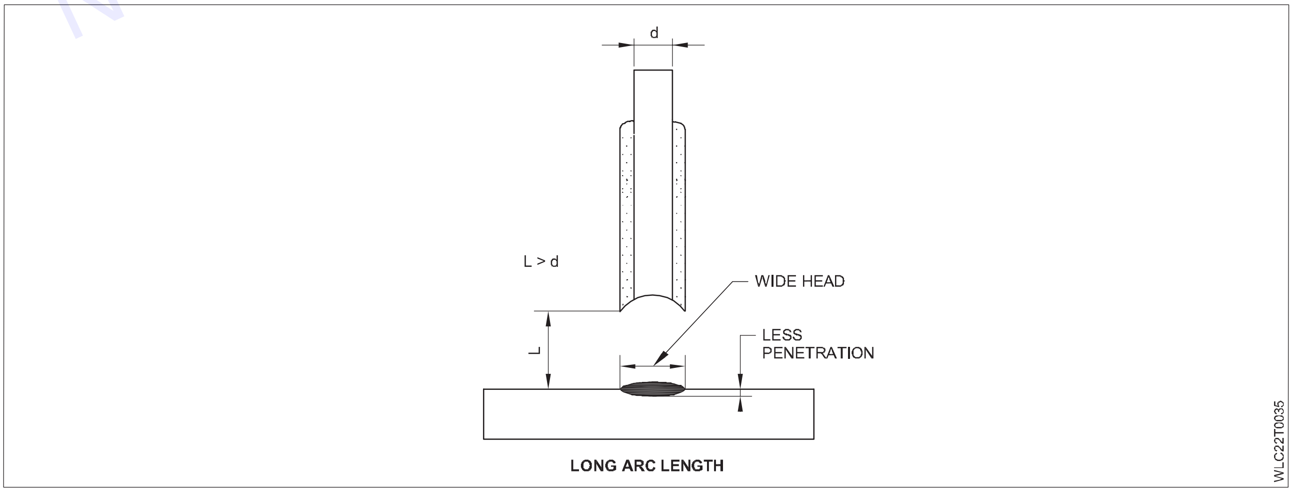
2 Long arc length.

3 Short arc length.

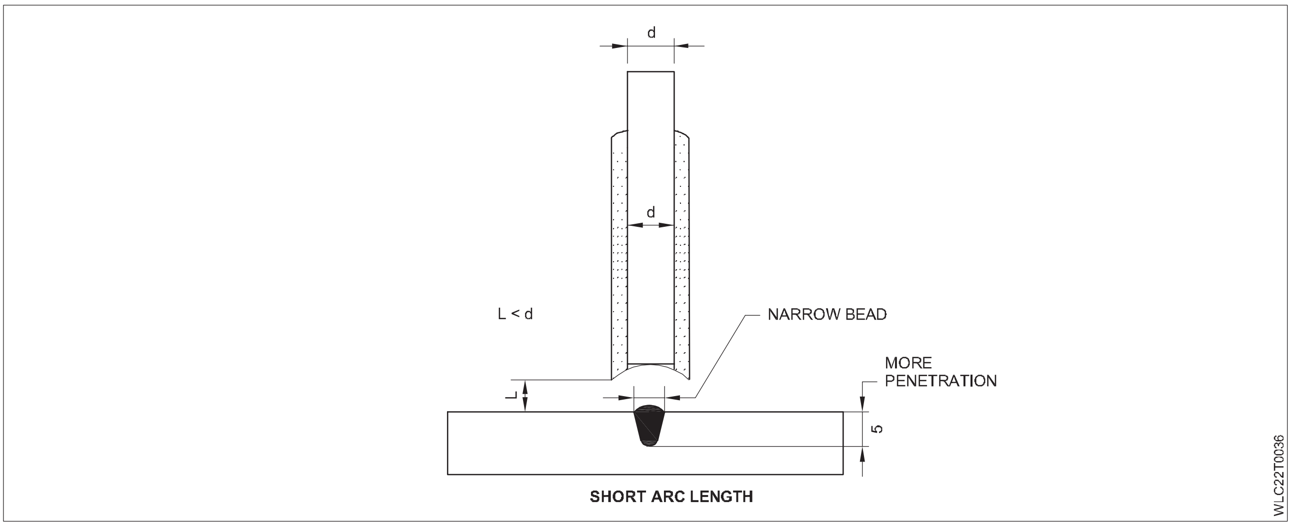
1 Medium or Normal Arc length: The correct arc length or normal arc length is approximately equal to the diameter of the core wire of the electrode.



2 Long arc length: 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



3 **Short arc length:** 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 the short arc.



Effect of medium arc length

i This is a stable arc producing steady sharp cracking sound and causing.

ii Even burning of the electrode.

iii Reducing of spatters

iv Correct fusion and penetration.

v Correct metal deposition.

Effect of long arc length

i It makes a humming sound causing

ii Unstable arc.

iii Oxidation of weld metal.

iv Poor fusion and penetration.

v Poor control and molten metal.

vi More spatter, indicating wastage of electrode metal

Effect of short arc length

i It makes a popping sound causing.

ii The electrode melting fastly and trying to freeze with the job.

iii Higher metal with narrow with bead.

iv Less spatters.

v More fusion and penetration.

Welding position- slop and rotation as per ASME and euro standard

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

- define and explain weld slope and weld rotation with respect to butt and fillet joint
- illustrate the various weld positions with respect to slope and rotation as per I.S.

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

1 Flat or down hand

2 Horizontal

3 Vertical

4 Overhead

Introduction

Types of welding position

Plate welding position

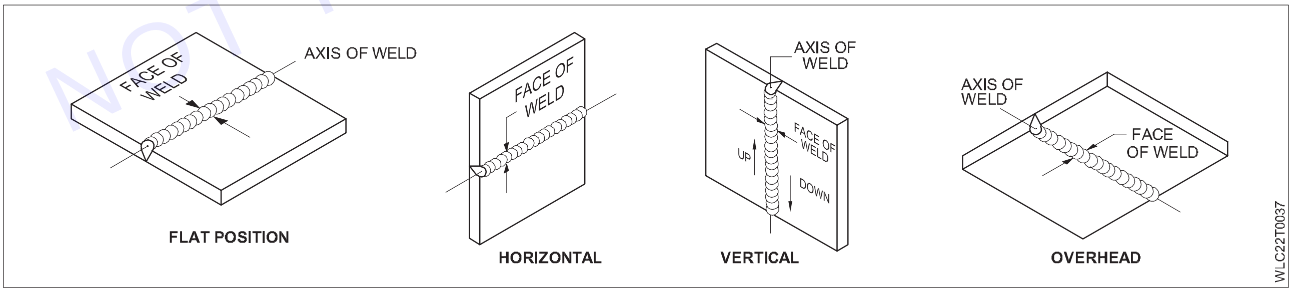
Welding position	EN		ASME	
	Groove fillet	Fillet	Groove	Fillet
Flat	PA	PA	1G	1F
Horizontal	PC	PB	2G	2F
Vertical	PG/PF	PG/PF	3G	3F
Over head	PE	PD	4F	4F

1 Flat position

2 Horizontal Position

3 Vertical Position

4 Overhead Position



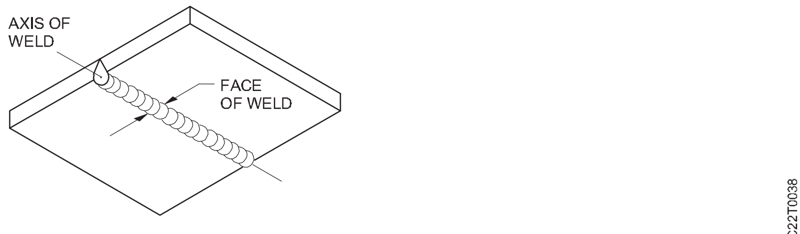
Pipe welding position

Welding position	EN	ASME
	Groove	Groove
Flat	PA	1G
Horizontal	PC	2G
Vertical	PF/PG	5G
Inclined 45 °	H-LO45	6G

Axis of weld - The imaginary line passing through the weld center lengthwise is known as axis of the weld.

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.

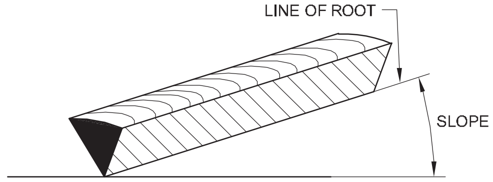
Fig 1



OVERHEAD

Weld Slope - It is angle formed between the line of the of the weld root and the horizontal reference plane.

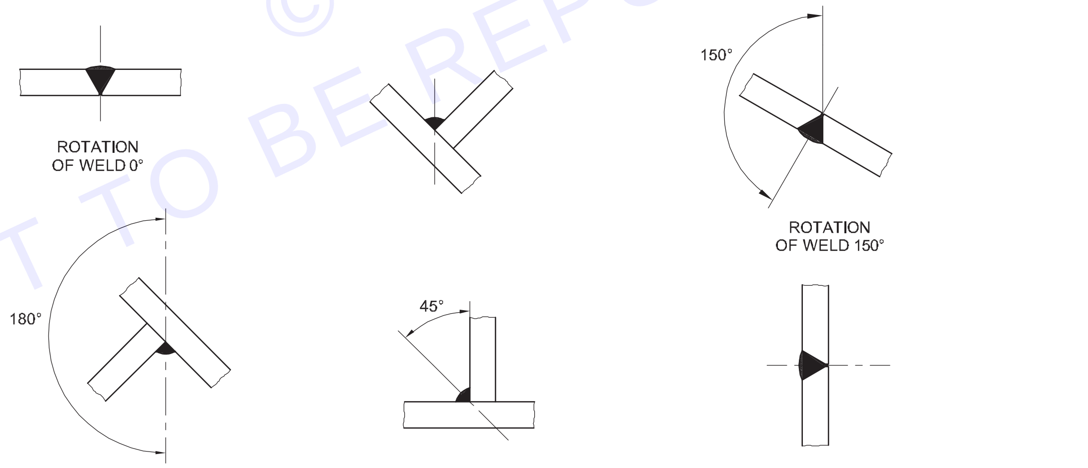
Fig 2



WELD SLOPE

Weld rotation - 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.

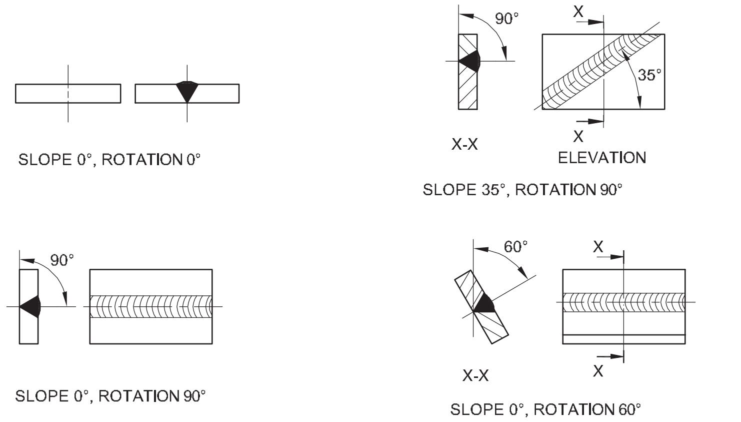
Fig 3



WELD ROTATION

Slope and rotation (Fig 4)

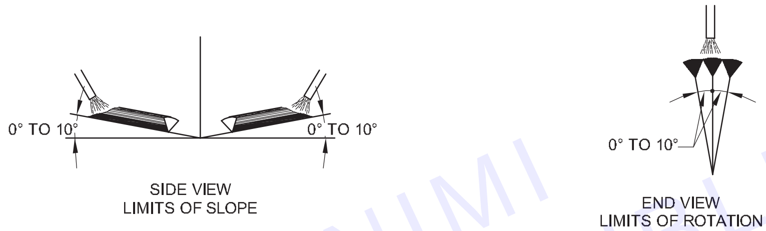
Fig 4



SLOPE AND ROTATION

Weld in flat position. (Fig 5)

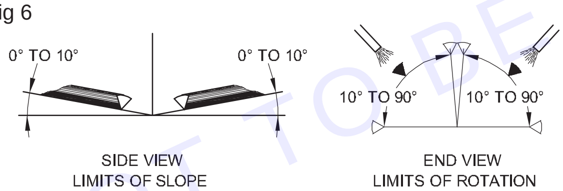
Fig 5



WELD IN FLAT POSITION

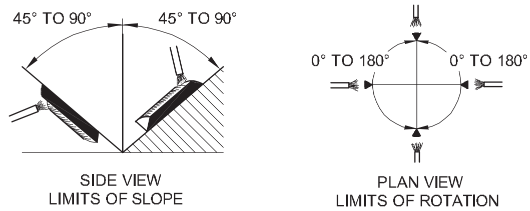
Weld in horizontal and vertical position. (Fig 6 & 7)

Fig 6



WELD IN HORIZONTAL POSITION

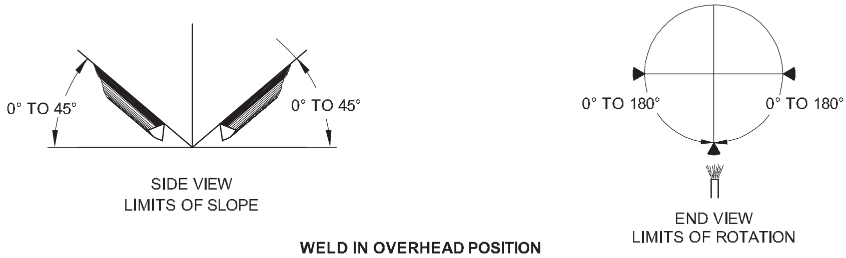
Fig 7



WELD IN VERTICAL POSITION

Weld in overhead position. (Fig 8)

Fig 8



WELD IN OVERHEAD POSITION

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

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

Definition of welding position

Position	Symbol	Slope	Rotation
Flat or down hand	F	Not exceeding 10°	Not exceeding 10°
Horizontal	H	Not exceeding10°	Exceeding 10° but not beyond 90°
Vertical	V	Exceeding 45°	Any.
Overhead	O	Not exceeding 45°.	Exceeding 90°

Polarity : Types and Application

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

- state of polarity in arc welding
- describe the types of polarity
- describe the application of straight and reverse polarity

Introduction: Polarity in welding refers to the direction of current flow between the welding electrode and work piece. It plays a critical role in determining the characteristics of the welding arc & resulting weld.

Definition of polarity

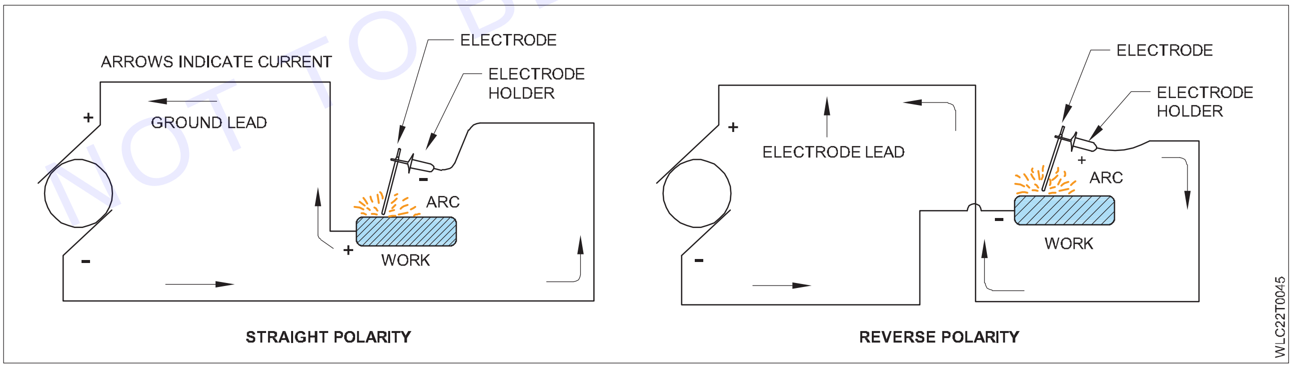
Direction of current flow called as polarity.

Types of Polarity

Polarity is categorized into two types.

1 Straight polarity (DCEN)(DCSP)

2 Reverse polarity (DCEP)(DCRP)



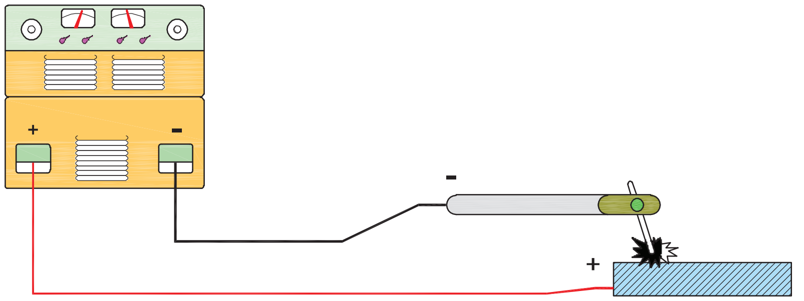
Direct Current Straight Polarity (DCSP)(DCEN)

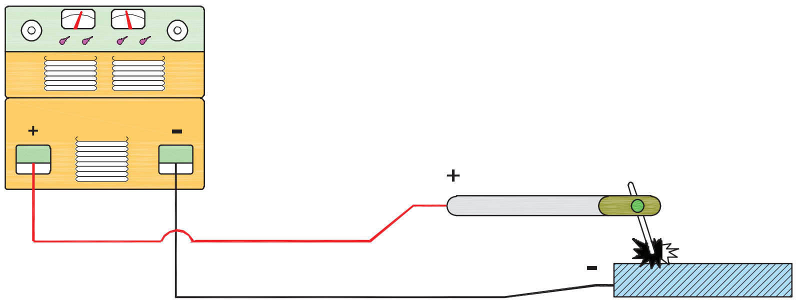
In DCSP, the work piece or the metal being welded is connected to the positive terminal of the power source, while the electrode (typically a consumable electrode) is connected to the negative terminal. This configuration results in heat concentrated at the work piece, leading to deeper penetration and faster deposition rates. DCSP is commonly used in processes like shielded metal arc welding (SMAW) and gas metal arc welding (GMAW).

Direct Current Reverse Polarity (DCRP)(DCEP)

In DCRP, the electrode is connected to the positive terminal, and the work piece is connected to the negative terminal. This configuration generates more heat at the electrode, facilitating better control over the weld pool and providing smoother arc characteristics. DCRP is often employed in processes like gas tungsten arc welding (GTAW) and flux-cored arc welding (FCAW).

(Direct Current (Negative Polarity DC)





(Direct Current (Positive Polarity DC+)

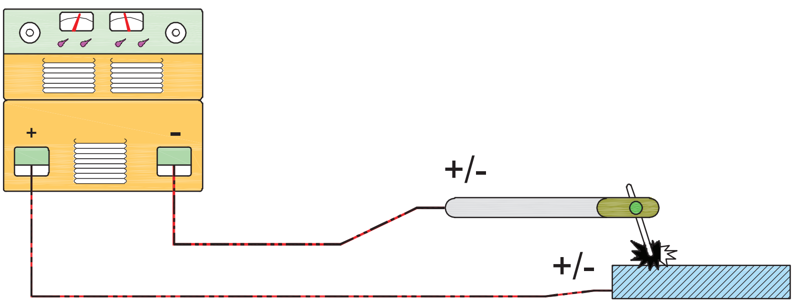
Applications

1 Straight polarity (DCEN) (DCSP)

- In GTAW (TIG), Micro plasma welding DCEN results in low heat input into the work piece, which is advantageous for faster welding speeds and better fusion, especially on thin materials.
- Which is beneficial for welding thin materials and for welding non-ferrous metals like aluminium, copper, and stainless steel.

2 Reverse polarity(DCRP) (DCEP)

- In SMAW, DCEP provides deeper penetration into the base metal, making it suitable for welding thicker materials.
- In GMAW, MIG, Co2 welding, Submerged welding (SAW), DCEP allows for better arc stability and improved control over the weld pool.
- In DCEN provides better penetration and weld bead profile, making it suitable for welding thicker materials and for outdoor welding where wind can blow away shielding gas.



Alternating Current (AC)

Lesson 12&13 : Arc blow and method to control arc blow

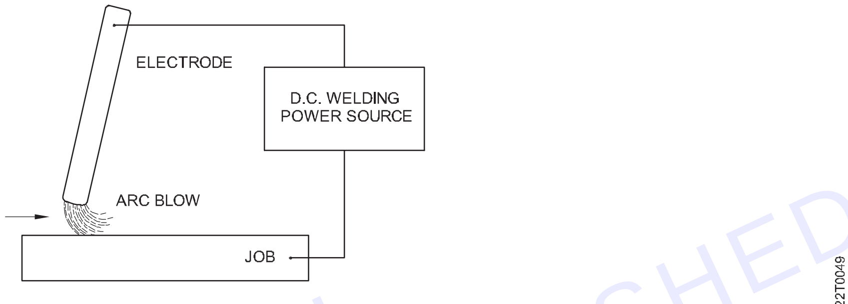
Objectives

At the end of this lesson you shall be able to

- explain the arc blow in DC welding
- explain the effects of arc blow on welds
- describe the various methods used to control the arc blow.

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

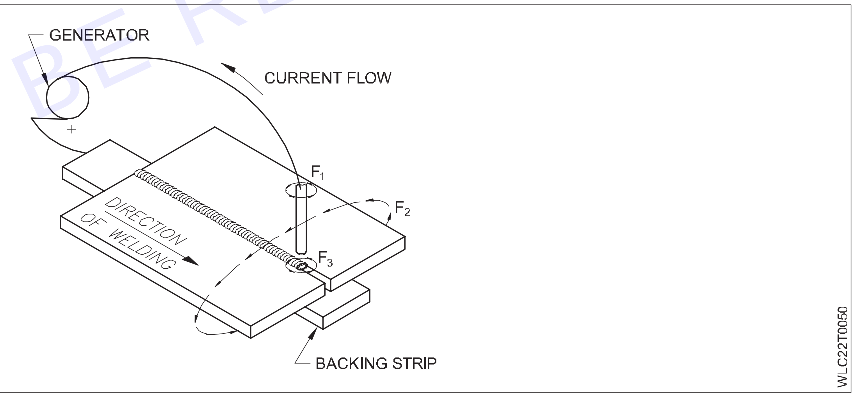
Fig 1



ARC BLOW IN DC ARC WELDING

Causes and effects of arc blow: Whenever a current flows in the electrode a magnetic field is formed around the electrode and the arc F1 and F3 (Fig 2). Likewise a similar magnetic field is also formed around the base metal F2 (Fig 2). Due to the interaction of these two magnetic fields, the arc is blown to one side of the joint. At the starting of the weld there will be forward blow and at the end backward blow. (Fig 3)

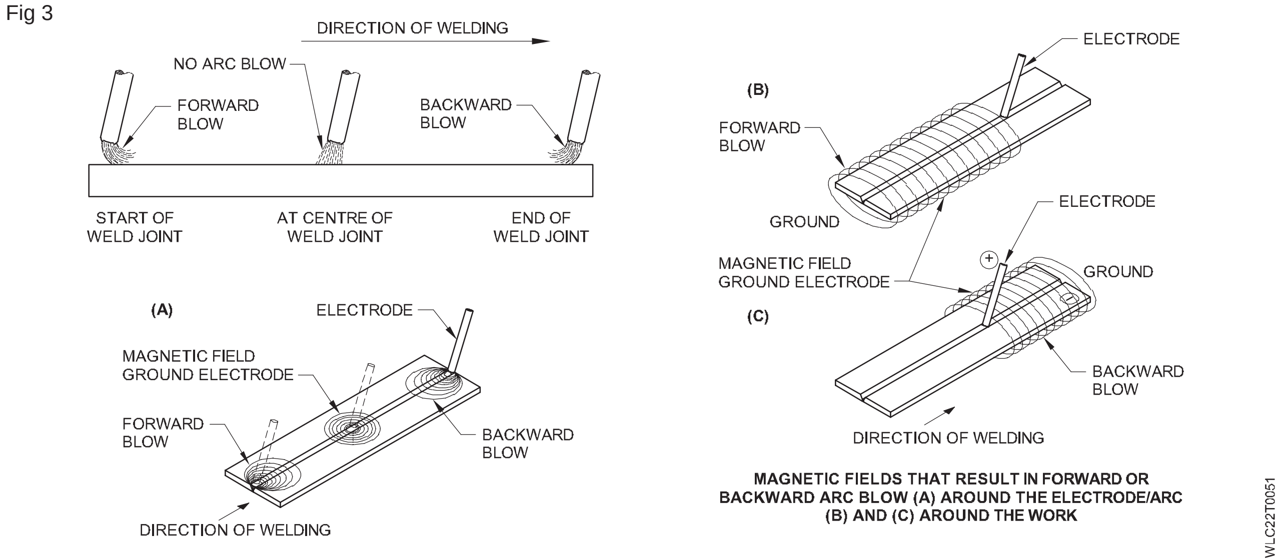
Fig 2



Due to this the following effects occur

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

Fig 3



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

Methods used to control the arc blow

The arc blow can be controlled by:

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

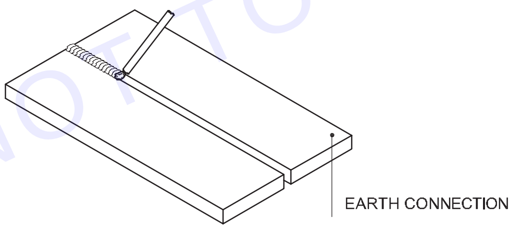


Fig 5

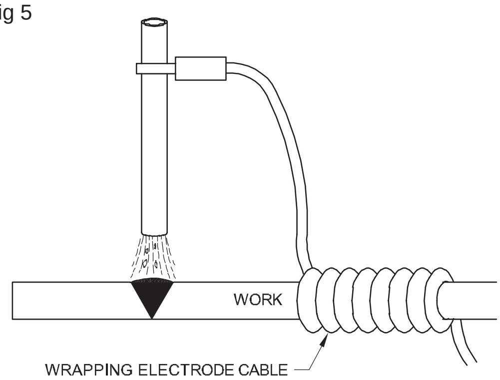
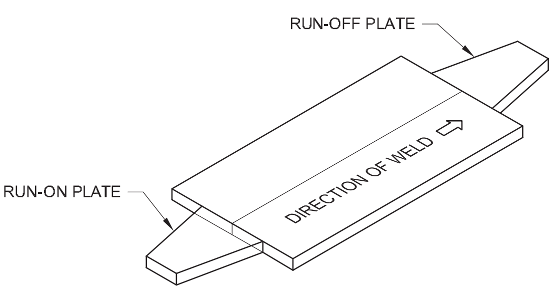


Fig 6



NOTE : THE RUN-ON AND RUN-OFF PLATES ARE REMOVED BY GAS CUTTING AFTER COMPLETION OF THE WELD.

Weld stresses, distortion and methods of 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

Weld Stresses- Welding stresses are stresses that exist during and after welding. The latter are called welding residual stresses. Thus, welding stresses are a special case of thermal stresses.

Distortion

Welding involves highly localized heating of the metal being joined together. The temperature distribution in the weldment is therefore non uniform. Normally, the weld metal and the heat affected zone (HAZ) are at temperatures substantially above that of the unaffected base metal. Upon cooling, the weld pool solidifies and shrinks, exerting stresses on the surrounding weld metal and HAZ.

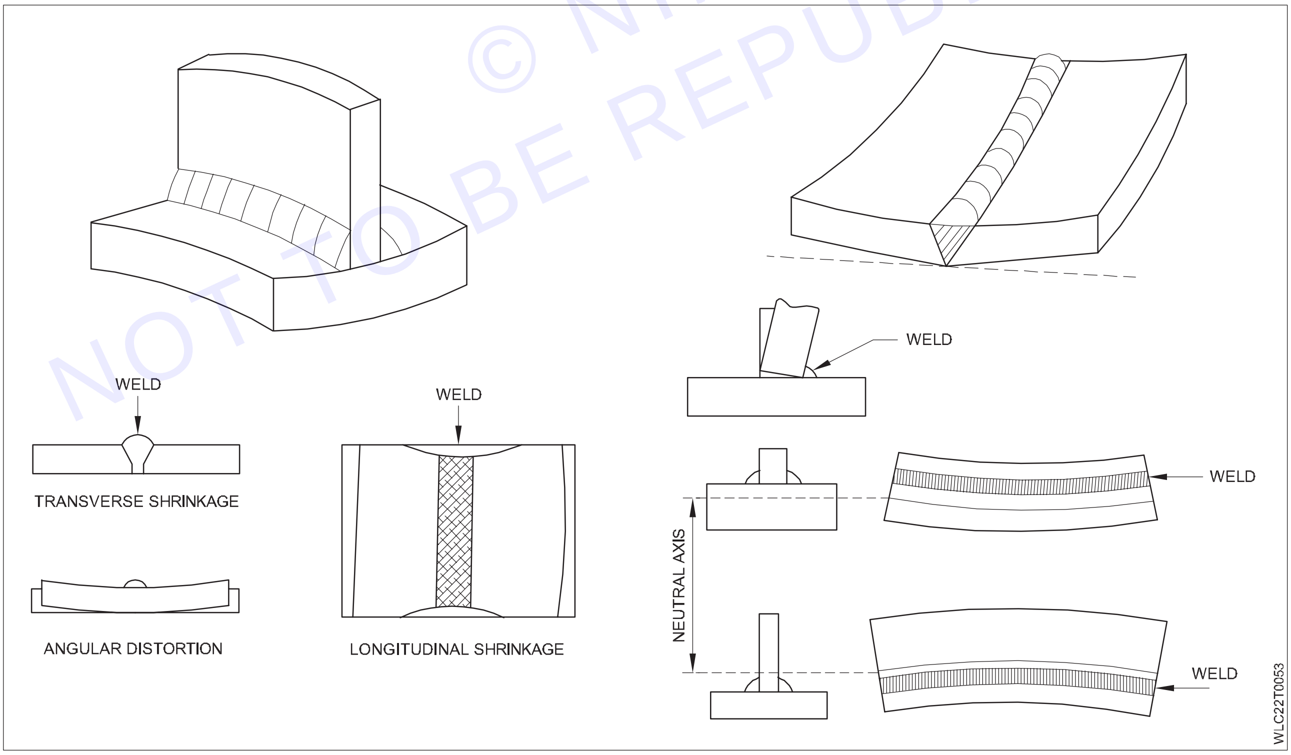
If the stresses produced from thermal expansion and contraction exceed the yield strength of the parent metal, localized plastic deformation of the metal occurs. Plastic deformation results in lasting change in the component dimensions and distorts the structure. This causes distortion of weldments.

Types of Distortion

Several types of distortion are listed below:

a) Longitudinal shrinkage, b) Transverse shrinkage, c) Angular distortion, d) Bowing,

e) Buckling f) Twisting.



Factors affecting distortion

If a component were uniformly heated and cooled distortion would be minimized. However, welding locally heats a component and the adjacent cold metal restrains the heated material. This generates stresses greater than yield stress causing permanent distortion of the component. Some of the factors affecting the distortion are listed below:

- Amount of restraint
- Welding procedure
- Parent metal properties
- Weld joint design
- Part fit up

Restraint can be used to minimize distortion. Components welded without any external restraint are free to move or distort in response to stresses from welding. It is not unusual for many shops to clamp or restrain components to be welded in some manner to prevent movement and distortion. This restraint does result in higher residual stresses in the components.

Welding procedure impacts the amount of distortion primarily due to the amount of the heat input produced. The welder has little control on the heat input specified in a welding procedure. This does not prevent the welder from trying to minimize distortion. While the welder needs to provide adequate weld metal, the welder should not needlessly increase the total weld metal volume added to a weldment.

Parent metal properties, which have an effect on distortion, are coefficient of thermal expansion and specific heat of the material. The coefficient of thermal expansion of the metal affects the degree of thermal expansion and contraction and the associated stresses that result from the welding process. This in turn determines the amount of distortion in a component.

Weld joint design will effect the amount of distortion in a weldment. Both butt and fillet joints may experience distortion. However, distortion is easier to minimize in butt joints.

Part fit up should be consistent to fabricate foreseeable and uniform shrinkage. Weld joints should be adequately and consistently tacked to minimize movement between the parts being joined by welding

Method of control

Prevention or minimization of distortion

Several ways can be used to minimize distortion caused by shrinkage:

1 Do not over weld

2 Control fitup.

3 Use intermittent Welding

4 Use as few weld passes as possible

5 Place welds near the neutral axis

6 Balance welds around the neutral axis

7 Use back step welding

8 Anticipate the shrinkage forces

9 Plan the welding sequence

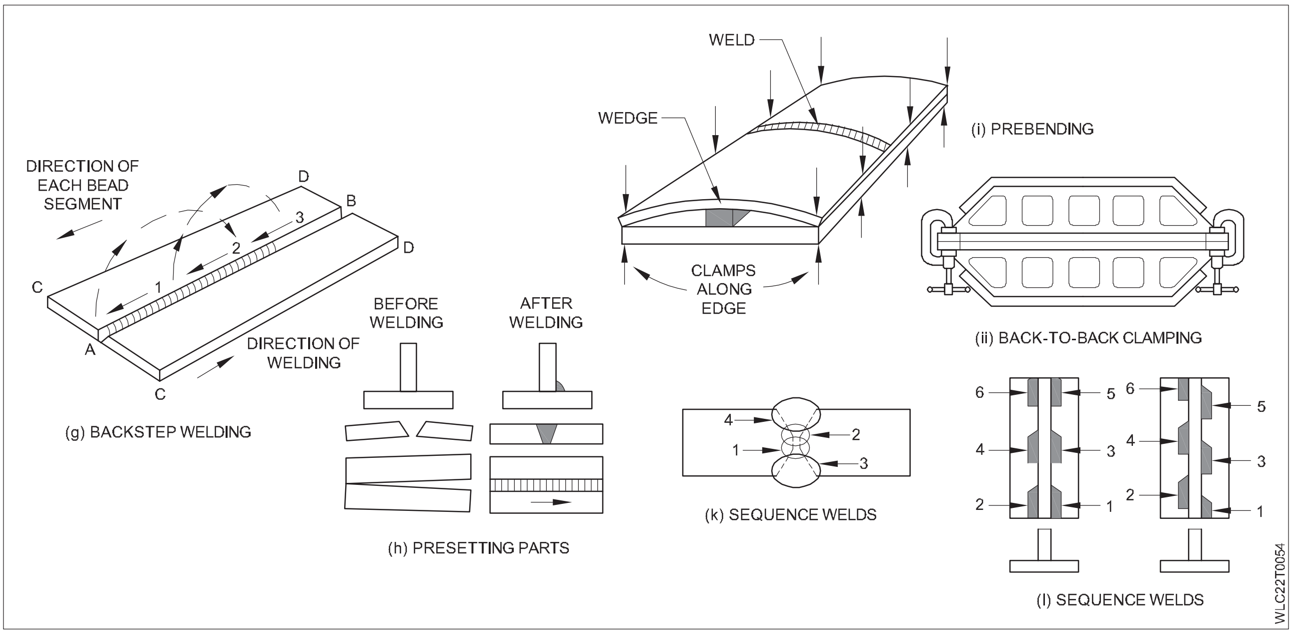
10 Remove shrinkage forces after welding

11 Minimize welding time

12 Use the smallest leg size permissible when fillet welding.

Prevention or minimization of distortion

For groove welds, use joints that will minimize the volume of weld metal. Consider double-sided joints instead of single-sided joints.



Weld alternately on either side of the joint when possible with multiple-pass welds.

Use low heat input procedures. This generally means high deposition rates and higher travel speeds.

Use welding positioners to achieve the maximum amount of flat-position welding.

The flat position permits the use of large-diameter electrodes and high- deposition-rate welding procedures.

Weld toward the unrestrained part of the member.

Use clamps, fixtures, and strong backs to maintain fit up and alignment.

Prebend the members or preset the joints to let shrinkage pull them back into alignment.

Sequence subassemblies and final assemblies so that the welds being made continually balance each other around the neutral axis of the section.

Arc welding defects, causes and remedies

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

- name different weld defects in arc welded joints
- define weld defect
- state the effect of defects on the welded joints
- differentiate between external and internal defects.

Definition

The word “Defect “ should be used carefully, as it implies that a weld is defective and requires corrective measures or rejection, In some cases repairs may be made unnecessarily and solely by implication without a critical engineering assessment. Consequently the engineering community has recently begun to use the word “Discontinuity” or “Flaw” instead of “Defect”, Discontinuity may be defined as interruptions in the desirable physical structure of a weld.

The significance of a weld discontinuity should be viewed in the context of the fitness-for-purpose of the welded construction. Fitness-for-purpose is a concept of weld evaluation that seeks a balance between quality, reliability and economy of welding procedure. It is not a constant varies depending in the service requirements of a particular welded structure as well as on the properties of the material involved.

Arc welding defects

1 Undercut

2 Slag inclusions

3 Porosity

4 Lack of fusion (LOF)

5 Lack of penetration (LOP)

6 Craters

7 Melt – through

8 Spatter

9 Arc Strikes (Arc burns)

1 Undercut: A groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal.

Undercutting is a defect that appears as a groove in the parent metal directly a long the edges of the weld. It is most common in lap fillet welds, but can also be encountered in fillet and butt joints.

Causes

1 Improper welding parameters; particularly the travel speed and arc voltage.

2 Excessive welding currents.

3 Slag inclusion: Non metallic solid material entrapped in weld or between weld metal and base metal.

4 Porosity: Cavity-type discontinuities formed by gas entrapment during solidification.

Porosity is gas pores found in the solidified weld bead. These pores may vary in size and are generally distributed in a random manner. However, it is possible that porosity can only be found at the weld centre. Pores can occur either under or on the weld surface.

The most common causes of porosity are atmosphere contamination, excessively oxidized work piece surfaces, inadequate deoxidizing alloys in the wire and the presence of foreign matter.

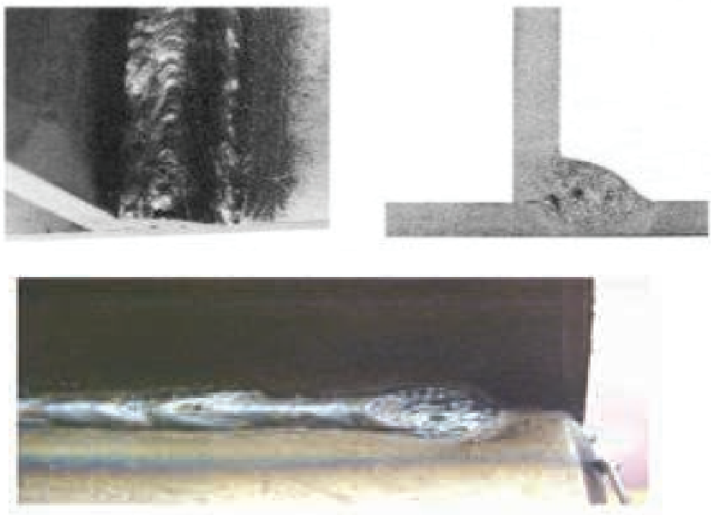
Atmospheric contamination can be caused by:

1 Inadequate shielding gas flow.

2 Excessive shielding gas flow. This can cause aspiration of air into the gas stream.

3 Severely clogged gas nozzle or damaged gas supply system (leaking hoses, fittings, etc.)

4 An excessive wind in the welding area. This can blow away the gas shield.



5 Lack of Fusion: A condition in which fusion is less than complete.

Lack of fusion, also called cold lapping or cold shuts, occurs when there is no fusion between the weld metal and the surfaces of the base plate.

Causes

1 Poor welding technique.

2 Use of a very wide weld joint.

3 Very low travel speed and attempting to make too large a weld in a single pass.

4 Low welding voltage.

5 Presence of Oxide layer.

6 Lack of Penetration:- A condition in which joint penetration is less than that specified.

Incomplete penetration

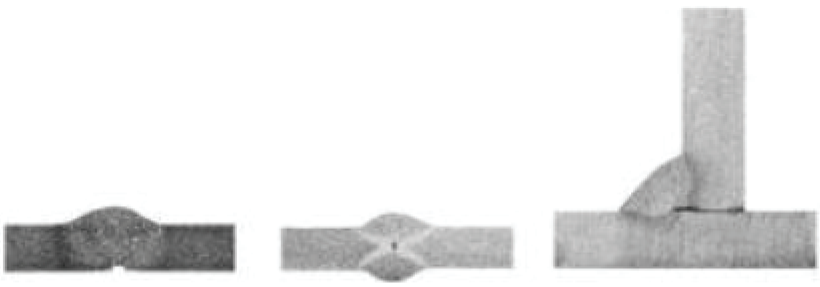
This type of defect is found in any of three ways:

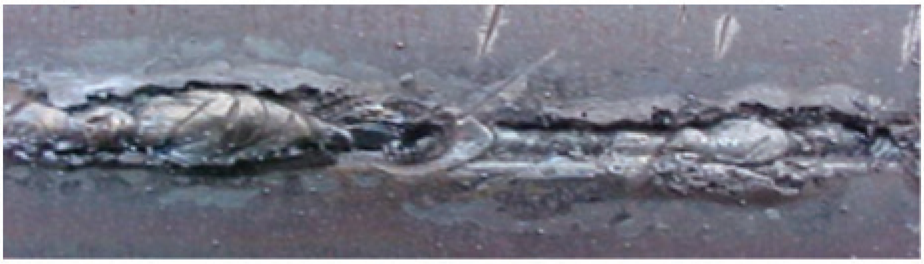
1 When the weld bead does not penetrate the entire thickness of the base plate.

2 When two opposing weld beads do not interpenetrate.

3 When the weld bead does not penetrate the toe of a fillet weld but only bridges across it.

Welding current has the greatest effect on penetration. Incomplete penetration is usually caused by the use of too low a welding current and can be eliminated by simply increasing the amperage. Other causes can be the use of too slow a travel speed and an incorrect torch angle. Both will allow the molten weld metal to roll in front of the arc, acting as a cushion to prevent penetration. The arc must be kept on the leading edge of the weld puddle.





Craters : Depression at the termination of a weld head or in the molten weld pool.

Melt-through : A condition resulting when the arc melts through the bottom of a joint welded from one side

Spatter : Metal particles expelled during welding which do not form a part of the weld.

Arc strikes (arc burns): Discontinuities consisting of any localized re melted metal, or change in the surface profile of any part of a weld or base metal resulting from an arc.

Cracking

This can occur due just to thermal shrinkage or due to a combination of strain accompanying phase change and thermal shrinkage.

In the case of welded stiff frames, a combination of poor design and inappropriate procedure may result in high residual stresses and cracking. Where alloy steels or steels with a carbon content greater than about 0.2% are being welded, self cooling may be rapid enough to cause some (brittle) marten site to form. This will easily develop cracks.

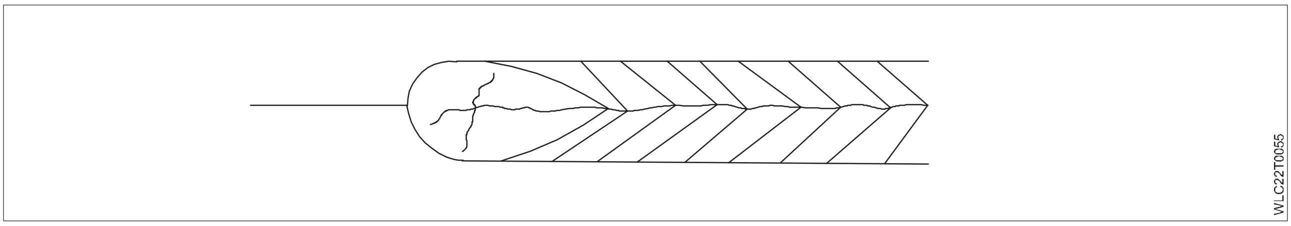
To prevent these problems a process of pre-heating in stages may be needed and after welding a slow controlled post cooling in stages will be required. This can greatly increase the cost of welded joins, but for high strength steels, such as those used in petrochemical plant and piping, there may well be no alternative.

Types of Cracking

Solidification Cracking

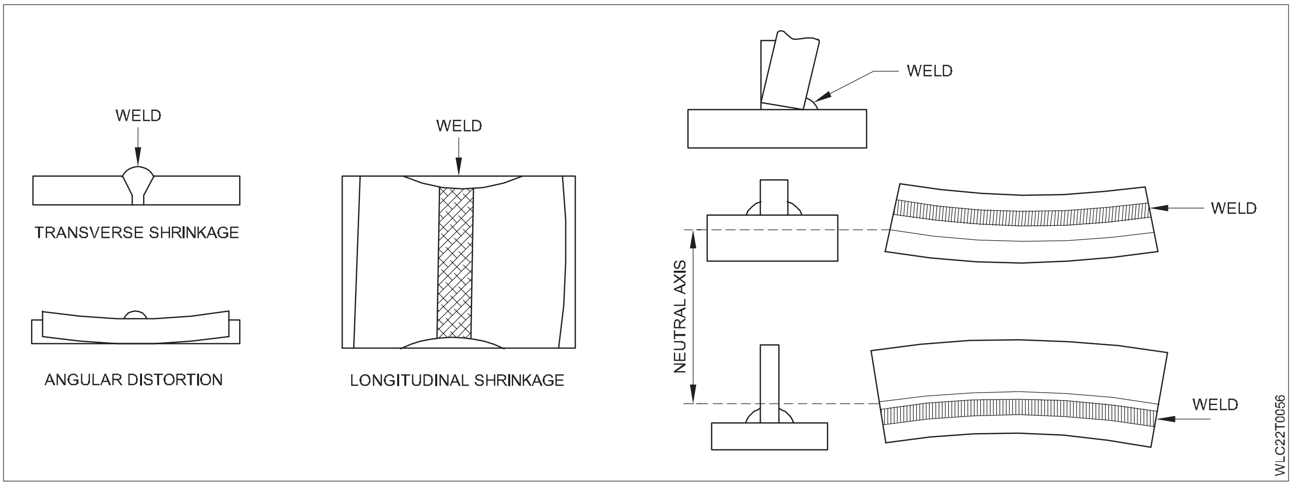
This is also called centre line or hot cracking. They are called hot cracks because they occur immediately after welds are completed and sometimes while the welds are being made. These defects, which are often caused by sulphur and phosphorus, are more likely to occur in higher carbon steels.

A schematic diagram of a centre line crack is shown below



Distortion after welding

Distortion of parts after welding : (a) butt joints; (b) fillet welds. Distortion is caused by differential thermal expansion and contraction of different parts of the welded assembly



Prevention or minimization of distortion

Several ways can be used to minimize distortion caused by shrinkage:

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2 Control fitup.

3 Use intermittent Welding

4 Use as few weld passes as possible

5 Place welds near the neutral axis

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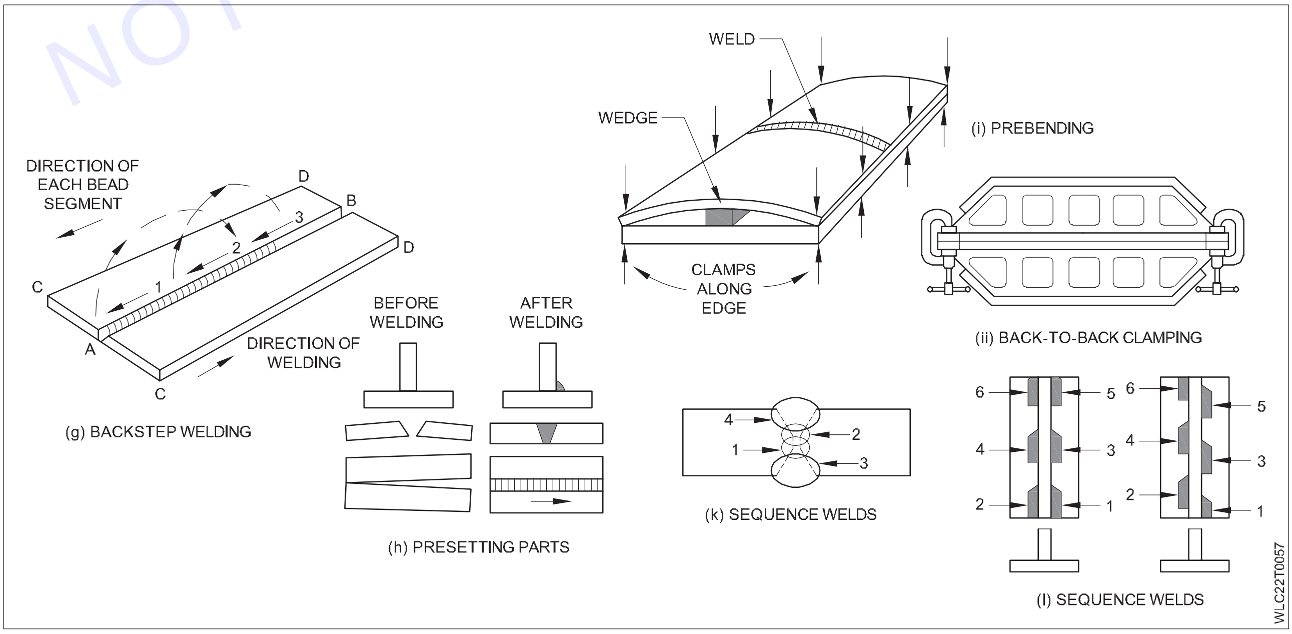
8 Anticipate the shrinkage forces

9 Plan the welding sequence

10 Remove shrinkage forces after welding

11 Minimize welding time

12 Use the smallest leg size permissible when fillet welding.



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Use low heat input procedures. This generally means high deposition rates and higher travel speeds.

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The flat position permits the use of large-diameter electrodes and high- Deposition-rate welding procedures.

Weld toward the unrestrained part of the member.

Use clamps, fixtures, and strong backs to maintain fit up and alignment.

Prebend the members or preset the joints to let shrinkage pull them back into alignment.

Sequence subassemblies and final assemblies so that the welds being made

Continually balance each other around the neutral axis of the section.

MODULE 3 : Weldability of metals (OAW, SMAW)

Lesson 14-26 : Common Gases used for Gas welding

Objectives

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

- name the different types of gases used for welding and cutting
- compare the different types of gas flame combinations.

Introduction:

In welding and cutting processes, gases play crucial roles in providing heat, protection. & control, oxy-acetylene flame is widely used on oxy-fuel welding & cutting.

The flame produced by mixing a flammable gas and oxygen in the nozzle or tip of the blow pipe is called flame.

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)

Types of Gases Used In Welding & Cutting

Comparison of different gas flame combinations and their use

Sl. No.	Fuel gas	Supporter Of combustion	Name of the gas flame	Temperature	Application/uses
1	Acetylene	Oxygen	Oxy-acetylene flame	31oo 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 2100°c (Medium temperature)	Only used for brazing, silver soldering and under water gas cutting of steel.
3	Coal gas	Oxygen	Oxy-coal gas flame	1800 to 2200°c (Low temperature)	Used for silver soldering underwater gas cutting of steel.
4	Liquid petroleum gas(LPG)	Oxygen	Oxy-liquid petroleum gas flame	2700 to 2800° C (Medium temperature)	Used for gas cutting steel heating purposes.(Has moisture and carbon effect in the flame.)
5	Acetylene	Air	Air-acetylene flame	1825 to1875°C (Low temperature)	Used only for soldering, brazing, heating purposes and lead burning.

Chemistry of oxy - acetylene flame and types of oxy acetylene flame and application

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

- identify the features and illustrate the different zones of an oxy-acetylene flame with their corresponding temperatures
- explain the chemical reaction between oxygen and acetylene during primary and secondary combustion in the flame.

Chemistry of oxy-acetylene flame:

Introduction: Oxy-acetylene flame is produced by the combustion of a mixture of oxygen and acetylene in various proportions. The temperature and characteristics of the flame depend on the ratio of the two gases in the mixture.

To know the characteristics and effects of oxy-acetylene flame a welder must know the chemistry of the flame.

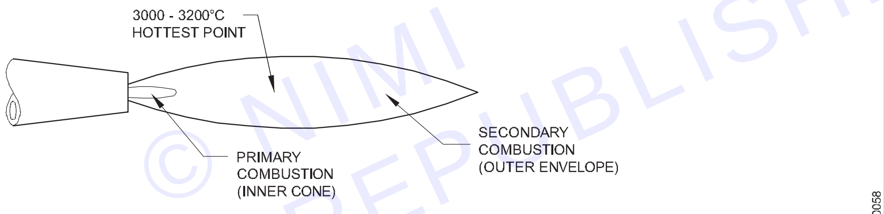
Features of neutral flame: Oxy-acetylene flame consists of the following features by appearance.

Inner cone

Inner reducing zone

Outer zone or envelope

Different zone sand temperature: To know and make the best use of oxy-acetylene flame, the temperature in different zones is shown in.



PRIMARY AND SECONDARY COMBUSTION STAGES IN THE OXY-ACETYLENE FLAME

The greatest amount of heat is produced at just ahead of the inner cone called the hottest point or region of maximum temperature.

Combustion ratio of oxygen and acetylene inflame

For complete combustion /burning one volume of acetylene requires two and a half volumes of oxygen.

Acetylene : Oxygen+O

1litre : 2.5litres

Equal volumes of acetylene and oxygen are supplied from the blow pipe to produce a neutral flame.

Acetylene : Oxygen

1litre : 1 liter (primary combustion)

So another 1.5 liters of oxygen is required for complete burning of acetylene.

The flame takes an additional 1.5 liters of oxygen from the surrounding atmosphere. (Secondary combustion)

Chemical reaction: 1 volume of acetylene combines with 2 1/2 volumes of oxygen and burns to form 2 volumes of carbon dioxide and 1 volume of water vapors plus heat.

Primary combustion: It takes place in the inner cone right in the tip of the nozzle. (Fig 1)

In the bright nucleus:

$C_2 H_2 \uparrow 2C + H_2$ + Heat

In the inner cone - first burning stage:

$2C + H_2 O_2 \uparrow 2CO + H_2$ + Heat

CO and H2 have reducing effect (no oxides are forming) Maximum heat (Hottest point) is just in front of the inner cone.

One volume of oxygen combines with one volume of acetylene (delivered through the torch) and burns to form. Two volume of carbon monoxide and one volume of hydrogen plus heat.

Secondary combustion: It takes place in the outer envelope of the flame.

In the outer envelope - secondary burning 2CO + O2 ↑ 2CO2 + Heat

2H2 + O2 ↑ 2H 0O + Heat

Combustion in air (Fig 1): Two volumes of carbon monoxide and 1 volume of hydrogen (Product of primary combustion) combine with 1.5 volume of oxygen from the surrounding air and burn to form. two volumes of carbon dioxide and 1 volume of water vapors.

The flame takes an additional 1.5 litres of oxygen from the surrounding atmosphere.(Secondary combustion) (Fig 1)

Chemical reaction:1 volume of acetylene combines with 2 1/2 volumes of oxygen and burns to form 2 volumes of carbondioxide and 1 volume of water vapour plus heat.

The product of primary combustion is further burnt in the reducing zone.

The region surrounding the inner cone and it stip is called reducing zone

The reducing zone protects them olten metal from atmospheric effect sasituses the Atmosphere combustion. oxygen for secondary

Types 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.

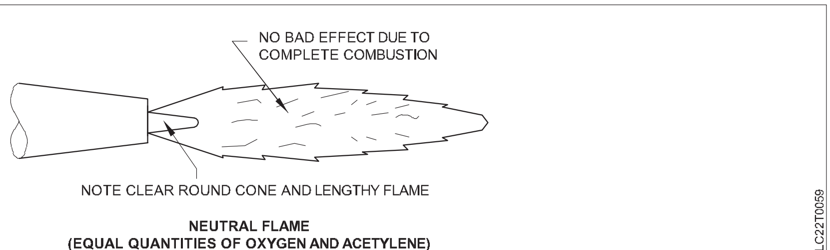
Three different types of oxy-acetylene flames as given below can be set.

1 Neutral flame

2 Oxidizing flame

3 Carburizing flame Characteristics and uses

Fig 1



NEUTRAL FLAME
(EQUAL QUANTITIES OF OXYGEN AND ACETYLENE)

Complete combustion take space in this flame.

This flame does not have a defection the base metal/weld i.e. the metal is not oxidized and no carbon is available for reacting with the metal.

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

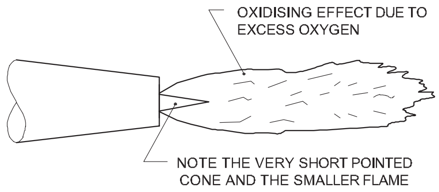
Oxidizing flame (Fig 2) : It contains excess of oxygen over acetylene as the gases come out of the nozzle.

The flame has an oxidizing affection metals which prevents evaporation of zinc / tin in brass welding/brazing.

Uses:-Useful for welding of brass and for brazing offer oust metals.

Carburizing flame (Fig 3): It receive an excess of acetylene over oxygen from the blow pipe.

Fig 2



OXIDISING FLAME
(EXCESS OXYGEN)

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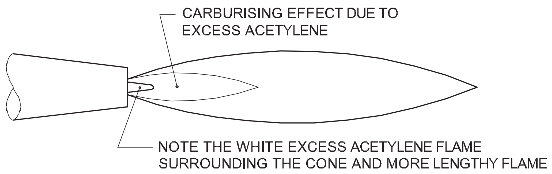
Fig 3



CARBURISING FLAME
(EXCESS ACETYLENE)

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

These lection 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

Mild steel Neutral

Copper (de- oxidized) Neutral

Brass Oxidizing

Cast iron Neutral

Stain less steel Neutral

Aluminum (Pure) Neutral

Satellite Carburizing

Production of calcium carbide

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

- state the ingredients and grades of calcium carbide
- describe the properties of calcium carbide
- explain the method of production of calcium carbide
- explain the safe storage and handling of calcium carbide.

Introduction

Calcium carbide is a chemical compound consisting of calcium 62.5 % and carbon 37.5 % by weight. Its chemical symbol is cac2

Properties of Calcium Carbide

1 It is a solid chemical compound of dark grey colour.

2 It is brittle.

3 Its density it 2.22 to 2.26 gmlc.c.

4 It easily absorbs moisture from the atmosphere and gradually changes into slaked line.

5 It is not soluble in kerosene.

6 It Cac_2 is allowed to come into contact with water, it produces Acetylene gas.

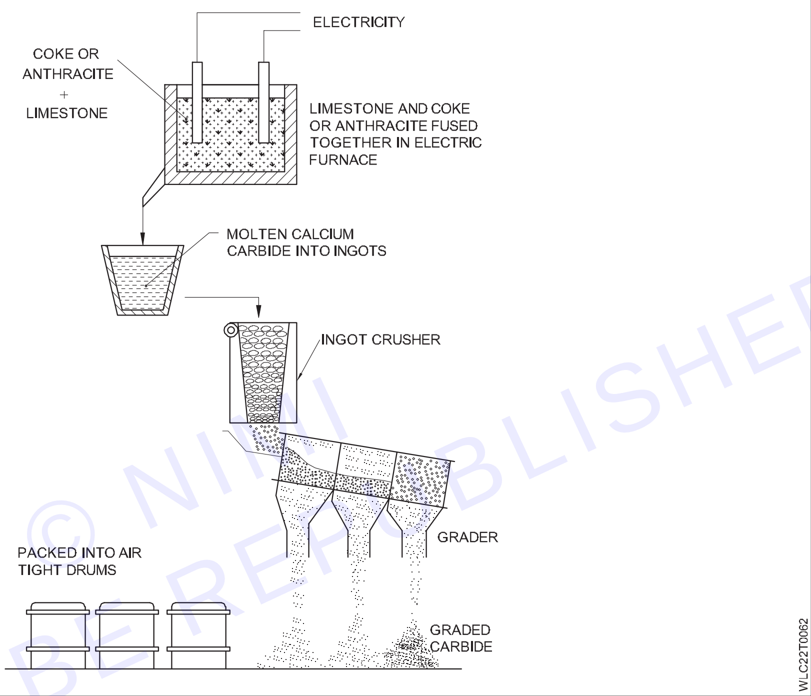
7 Powder of Cac_2 mixed with borax, it is used as a flux for copper welding.

Production Of Calcium Carbide

Calcium carbide is produced in an electric furnace by melting coke and lime in right proportion. It take 0.875 Kg calcium and 0.562 Kg carbon to produce one kilogram of chemically pure calcium carbide with the intense heat (3000-3600°C) of the carbon arc in the furnace lime and coke turn to a liquid compound called calcium carbide.

Carbon monoxide escapes and burns at the mouth of the furnace. Molten carbide is drawn out of the furnace and cast into ↑ ingots. The ingots are crushed, graded to definite size and packed into air tight steel drums

Lime + coke+ heat= Calcium carbide +Carbon $Cao+3c$ + Heat= Cac_2 Co monoxide.



Grades/Sizes of Calcium Carbide

Different grades/sires of calcium carbide are available for use in different types of acetylane generators.

These are designated as:-

- LUMP
- EGG
- NUT-14 NDT

The size given above indicate the range in the Screening sizes. For example (LUMP) size 90X50 means that no piece is larger than 90 mm smaller than 50 mm.

Effect of Each Elements On

Metals

1 If it contains much phosphorous, it forms phasphorated hydrogen, produce noxious fumes and does not born properly.

2 2. The presence of aluminium and iron, gas becomes dark and reduce the quality as well as quantity.

3 If more sulphur present in row materials, it forms sulphurated hydrogen which is poisonous substances. It will reduce the quality of acetylene gas.

Safety Precautions for Handling and Storage of Cac_2

1 Calcium carbide can be stored in approved places only and must be stored in perfect air tight containers.

2 Storage building must not have either water line or high temperature.

3 Do not allow the carbide to come in contract with water or moisture outside thy acetylene generator.

4 Never put a naked light of any kind or any other source of ignition into or near the carbide container.

5 Carbide drums should be opened with tools which will not produce sparks. Use a brass chisel and hammer.

6 Fire break out in a carbide storage room must be extinguished with Co2 fire extinguisher or dry Sand and not with water.

7 After taking out the Cac2 from a drum, it mist be closed and made air light immediately.

8 Preserve carbide in kerosene oil in case of emergency.

9 The person, handling Cac2, must wear rubber gloves.

10 Empty carbide drums must be filled completely with water before disposing of.

11 License must be required to store CoC2.

12 Notice should given in CaC2 Store.

Acetylene gas properties , Manufacturing method Acetylene gas purifier

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

- explain the composition and properties of acetylene gas
- explain the acetylene manufacturing method.
- explain the working principle of the types of acetylene generators
- explain the acetylene gas purifier.

Introduction

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 C2 H2 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/cm2. The normal temperature pressure (N.T.P) I 1.091 kg/cm2.The normal temperature is 20°C and the normal pressure 760mm of mercury or 1 kg/cm2. 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/cm2 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.

Composition of acetylene: Acetylene is a fuel gas composed of: carbon 92.3% and Hydrogen 7.7% Its chemical symbol is C2 H2.

Principle of acetylene gas generation: It is the product of chemical reaction between calcium carbide and water. When water is added to calcium carbide it reacts and produces acetylene gas and calcium hydroxide (slakedlime).Calcium carbide is composed of calcium and carbon. Water is Composed of hydrogen and oxygen. When calcium carbide is allowed to react with water the carbon of the calcium carbide combines with the hydrogen of water forming acetylene gas. calcium combines with oxygen and hydrogen in water to form slaked lime (Calcium hydroxide).

Methods of acetylene generation: Acetylene is produced in acetylene generators based on two methods.

- Water-to-carbide method
- Carbide-to-water method

In the water-to-carbide method water falls on calcium carbide to produce acetylene. Carbide-to-water means calcium carbide grains fall on a mass of water producing acetylene. An acetylene generator is a device which brings proper amounts of calcium carbide and water together to generate the acetylene gas at the required rate. Acetylene generators are of two types.

- Water-to-carbide type acetylene generator (low pressure)
- Carbide-to-water type acetylene generator (medium pressure).

Water to carbide acetylene gas generator

In this low pressure acetylene gas generator, water falls on the carbide to generate acetylene gas. Acetylene pressure up to 0.17 kg / cm2 can be generated. Carbide is placed in a carbide container located at the bottom of the generator. Water (Controlled by a float valve) is fed into the carbide container. The generated acetylene is collected in a gas bell which rises and then cuts off the water supply automatically. The features of a generator are shown in Fig 1.

Working principle: Water is filled in the outer vessel through the water filling pipe and the water tap is turned off when there is sufficient water. Calcium carbide is filled in the carbide container, inserted through the door at the bottom. Initially the rising bell is at its bottom level and the cross (fixed to the rising bell) holds the float ball down thus opening the water valve. Water flows down the water supply pipe and enters the carbide container.

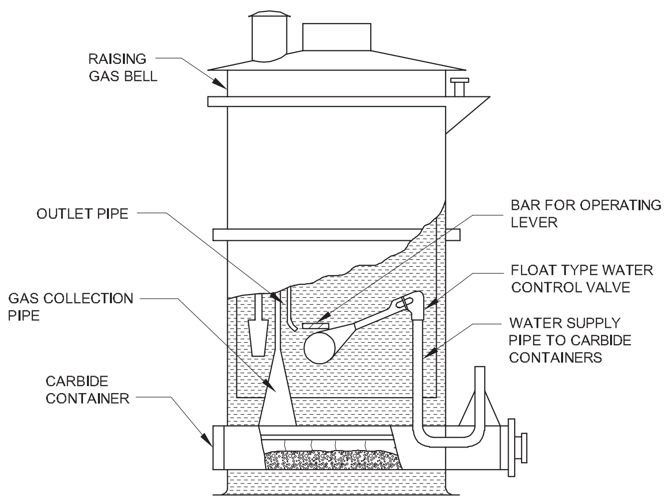
Acetylene gas is generated due to chemical reaction. The generated gas goes up in the gas collection pipe, passes through the water in the form of bubbles (washed and cooled) and enters the rising bell. The rising bell rises with gas pressure and lifts the crossbar up, thus closing the water valve automatically and preventing further supply of water into the carbide container.

The gas is taken out through the outlet pipe from where it goes into the purifier and then to the hydraulic safety valve before its use in welding. A weight is provided on the top of the rising bell to keep it in position and enable it to supply the gas with the required pressure.

A safety outlet pipe is also provided with the rising bell to release excess (generated) gas in emergency. Further generation of acetylene gas is controlled automatically by the downward and upward movement of the rising gas bell. When the gas is consumed, the rising bell comes down and its crossbar presses the float ball down to open the water valve.

Water flows down into the carbide container to generate acetylene gas again. With the entry of the generated gas, the rising bell moves up again and stops the water supply to carbide container. This operation continues till all the calcium carbide in the carbide container has reacted with water. Non-automatic type generators are also available, in which the welder himself pours water on the carbide, by a hand operated valve, as per his requirements of acetylene gas.

Fig 1



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Carbide to water acetylene gas generator

In this generator carbide falls on water automatically to generate the acetylene gas. Acetylene pressure up to 1 kg/cm2 can be generated. Calcium carbide is placed in the hopper at the top of the generator. The generator is partially filled with water to the required level. A feed mechanism in the hopper feeds the carbide into the water and acetylene is generated. Ata predetermined acetylene pressure (inside the generator) carbide feeding stops. Carbide feeding starts, when the acetylene is drawn out and its pressure in the generator decreases. The features of this type of generator are shown in Fig 2.

Working principle: The water tank cum gas-holder is filled with clean water to the water level. The carbide hopper is charged with ND 14 size calcium carbide through the carbide hopper door. (The hopper door is closed.) The carbide hopper is attached at the top of the water tank tightly. After starting the generator, the outlet valve and relief valve are closed. Calcium carbide is allowed to fall into the water by operating the feeding lever with the assistance of the other mechanism mentioned below.

The carbide feed valve is controlled by the feed rod and diaphragm (all connected to one another). A compound spring fitted to the opposite side of the diaphragm is supported by a pressure by a pressure adjusting screw. Then pressure adjusting screw controls the carbide feeding i.e., more pressure, more feeding and vice versa. By operating the feeding lever the pressure of the compound spring pushes the diaphragm down and thus the feeding rod also moves down to open the feed valve. The falling carbide reacts with water to generate acetylene gas.

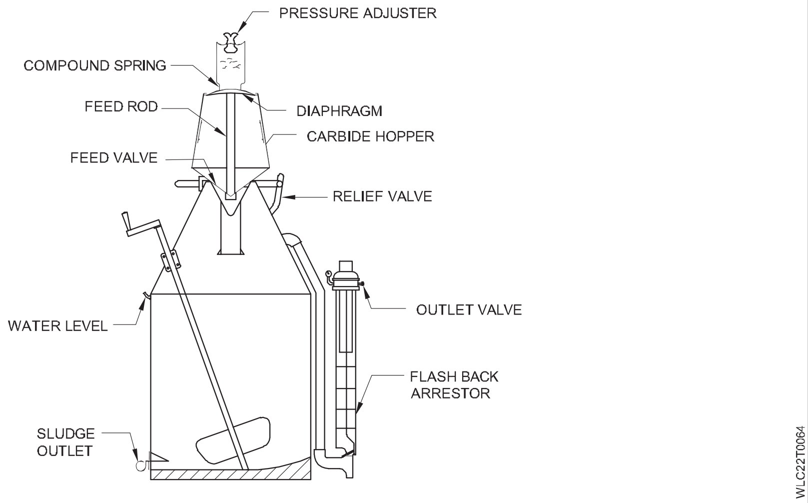
The acetylene gas passes up through the water (washed and cooled) into the gas storage chamber. When the pressure of the generated acetylene increases in the gas chamber more than the pressure of the compound spring, the feeding rod moves up with the help of the diaphragm to close the feeding valve. Thus the carbide flow stops automatically. The generated acetylene is taken out through the gas outlet pipe, flashback arrester cum purifier and outlet valve.

The pressure of the generated gas is indicated on the pressure gauge fitted near the outlet valve. When the pressure of gas in the gas chamber decreases, the carbide falls into the water and as the pressure increases, the carbide flow stops automatically. This operation continues until all the carbide in hopper is exhausted. The calcium hydroxide (slaked lime or sludge) collected at the bottom of the generator is cleaned out through the sludge outlet by operating the agitator.

The agitator prevents the formation of solid form of calcium hydroxide and mixes the calcium hydroxide with water and this makes it easy to remove (the thin milky fluid) from the generator completely.

The generation of gas in this generator is completely automatic and is under close control of pressure with the demand. An emergency relief valve is provided to discharge the gas out of the generator immediately if the pressure exceeds the safety limit and in case of any emergency.

Fig 2



Acetylene gas purifier

Definition : It is a cylindrical device which is used to purify the generated acetylene gas from its impurities.

Necessity : The generated acetylene gas will have the following impurities.

1 Water vapour.

2 Ammonia.

3 Lime dust.

4 Sulphureted hydrogen.

5 Phosphoresced hydrogen.

These impurities, if not removed from the generated acetylene gas, may accur the following harmful effects:

1 Reduction in flame temperature.

2 Reaction with metal and influencing welding defects like blow holes, porosity etc.

For quality gas welding and cutting acetylene gas used must be free from above impurities. To remove these impurities from the generated acetylene gas, a suitable gas purifier must be used.

Construction: Purifier is mode by thin M.S. sheet. At the bottom of the purifier gas inlet pipe is fitted and tap wall outlet pipe is fitted. There are three main compartments in a purifier.

Working Principle:

a The acetylene gas from the generator enters the purifier at the bottom chamber through the gas inlet pipe and goes to the first comportment. The first compartment contains pumice stone which absorbs moisture and water vapour from the acetylene.

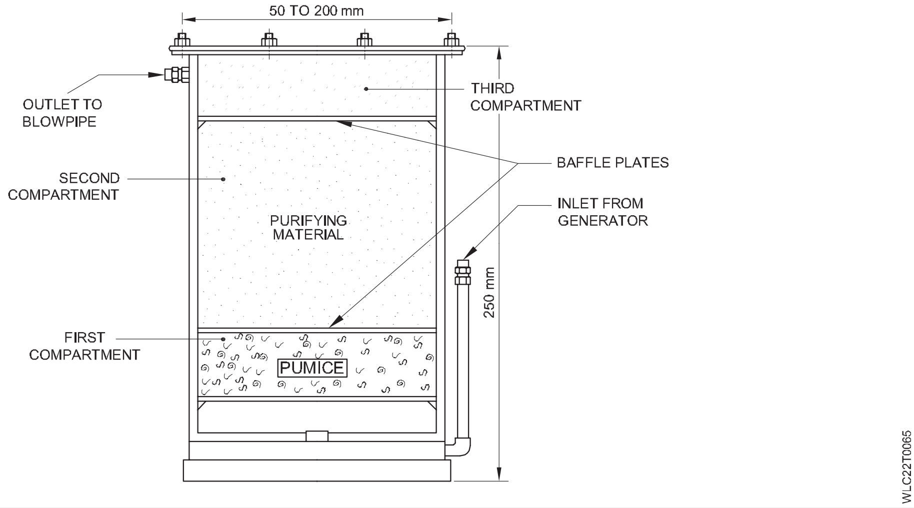
b Then the gas goes to the second compartment and there are purifying materials such as bleaching powder, chromic acid, salts of ferric iron etc These purifying materials absorb impurities sulphurated hydrogen and phosphorated hydrogen.

c The third comportment contains filter wool, which filters the lime dust and other foreign materials. Acetylene gas released from the second compartment may carry some amount of purifying materials and these materials also filtered by the filter wool in this third comportment. Ammonia is removed within the acetylene generator when the gas passes through the water.

d Then the purified gas released at the top from the third compartment through the gas out let pipe and goes to the H.B.P. valve.

Method of Testing : Hold the filter paper soaked in 10% Silver Nitrate solution against the stream of purified C2H2 gas for about 10 seconds. If it is properly purified there will be no trach of brownish spot on the filter paper. It the gas is impure the filter paper changes in to brownish colour.

Fig 3



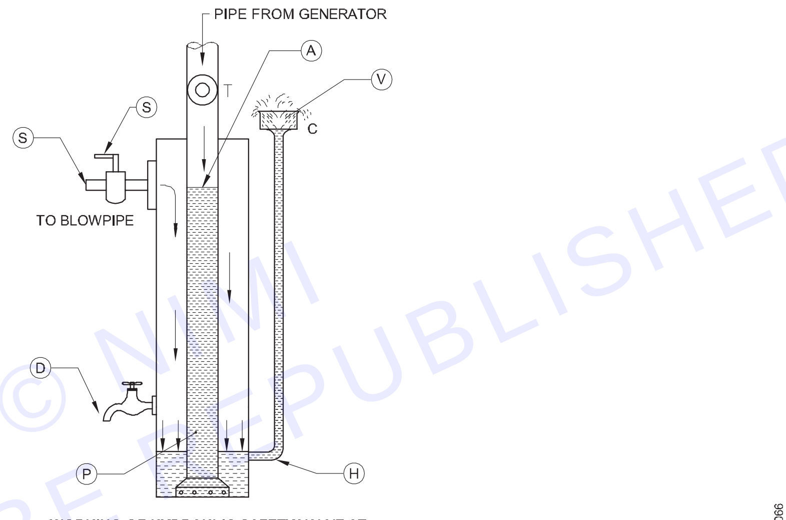
Hydraulic backpressure valve and flash back arrestor

Objectives : At the end of this lesson you shall be able to
- state the necessity of the hydraulic back pressure valve
- explain the Working principle of a hydraulic back pressure valve.
- explain the Working principle of a flash back arrestor.

Necessity of Hydraulic Safety Valve: In the low pressure system the oxygen pressure is always greater than the generated acetylene gas pressure.

During welding, due to back fire or nozzle hole blockage, the high pressure oxygen may enter into the acetylene passage and enter the acetylene generator, which will lead to an explosion.

To prevent the entry of high pressure oxygen or back fire to the generator, a hydraulic safety valve must be fitted in the acetylene pipe line between the blow pipe and the generator or purifier.



WORKING OF HYDRAULIC SAFETY VALVE AT THE TIME OF BACK FIRE TO PREVENT EXPLOSION IN THE GENERATOR

The pipe (P) has a baffle plate fixed a tit slowerend.

In the vent of backfire or flash back (backpressure) from the blow pipe side, the water level (A)is pushed down and water is forced up into the vent pipe until the hole (H) is exposed.

Constructional Features Of Hydraulic Back Pressure valve : It is a cylindrical shaped device having 250mm depth and 50 to 100mm dia, as per the generator's capacity.(Fig 1)

Working Principle

The cylindrical device is filled with water through the VENTPIPE(v) upto the level of water level (D).(Fig1)Gas enters from the generator through the in let pipe valve and comes down the center pipe(P),bubbles through the outlet pipe(R) and valve(S). The burnt gases in case of aback fire, or the back pressure gases, pass up the vent pipe in to the atmosphere and are prevented from getting in to the generator.(Fig 2)

Flash back arrestor

Introduction : It is a safety device and fitted with carbide to water acetylene generator. It is made out of mild steel cylindrical body.

Parts : Flash back arrestor has the following parts

1 Inlet

2 Drain plug

3 Non-return value

4 Water level

5 Water

6 Baffle plate

7 Purifying materials

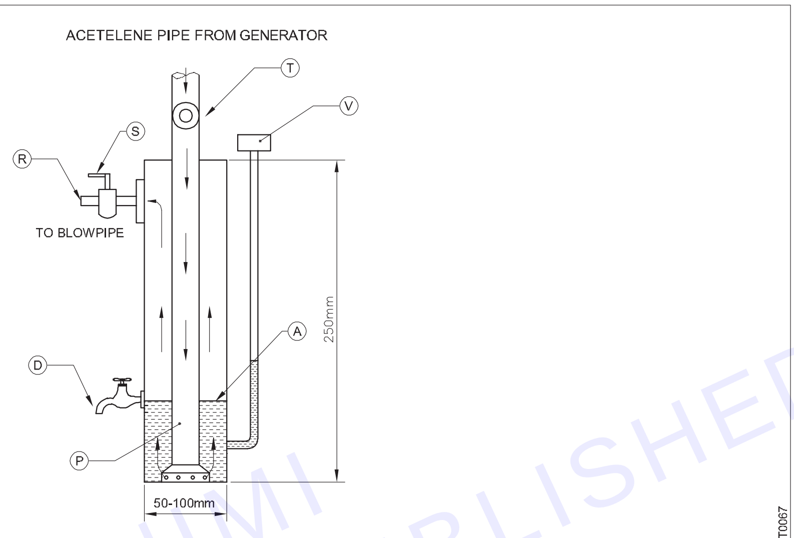
8 Filter wool

9 Wire screen10 Bursting disc

11 Pressure gauge

12 Gas controlling tap

Fig 1

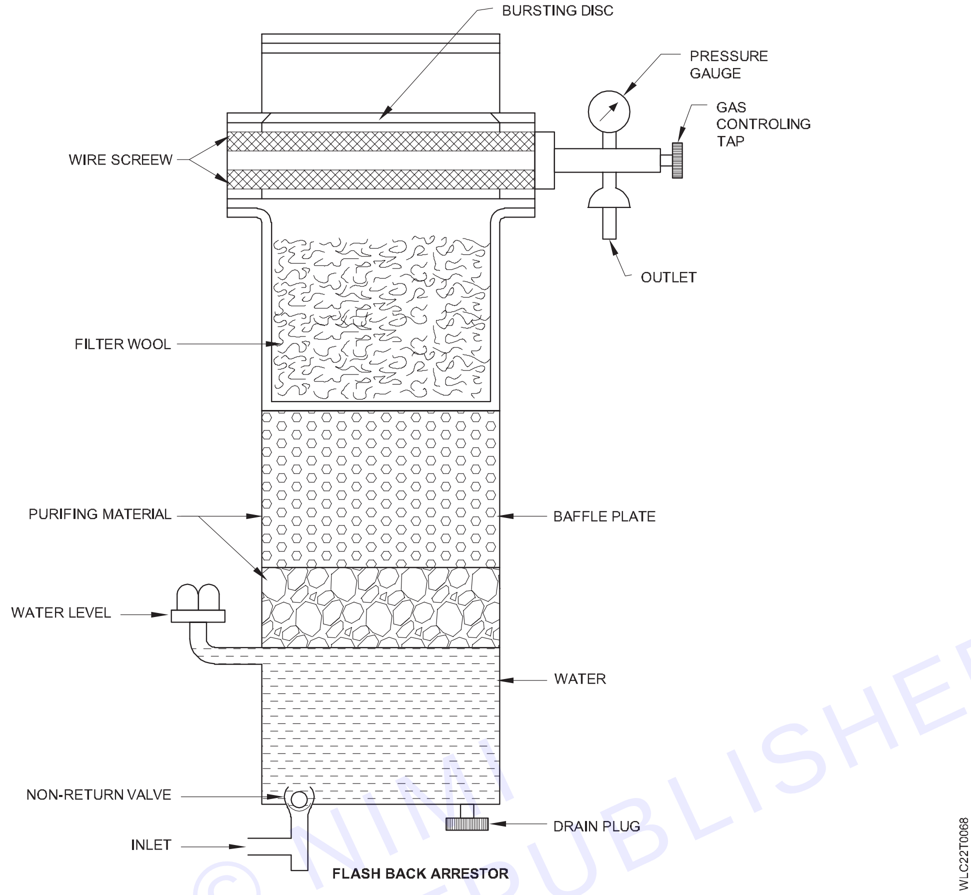


CONSTRUCTION AND NORMAL WORKING OF A HYDRAULIC SAFETY VALVE

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

Accidental Condition: Flash back from the blow pipe enters through the outlet connection in flashback arrestor and goes to the non-return valve through the filter wool, baffle plate and water. Flash back creates the pressure and pushes the water down wards when the ball of non-return valve comes down and closes the inlet acetylene gas with the help of the disc. With the result, no more gas enters inside the flash back arrestor.The acetylene gas which is already in the flask back arrest or burns due to this pressure, the bursting

Fig 2



Oxygen - properties - manufacturing method

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

- explain the oxygen properties.
- explain the oxygen manufacturing method.

Introduction

Properties of oxygen gas:

1 Oxygen is a supporter of combustion. Its chemical symbol is O2

2 Oxygen is colourless, odorless and tasteless gas,

3 It has atomic weight of 16.

4 Its specific gravity at 32° F and at normal atmosphere pressure is 1.1053, as compared with air. It is slightly soluble in water.

5 it does not burn itself, but readily supports combustion 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.

Manufacturing method

Air liquefaction process:

This method is based upon the idea of separating the various gases that constitute the air by liquefaction process. This process is done in three stages.

a purification

b liquefaction

c Distillation

The composition of air and the boiling points of its components are given in. Air is a mixture of roughly 78% nitrogen, 21% oxygen and 1% argon and other inert gases.

Composition of air

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

The basis of the separation of the elements in air by this method depends on the difference in the boiling point of the major elements. Between nitrogen and oxygen - 13°C, Between nitrogen and argon - 10°C,Between oxygen and argon - 3°C

Steps for separating oxygen

Purification:

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

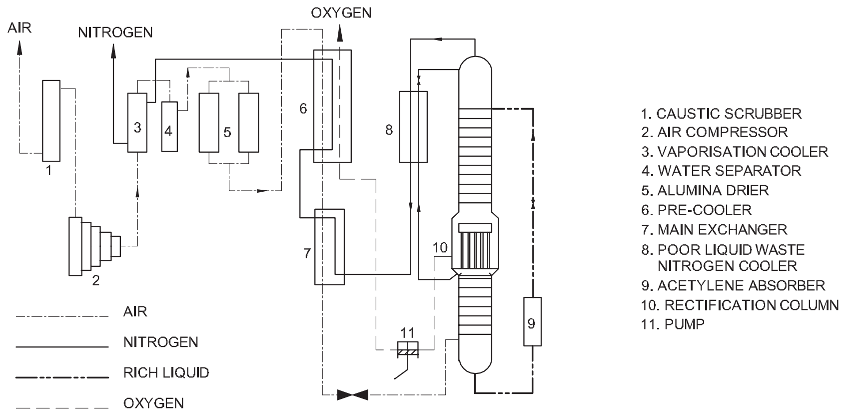
Liquefaction:

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

Distillation:

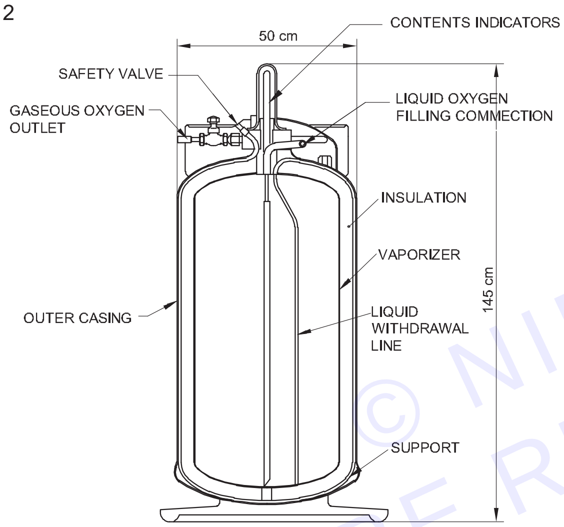
The liquid air is then rectified in the CONDENSER column by increasing the temperature on the basis of difference in the boiling points of its elements. Nitrogen having a lower boiling point (-195.8°C) evaporates first. Argon having a boiling point (-185.70°C) evaporates second leaving liquid oxygen in the bottom of the condenser. Liquid oxygen can be stored in liquid form as shown in the liquid oxygen container (Fig 2). The liquid oxygen next passes through a heated coil which changes the liquid into a gaseous form. The gaseous oxygen goes into a storage tank from where it is drawn and compressed into oxygen gas cylinders. Electrolysis of water (Fig 3): In this method. DC electricity is passed through water causing the water to separate into its elements which are oxygen and hydrogen oxygen will collect at the positive terminal and hydrogen at the negative. Caustic soda is added to the water to make it a good electrolyte since pure water will not allow the current to pass.

Fig 1



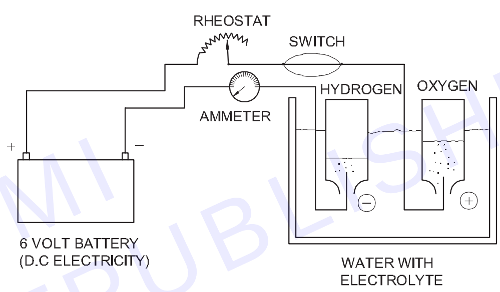
PRODUCTION OF OXYGEN BY AIR LIQUEFACTION METHOD

Fig 2



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

Fig 3



PRINCIPLE OF PRODUCING OXYGEN BY ELECTROLYSIS OF WATER METHOD

WLC22T0070

Oxygen and Acetylene gas cylinders-charging methods

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

- explain the oxygen gen cylinder charging method.
- explain the acetylene gen cylinder charging method.

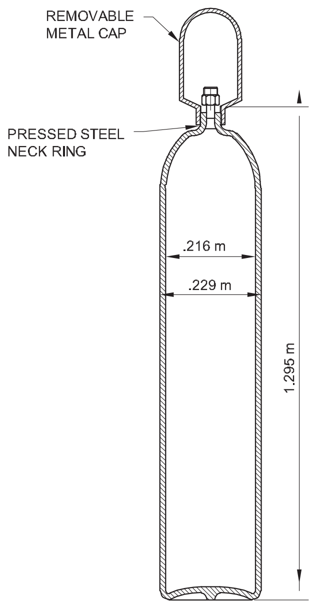
Oxygen gas cylinder- charging methods

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) The oxygen cylinder safe filled with oxygen gas under a pressure of 120-140kg/cm2.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. It is a steel container, used to store different gases at high pressure safely and in large quantity for welding or other industrial uses. It is a seamless steel container used to store oxygen gas safely and in large quantity under a maximum pressure of 140 kg /cm2, for use in gas welding and cutting.

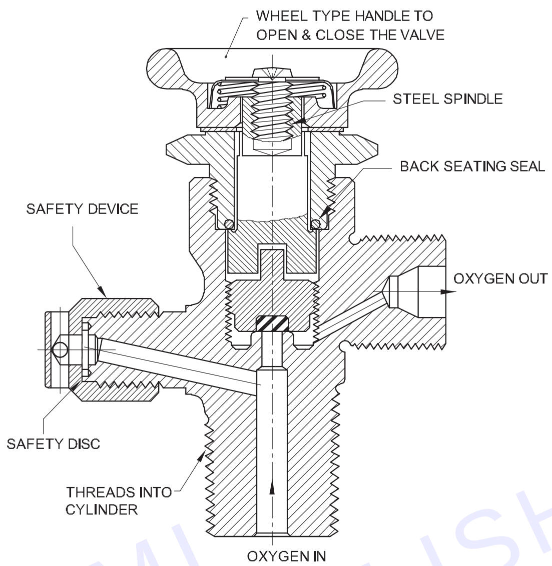
It is made from seamless solid drawn steel and tested with a water pressure of 225kg/cm2. The cylinder top is fitted with a high pressure valve made from high quality forged bronze. (Fig 2) The cylinder valve has a pressure safety device, which consists of a pressure disc, which will burst before the inside cylinder pressure becomes high enough to break the cylinder body. The cylinder valve outlet socket fitting has standard right hand threads, to which all pressure regulators may be attached. The cylinder valve is also fitted with a steel spindle to operate the valve for opening and closing. A steel cap is screwed over the valve to protect it from damage during transportation. (Fig 1)

Fig 1



CONSTRUCTIONAL FEATURE OF OXYGEN GAS CYLINDER

Fig 2



CONSTRUCTIONAL FEATURES OF A CYLINDER VALVE

WLC22T0071

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

The capacity of the cylinder may be 3.5m3 - 8.5m3. Oxygen cylinders of 7m3 capacity are commonly used.

Acetylene gas cylinder - charging method

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

Constructional features:

The acetylene gas cylinder is made from seamless drawn steel tube or welded steel container and tested with a water pressure of 100kg/cm2 the cylinder top is fitted with a pressure valve made from high quality forged bronze. The cylinder valve outlet socket has standard left hand threads to which acetylene regulators of all makes may be attached. The cylinder valve is also fitted with a steel spindle to operate the valve for opening and closing.

Steel cap is screwed over the valve too protect it from damage during transportation. The body of the cylinder is painted maroon. The capacity of the DA cylinder may be 3.5m3-8.5m3.

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

Method of charging DA gas cylinder:

The storage of acetylene gas in its gaseous form under pressure above 1kg/cm2 is not safe. A special method is used to store acetylene safely in cylinders as given below.

The cylinders are filled with porous substances such as:

a Pith from corm stalk

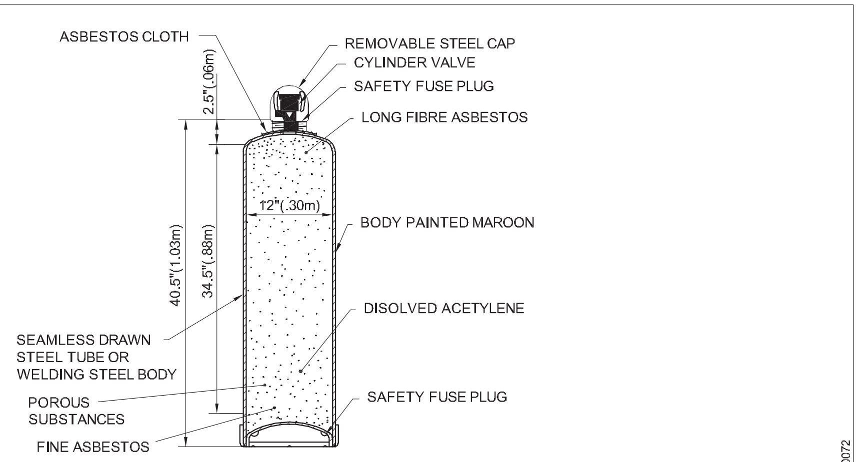
b Fullers earth

c Lime silica

d Specially prepared charcoal

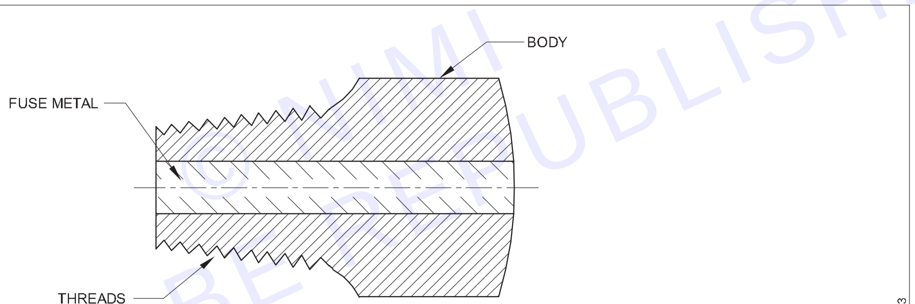
e Fiber asbestos.

Fig 3



CONSTRUCTIONAL FEATURES OF A DISSOLVED ACETYLENE GAS CYLINDER

Fig 4



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

The hydro carbon 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.15kg/cm2.

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/cm2 pressure at normal temperature. While charging cold water will be sprayed over the cylinder so that the temperature inside the cylinder does not cross certain limit.

Colour coding for different gas cylinders, safe handling and storage

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

- identify different gas cylinders
- state the cylinder safe handling and storage.

Introduction - 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)

Identification of gas cylinders

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

Oxygen & acetylene cylinder safe handling and storage

1 Make sure you have received the necessary training, including WHMIS. Only trained workers are allowed to handle compressed gases.

2 Do not smoke in compressed gas storage areas (indoors or outdoors). Note that oxygen alone will not combust, but it will vigorously support and accelerate combustion, causing flammable materials to burn with great intensity. Oil or grease in the presence of oxygen can ignite readily and burn violently.

3 Wear the required (if any) personal protective equipment (PPE) and use only the appropriate equipment (e.g., carts, tools, fittings, and equipment).

4 Before using or storing the cylinders, make sure they are properly identified or labelled and that they are in good condition. For cylinders that are not in good condition place a warning label on it, and report it to the supervisor to have it removed from service.

5 Store cylinders in a clearly identified, dry, well-ventilated storage area that is not exposed to heat or the direct rays of the sun, and away from doorways, aisles, elevators, gangways, stairs, electrical outlets, etc.

6 Identify empty cylinders with a tag and store them separately from full cylinders. Store cylinders, both empty and full, in the upright position (unless otherwise instructed).

7 During storage, close the cylinder valves with the protective caps or a specific protective device in place.

8 Secure cylinders with an insulated chain or non-conductive belt to protect cylinders from falling or becoming damaged.

9 When storing outside, make sure the cylinders are stored in the designated storage area. Place the cylinders on a raised concrete pad (or other non-combustible platform) or non combustible rack inside a secure designated area that is fenced in.

10 The plat form should be designed to prevent the cylinders from corroding from contact with ground, ice, snow, water, salt, and high temperatures.

11 Unless otherwise instructed, when storing indoors, store the cylinders only in rooms that are specifically designated. These rooms must meet specific design, electrical, and ventilation requirements as outlined in the fire, electrical and building codes.

12 Protect cylinders from falling. Secure the cylinders according to the instructions in the safe operating procedure. Tip! Securing each cylinder separately prevents other cylinders from falling when one of them is removed from storage.

13 Store acetylene and liquefied gas cylinders valve end up. Close the valve and keep the protective device in place.

14 Cylinders must also be separated away from flammable products and from materials that easily ignite (such as wood, paper, oil, grease, etc.).

15 Unless otherwise specified in the safe operating procedure, the general recommendation is to store oxygen cylinders and fuel gas cylinders separately when “not in use.” This method applies to indoor and outdoor storage.

16 Separate oxygen from fuel gas cylinders by at least 6.1 m (20 ft), or by a wall at least 1.5m (5 ft) high with a minimum half-hour fire resistance.

Gas Pressure Regulator

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

- state the different types of regulators
- describe the working principle of a single and double stage regulator
- explain the parts of each type of regulator
- explain the care and maintenance of the regulators.

Introduction

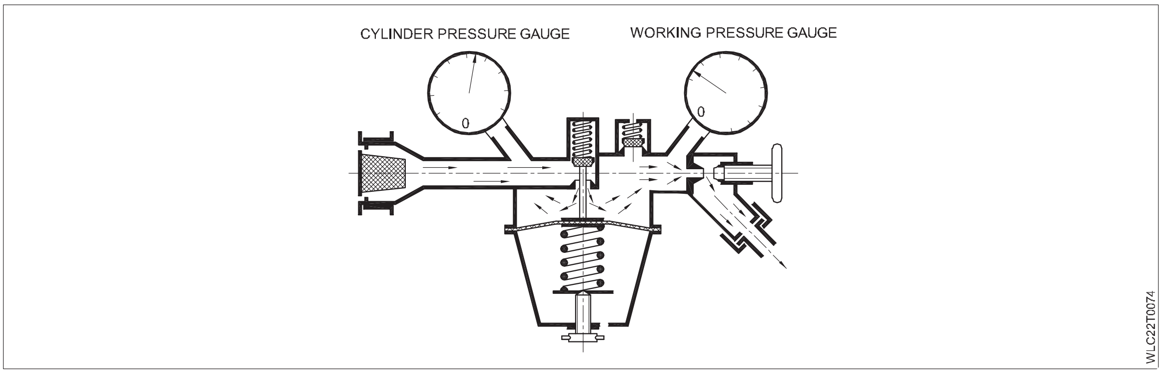
Types of regulators

1 Single stage regulator (Fig 1)

2 Double stage regulator (Fig 2)

Welding regulator (Single stage)

Working principle:

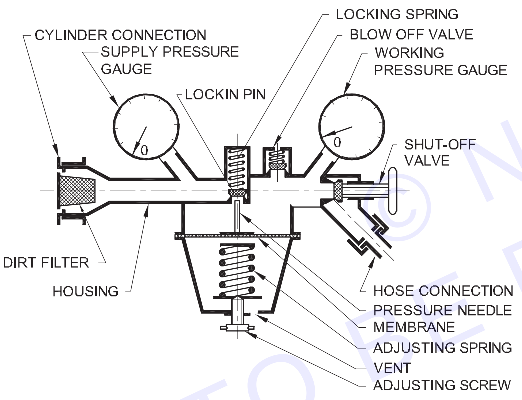


When the spindle of the cylinder is opened slowly, the high pressure gas from the cylinder enters into the regulator through the gas then enters the body of the regulator which is controlled by the needle valve. The pressure inside the regulator rises which pushes the diaphragm and the valve to which 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.

Welding regulator (Double stage):- Working principle:

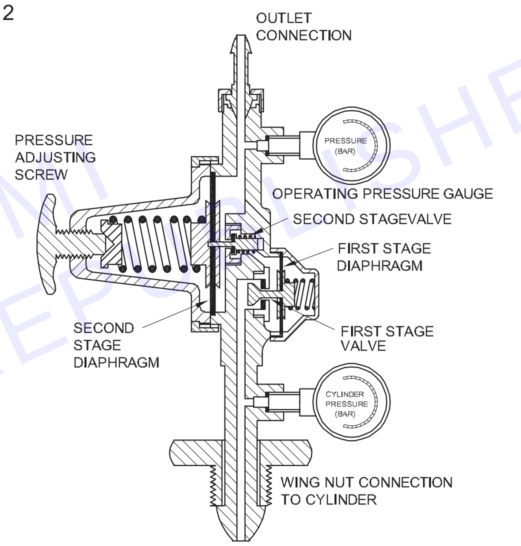
The two-stage regulator (Fig 2) is nothing but two regulators in one which operates to reduce the pressure progressively in two stages instead of one. The first stage, which is pre-set, reduces the pressure of the cylinder to an intermediate stage (i.e.) 5 kg/mm2 and gas at that pressure passes into 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 1



SINGLE STAGE REGULATOR

Fig 2



TWO STAGE REGULATOR

WLC22T0075

Gas welding and cutting blow pipe

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

- state the uses of the different types of blowpipes
- describe the working principle of each type of blowpipes
- explain its care and maintenance.

Types

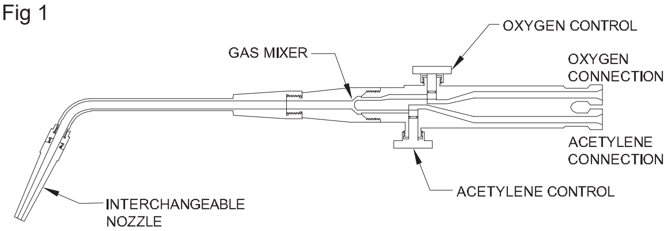
There are two types of blowpipes.

- 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.

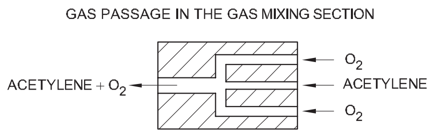
The equal pressure blow pipe (Fig.1) consists of two inlet connections for acetylene and oxygen gases kept in high pressure cylinders. Two control valves to control the quantity of flow of the gases and a body inside which the gases are mixed in the mixing chamber (Fig.2). The mixed gases flow through a neck pipe to the nozzle and then get ignited at the tip of the nozzle. Since the pressure of the oxygen and acetylene gases are set at the same pressure of 0.15 kg/cm2 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 1



EQUAL OR HIGH PRESSURE BLOWPIPE

Fig 2



EQUAL PRESSURE TYPE TORCH

WLC22T0076

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

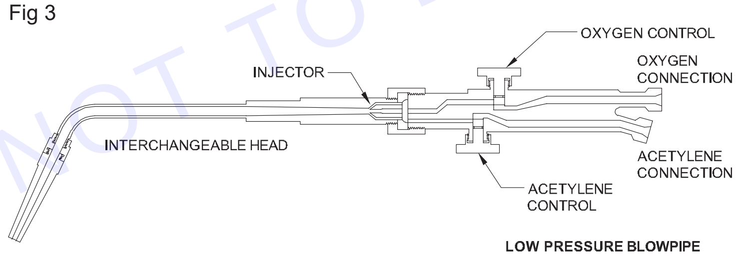
High pressure blowpipe (Fig 1): The H.P. blowpipe is simply a mixing device to supply approximately equal volume of oxygen and acetylene to the tip, and is fitted with valves to control the flow of the gases as required i.e, the blow pipes/gas welding torches are used for welding of ferrous and non-ferrous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

Low pressure blowpipe (Fig 3)

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

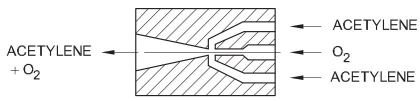
The low pressure blow pipe is similar to the equal pressure blow pipe except that inside its body an injector with a very small (narrow) hole in its center through which high pressure oxygen is passed. This high pressure oxygen while coming out of the injector creates a vacuum in the mixing chamber and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

Fig 3



LOW PRESSURE BLOWPIPE

Fig 4



INJECTOR TYPE TORCH

WLC22T0077

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

Care and maintenance

Welding tips made of copper may be damaged by careless handling. Nozzles should never be dropped or used for moving or holding the work. The nozzle seat and threads should be absolutely free from foreign matter in order to prevent any scoring/scatter on the fitting surfaces when tightening on assembly. The nozzle orifice should only be cleaned with a tip cleaner specially designed for this purpose. (Fig 5,6 &7)

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

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

Fig 5

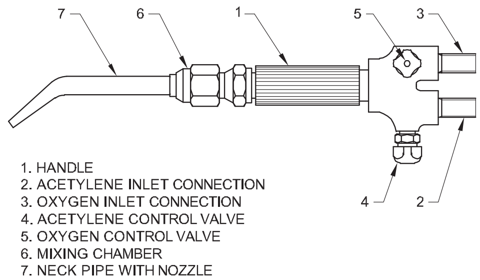
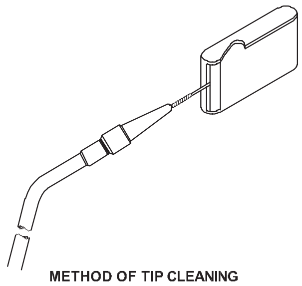
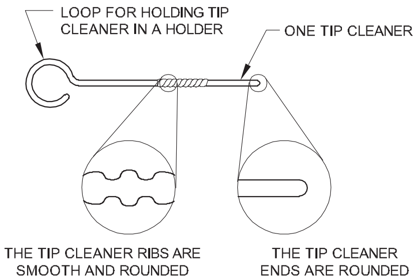


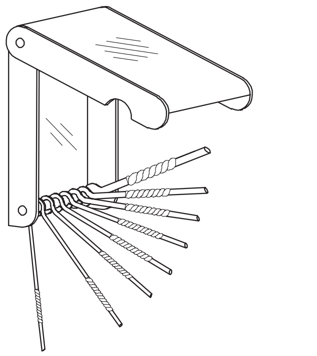
Fig 6



METHOD OF TIP CLEANING

Fig 7





SET OF DIFFERENT SIZE TIP CLEANERS IN A HOLDER

WLC22T0078

Fig 8

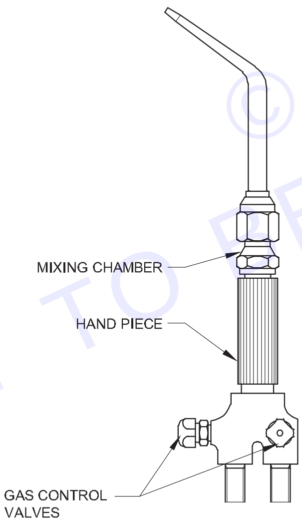
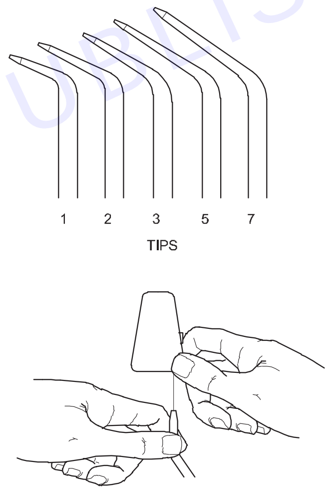


Fig 9



ALWAYS USE TIP CLEANERS

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

plate thickness mm	Nozzle size 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

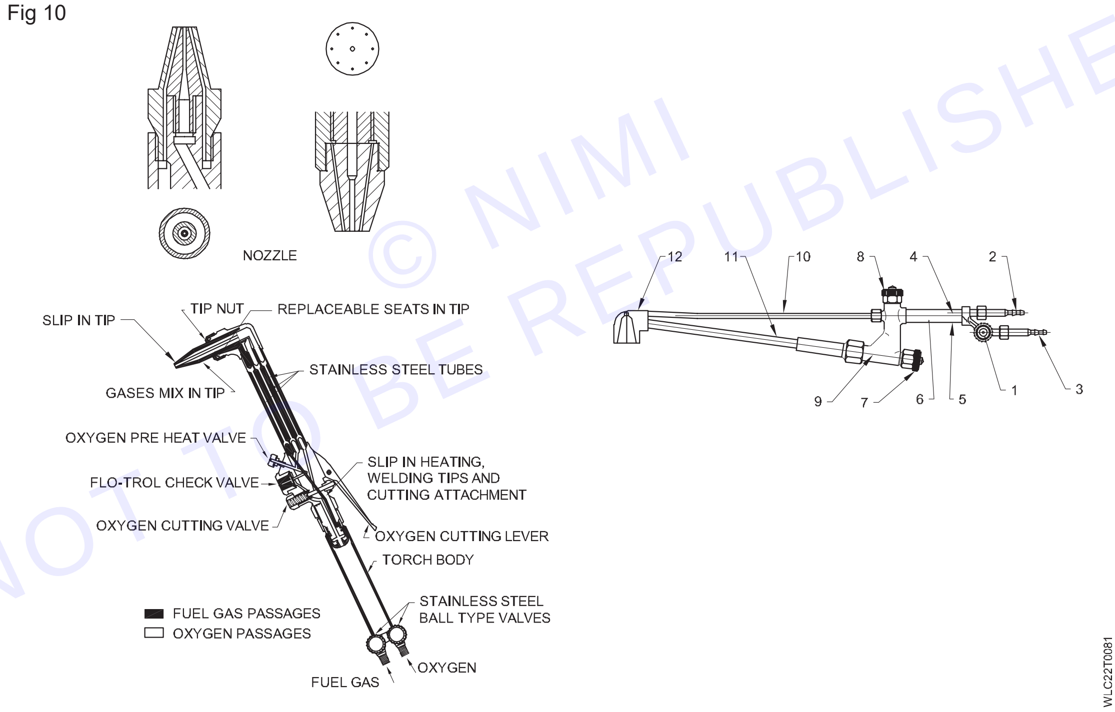
Gas Cutting blowpipe: Fig 10 Oxygen and fuel gas are mixed and then the gas is carried to the tip of the orifice to form 'preheat' flames. If oxygen is carried directly to the tip it oxidises the metal and blows it away to form the cut.

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

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

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

Fig 10



No	Name	Function
1	Acetylene gas valve	To adjust the flow rate of acetylene gas.
2	Oxygen Regulator	To connect Regulator
3	Acetylene gas hose joint	To connect with the acetylene gas hose.
4	Oxygen conduit	To lead oxygen.
5	Acetylene gas conduit	To lead acetylene gas.

6	Grip	To hold the torch.
7	Preheating oxygen valve	To adjust the preheating flame.
8	Cutting oxygen valve	To adjust the cutting oxygen flow rate.
9	Injector	To mix the acetylene gas with oxygen.
10	Cutting oxygen conduit	To lead the cutting oxygen.
11	Mixed gas conduit	To lead the mixture of acetylene gas and oxygen.
12	Torch head	To attach the nozzle.

Troubleshooting

SI.No	Trouble	Part to be	Method	Remedy	
1		Hose joint	soap water or water	Tighten further or replace	At the beginning of the work
2	Gas leakage	Valve & regulator	Soap water or water	Replace the torch	At the beginning of the work
3		Cutting tip attaching part	soap water or water	Tighten further or replace	At the beginning of the work.
4	Suction of Acetylene	Injector	plug the fuel gas hose mouth with your finger.	Replace.	Periodical check for the low pressure torch.
5	Preheating flame shape		Preheating flame shape	Clean or replace.	At the beginning of the work or at random.
6	Cutting oxy gen flow		Visible gas Visual inspection	Clean or replace	At the beginning of the work or at random.

Welding technique Rightward and Leftward Techniques

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

1 Leftward welding technique (Forehand technique)

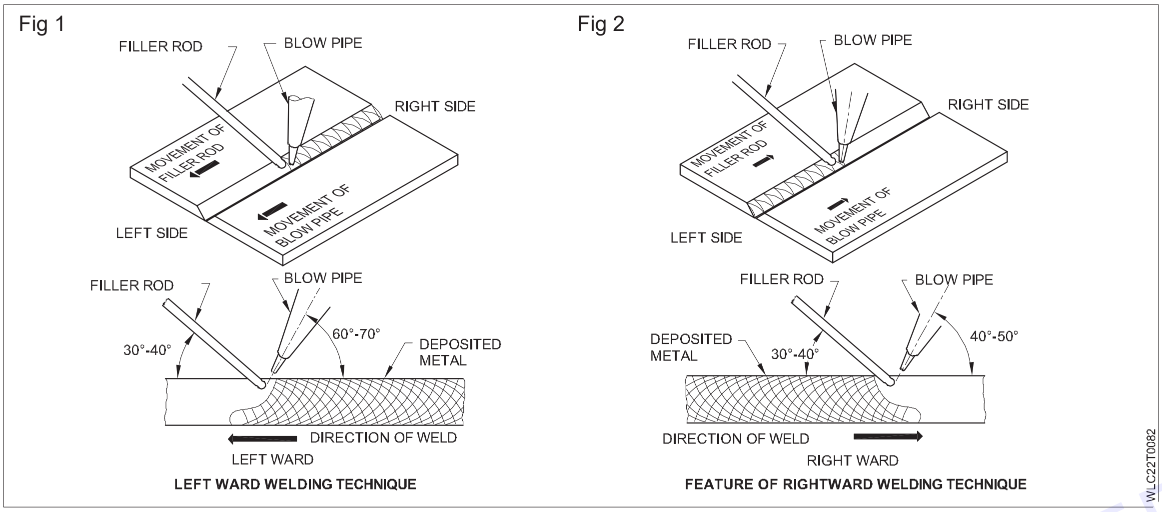
2 Rightward welding technique (Backhand technique)

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) 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.

Rightward welding technique:

It is an oxy-acetylene gas welding technique, in which the welding is begun at the left hand edge of the welding job and it proceeds towards the right. This technique was developed to assist the production Work on thick steel plates (Above 5mm) so as to produce economic welds of good quality. It is also called backward or back hand technique. the following are its features. (Fig 1)



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.

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

Application:

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

Advantage:

Less cost per length run of the weld due to less bevel angle, less filler rod being used, and increased speed. Welds are made much faster. It is easy to control the distortion due to less expansion and contraction of a smaller volume of molten metal. The flame being directed towards the deposited metal, is allowed to cool slowly and uniformly. Greater annealing action of the flame on the weld metal as it is always directed towards the deposited metal during welding. We can have a better view of the molten pool giving a better control of the weld which results in more penetration. The oxidation effect on the motion metal is minimized as the reducing zone of the flame provides continuous coverage.

Gas Welding Filler rods, Specifications and sizes

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.

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 up to 6.3 mm dia. issued. 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.

Types of filler rods:

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

In certain rare cases, it may be necessary to use filler rods of composition not covered by these specifications; in such cases filler rods with well established performances should be used. To select a filler rod in respect to the metal to be welded, the filler rod must have the same composition with respect to the base metal to be welded. Factors to be considered for selection of filler rod are:

a The type and composition of base metal

b The base metal thickness

c The type of edge preparation

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

e Welding position

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

Care and maintenance

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

2 Do not mix different types of filler rods.

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

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

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

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

Each metal requires a suitable filler rod. Refer to IS : 1278 - 1972 and IS : 2927 - 1975 attached.

Table 1

Filler metals and fluxes for gas welding

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/mm2 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/mm2 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 nece-ssary for brazing copper alloys.
Silver-copper-zinc (61 per- cent silver) type brazing alloys - Type BA-CuP3	Similar to type BA-CuP5 but with a slightly lower tensile strength and electrical conductivity (flame slightly oxidising on copper; neutral on copper alloys). NOTE: Phosphorus bearing silver brazing alloys should not be used with ferrous metal or alloys of high nickel content.	None for copper. A flux is necess-ary for brazing copper alloys.
Silver-copper-zinc (61 percent silver) - Type BA- Cu-AG6	This brazing alloy is particularly suitable for joining electrical components requiring high electrical conductivity. (Flame neutral)	Flux necessary
Silver-copper-zinc (43 per- cent 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.

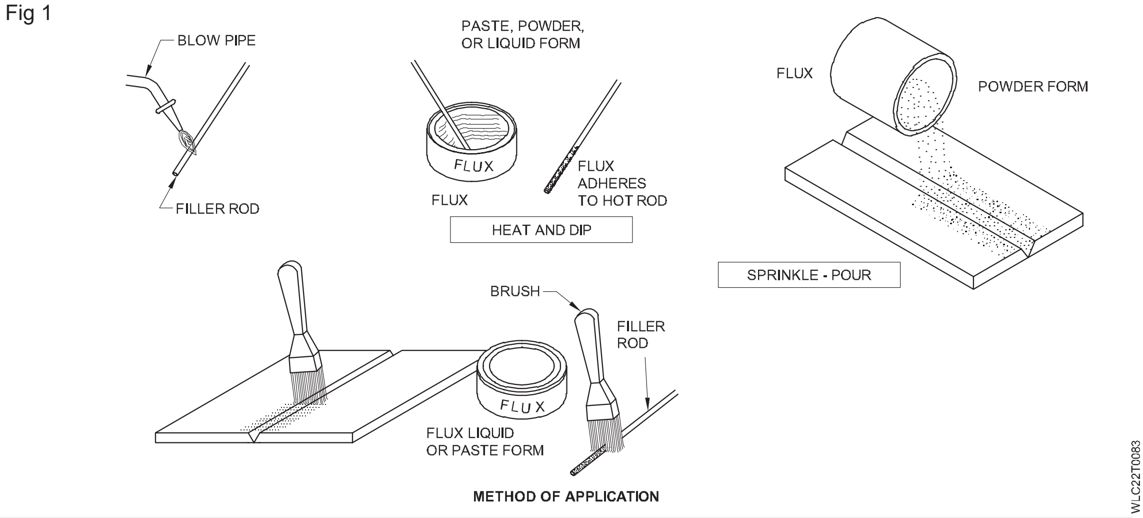
The method of application of flux is shown in Fig 1.

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.

Though the inner envelope of an oxy-acetylene flame offers protection to the weld metal, it is necessary to use a flux in most cases. Flux used during welding not only protects the weldment from oxidation but also from a slag which floats up and allows clean weld metal, to be deposited. After the completion of welding, flux residues should be cleaned.

Fig 1



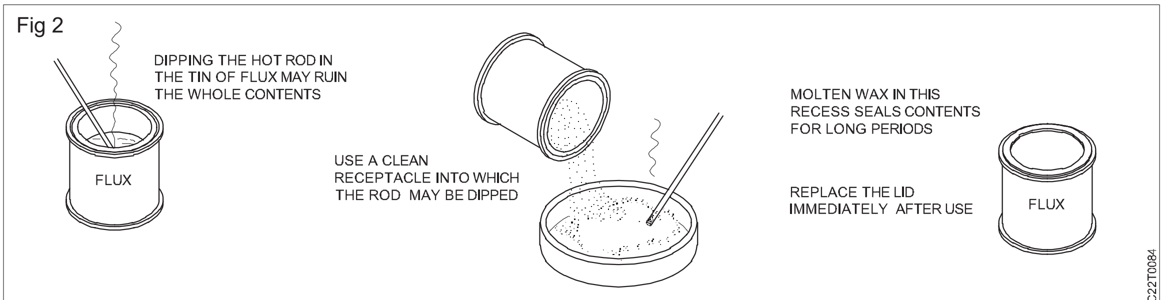
Removal of flux residues: After welding or brazing is over, it is essential to remove the flux residues. Fluxes in general are chemically active. Therefore, flux residues, if not properly removed, may lead to corrosion of parent metal and weld deposit.

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 hydro fluoric acid (40 percent strength). The solution used at room

Fig 2



METHOD OF STORING FLUX

Gas welding Defects, Causes and remedies

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.

Introduction A fault is an imperfection in the weld which may result in failure of the welded joint while in service. The following defect occur commonly in gas welding.

1 **Undercut** - A groove formed along the toe of the weld on one side or both sides

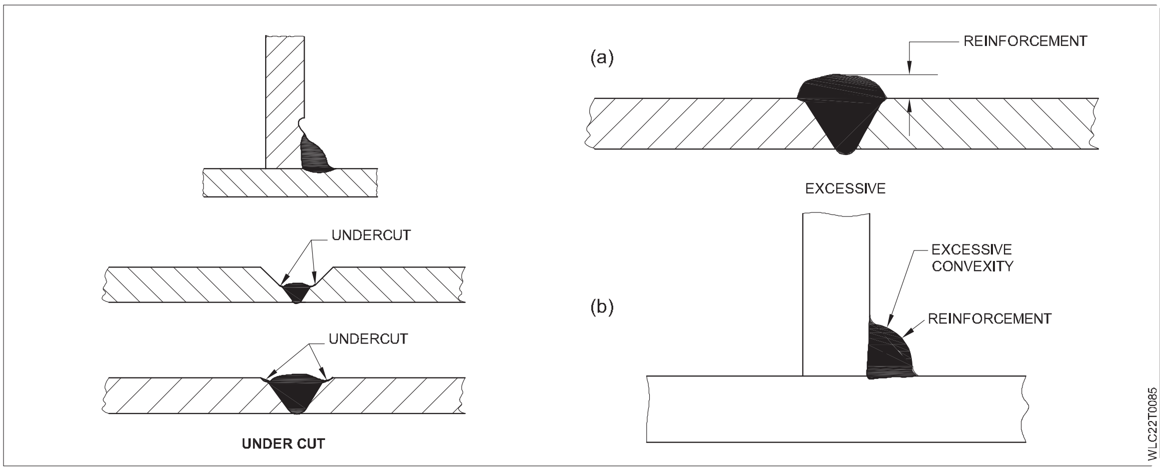
Causes - Incorrect angle of tilt used in blow pipe manipulation.

Incorrect distance from plate surface. Use of too large a nozzle, Use of flame density high of oxidizing flame.

Remedies of undercut - maintain blowpipe at the correct angle, Use correct nozzle, speed of travel blow pipe manipulation to semi circular.

2 **Excessive convexity**- Too much weld metal added to the joint so that there is excessive weld reinforcement.

Causes - weld speed very slow, Filler rod use more thickness, Excess heat build - up , use to large a nozzle.



Remedies - weld speed keep the correct, filler rod use correct thickness, set the correct flame. Use to correct nozzle size.

3 Overlap - Metal flowing into the surface of the base metal without fusing it.

Causes - not correct to edges preparation. not a correct flame, weld joint not a clean, welding technique wrong.

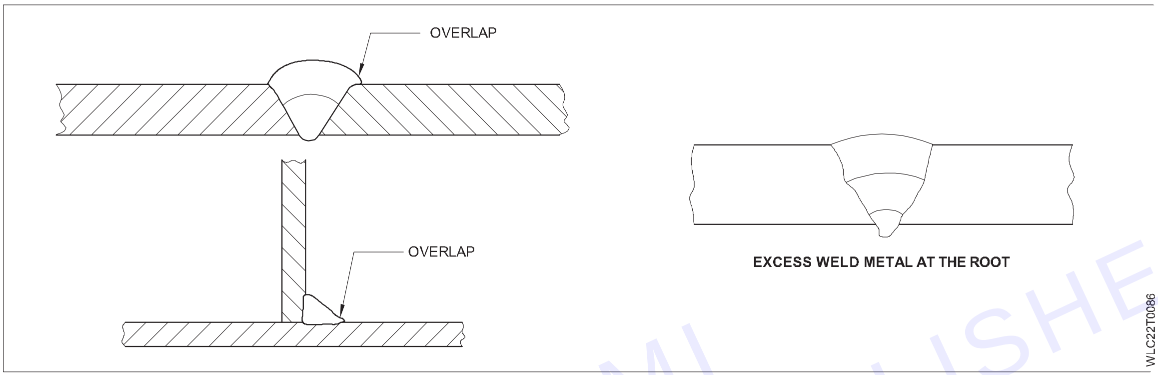
Remedies - correct to edges preparation. use to correct flame, weld joint should be clean need.

4 Excessive penetration

Depth of fusion at the root of the groove joint is more then the required amount.

Causes - nozzle use too large size, flame keep the one place more time, nozzle angle not proper maintain. Flame making the (velocity) large size, edge preparation not correct. Base metal gap also not correct

Remedies - nozzle use correct size flame, do not keep the one place more time, nozzle angle proper maintain 60 to 70 degree, flame making the (velocity) small size, edge preparation.



5 Lack of penetration / lack of fusion-

Required amount of penetration is not achieved. Fusion does not take place up to the, root of the weld. No melting of the edges of the base metal at the root face.

Cause - Incorrect joint preparation and set up. Wrong edge preparation. Nozzle use very small size, Welding use more speed, Flame use very small.

Remedies - Edge preparation correct need, and setup correct need, Nozzle use correct size .

Welding use correct speed, flame use correct - neutral flame.

6 Porosity - Number of pinhole on the surface of the deposit metal.

Blow Hole - These are similar to pin holes but have a greater diameter.

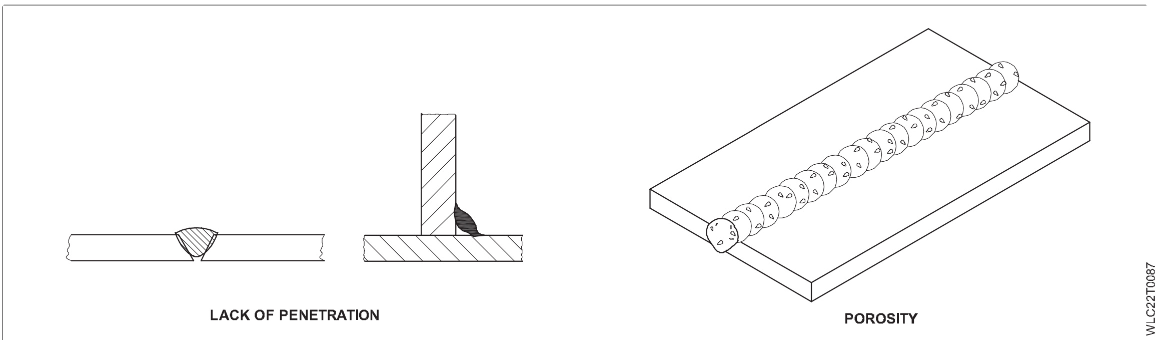
Causes - Use of incorrect/old filler rod and technique, Welding surface not proper clean.

Use the old stored fluxes, Not dry the job and filler wire and atmosphere. Effect of oxidization & hydrogen ,Entry of Atmospheric contamination

Remedies - Use of correct filler rod and technique.

Welding surface proper clean.

Use the new fluxes



7 Cracks

A discontinuity in the base metal or weld metal or both.

Causes - Not have similar both base metal. Base metal and filler rod not similar .Not proper pre-heat Weld metal cooling very fast. not proper heat treatment.

Remedies - Similar need both base metal. Base metal and filler rod similar need. proper pre-heat need. Weld metal cooling slow need. proper heat treatment need.

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

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

- state the main classification of steels
- explain the effect of carbon content in steel
- describe the uses of various types of carbon steel.

Classification of steel:

The classification of steel is mainly based on the chemical composition of various elements like traces of sulphur, phosphorus, silicon, manganese with a percentage of less than1%carbon content in steel.

Wrought iron	Wrought iron	Less than 0.05	Chain for lifting tackle, crane hooks, architectural iron work.
Dead mild steel	Plain carbon steel	0.1to0.15	Sheet for pressing out such shapes as motor carboy panels. Thin wire, rod, and drawn tubes.
Mild steel	Plain carbon steel	0.15to0.3	General purpose workshop bars ,boiler plates, girders.
Medium carbon carbon steel	Plain carbon steel	0.3 to 0.5 0.5 to 0.8	Crank shaft for gings, axles .Leaf springs ,cold chisels.
High carbon steel	Plain carbon steel	0.8 to 1.0 1.0 to 1.2 1.2 to 1.4	Coils prangs, chisels use din wood work. Files, drills, tap sandiest. Fine edge tools (knives etc).

Thus, the steel is classified as follows,

Carbon steel

Alloy steel

Effects of carbon content in steel:

Steel can be defined as an alloy of carbon and iron, in which carbon is in a combined state. The carbon content is a very important factor to get the desired properties of steel.

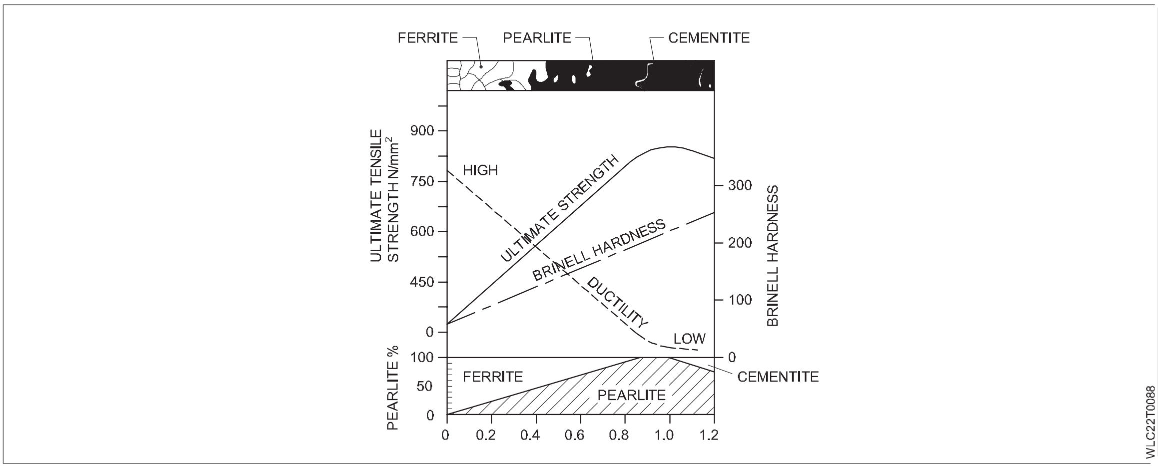
Carbon:

Carbon is a very important constituent of steel. The addition of carbon at very in proportions modifies the characteristics of iron and makes it harder, stronger and of greater ruse in then gingering industry. Slight variations in the carbon content of steel lead to great differences in the properties of steel. Depending up on the properties it is put to different uses.

Ferrite is a very weak solid solution of carbon and iron with about 0.006% carbon. This is a very soft and ductile constituent. Pearlite contains alternate layers of ferrite and cementite. This laminated structure makes pearlite stronger. As the carbon content increases, the pearlite structure formation is also increased, and this increases the tensile strength and hardness.

It may be noted from the figure that addition of carbon beyond 0.83% cementite will not exist in the combined form but appear around the crystal boundaries. Carbon, existing in this form, reduces in tensile strength and ductility but the hardness continues to increase even beyond 0.83% of carbon.

It may be said that plain steel will have a maximum strength at 0.83% carbon - i.e. when the constituent of steel is fully pearlite. Addition beyond 0.83% reduces its strength and ductility.



Hardness of carbon of plain carbon steel increases proportionately even beyond 0.83% carbon content.

At room temperature in the annealed condition plain carbon steel contains three main constituents.

a Ferrite

b Cementite

c Pearlite

Welding Of Low Carbon Steel, Medium And High Carbon Steel:

Introduction:

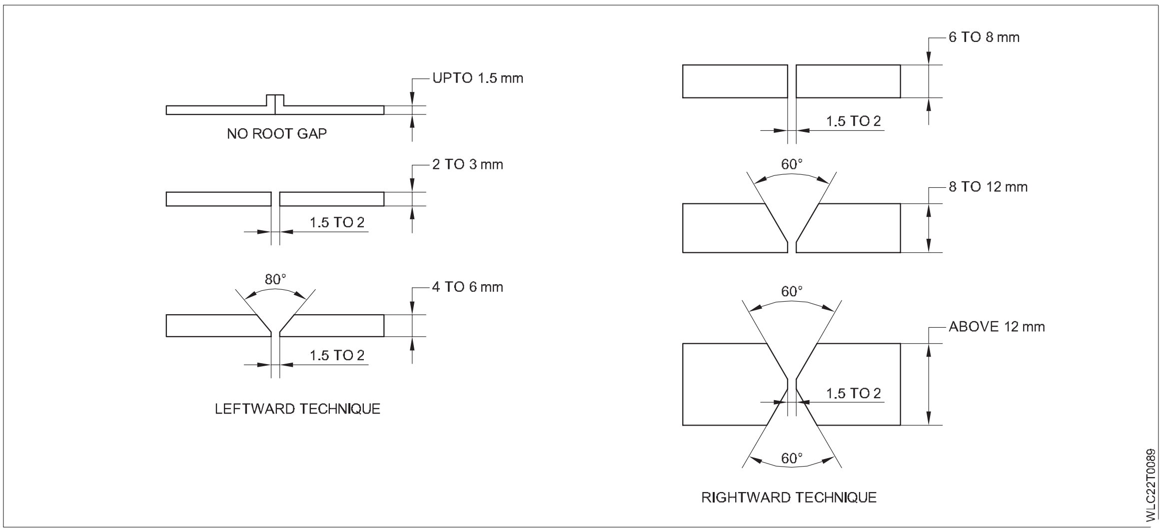
A plain carbon steel is one in which carbon is the only allowing element.

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 refer red to as low, medium and high carbon steels.

Low Carbon Steels: Steels with arrange of 0.05 to 0.30 percent 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 6mm,left ward technique is a suitable one. Above 6mm right ward technique is preferable.



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 can not be welded as easily a slow carbon steels due to the higher carbon content. They can be heat treated. It needs greater care to prevent formation of crack 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 to160°C to320°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.

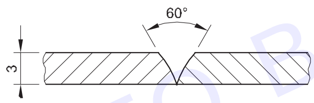
Plate edge preparation: the plate edge preparation depending on the thickness of the material to be welded.

High carbon steel: High carbon steels contain 0.6%to1.2% carbon. This type of steel is not wieldable by gas welding process because it is difficult to avoid cracking of base metal and the weld.

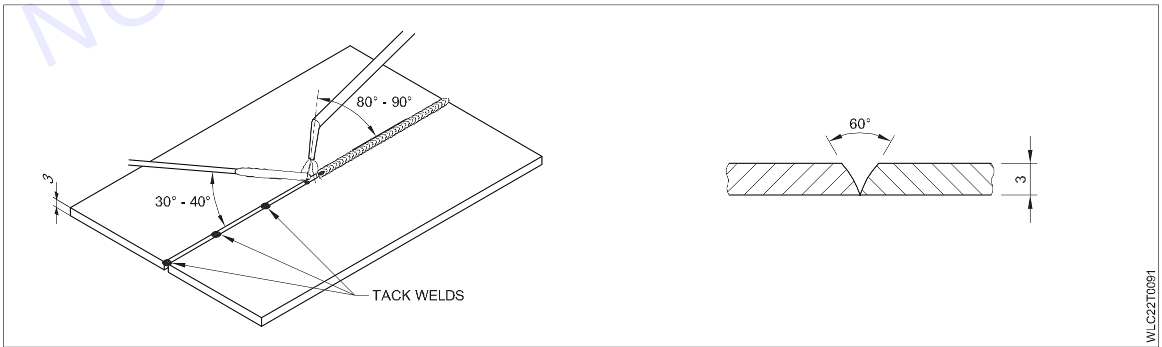
Welding procedure:

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

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

Thickness	Preparation	Assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1mm	Square edge	No gap	20	1	1.2mm
1.2mm	Square edge	No gap	20	2	1.2mm
1.5mm	Square edge	No gap	25	2	1.6mm
3mm		No gap	45	5	3mm

Keep the tip of the inner cone of the flame within 1 to1.5 mm of the molten puddle, and hold the blowpipe at an angle of 80-90° to the work.



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. Shows the type of edge preparation used for 3mm thick metal.

Aluminium Properties and weldability

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.

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.

Properties of aluminum its alloys

i Silvery white in colour.

i Weighs only about one third as much as the commonly used low carbon steel.

iii Highly resistant to corrosion.

iv Possesses great electrical and thermal conductivity.

v Very ductile, adaptable for forming and pressing adaptable for forming and pressing operations.

vi Non-magnetic.

vii Melting point of pure aluminum is 659°C.

viii Aluminum oxide has a higher melting point (1930°C) than aluminum.

Types

Aluminum is classified into three main groups.

1 Commercially pure aluminum

2 Wrought alloys

3 Aluminum cast alloys

Commercially pure aluminum has a purity of at least 99% the remaining 1% consisting of iron and silicon.

Difficulties in welding of aluminum by gas:

Aluminum does not change in colour before it reaches the melting temperature. When the metal begins to melt, it collapses suddenly.

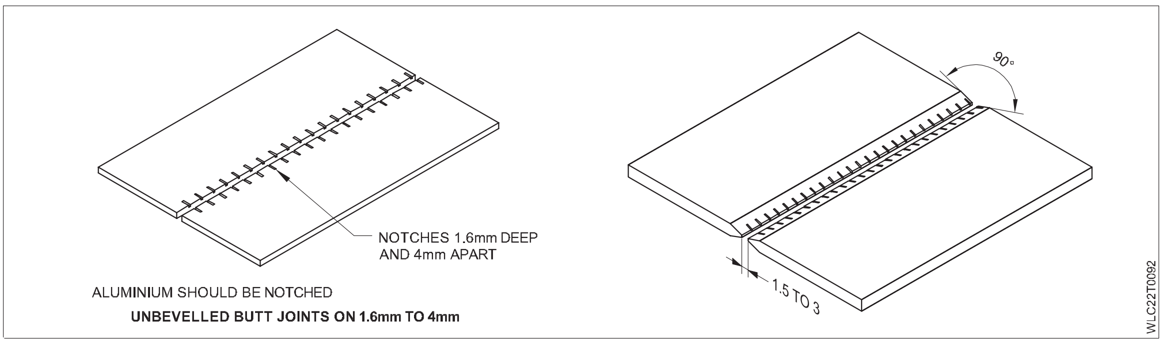
Molten aluminum oxidizes very rapidly form a heavy coating of aluminum oxide on the surface of the seam which has a higher melting point – 1930°C. This oxide must be thoroughly removed by using a good quality flux.

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

Joint design:

a Upto1.6mm, the edges should be formed to a 90° flange at a height equal to the thickness of the material.

b From1.6 to 4mm it can be butt-welded provided the edges are notched with as a word cold chisel.



ALUMINIUM SHOULD BE NOTCHED

UNBEVELLED BUTT JOINTS ON 1.6mm TO 4mm

For welding heavy aluminum plates, 4 mm or more in thickness, the edges should be beveled to form 90° Included angle with

a root gap of 1.6mm to 3mm.

Preparation, pitch of tack, nozzle, size, filler rod etc. are given in Table1 for butt joints.

Importance of flux:

Since aluminum oxidizes very rapidly, a layer of flux must be used to ensure a sound weld. Aluminum flux powder I strobe mixed with water (two parts of flux to one part of water).

The flux is applied to the joint by mean so f 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.

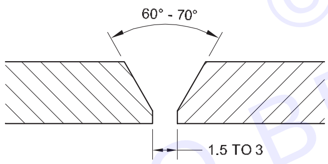
Necessity of preheat:

Aluminum and its alloys possessing 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, aluminum casting sand assemblies in wrought alloys of above 0.8mmaretobepreheated.

Preheating temperature varies from 250°C to 400°Caccording 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: Various processes of welding of aluminium-Oxy-acetylene welding

Thickness	Preparation	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

a) Manual metal arc welding, b) TIG welding, c) MIG welding, d) Resistance welding, e) Carbon arc welding, f) Solid state welding, g) Cold welding, h) Diffusion welding, i) Explosive welding, j) Ultrasonic welding.

Advantages of adopting oxy-acetylene process for welding of aluminum

i Simple and low cost equipment

ii For welding thinner sheets, gas welding may prove to be economical.

Disadvantages

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

ii Distortion is greater than in arc welding.

iii Heat-affected zone is wider than in arc welding. Welding speed is lower

Copper Types- Properties and welding method

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 weld able.

De-oxidized copper:

In this type a small quantity of phosphorous, a de-oxidizing element is added to the electrolyte copper.

This type of copper is weld able.

Characteristics of copper

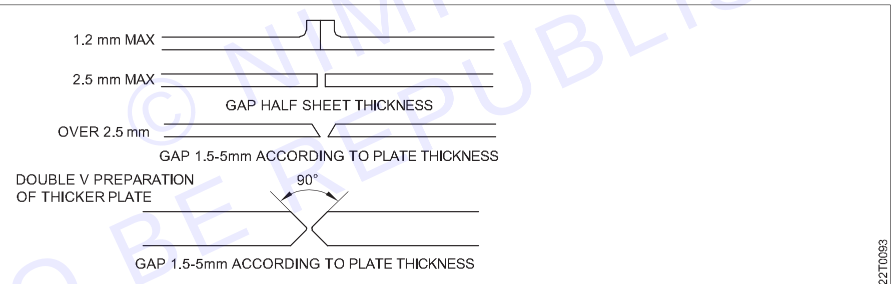
1 Reddish in colour.

2 High thermal and electrical conductivity. Excellent resistance to corrosion.

3 Excellent work ability in either hot or cold condition or informing wires, sheets, rods, tubes and castings.

4 Melting point: 1083°C. Density: 8.98g/cm3

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



PREPARATION OF COPPER PLATES FOR WELDING

Edges preparation:

a Upto1.2mm - edge or flange point.

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

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

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

Types of cleaning:

Mechanical cleaning is done to removed it 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 'oxidizing 'flame

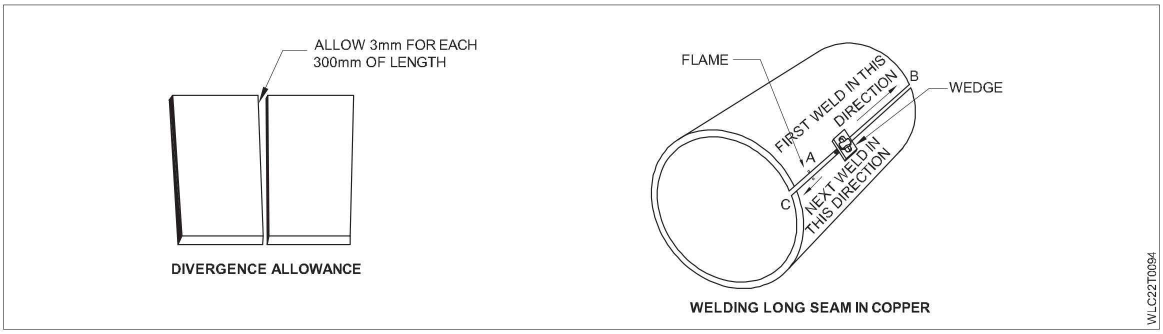
a Too much oxygen will cause the formation of copper oxide and the weld will be brittle.

b 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 3-4mm per 300mm run.

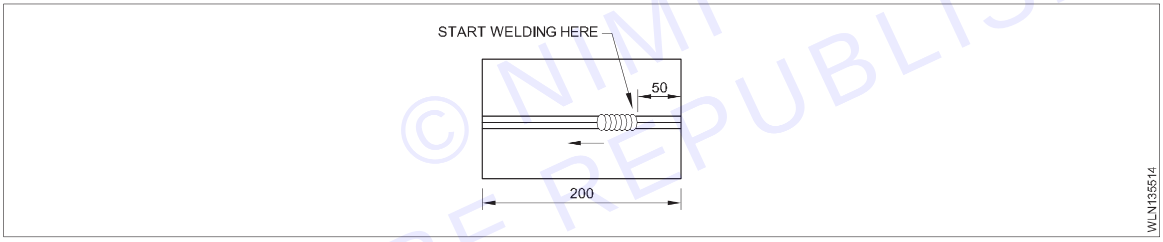
Use wedge for welding longs e a min copper. No tacking is done.



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

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 50mm 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



Control 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:

Penning is done in order to reduce the grain size and the locked up stresses. This is done when the metal is in hot condition

Brass - Types - Properties and welding weldability

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 proportions, 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.

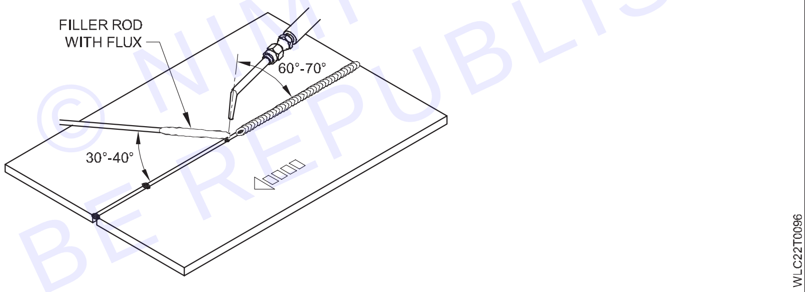
Flux is very important in welding brass. A fresh mixture of borax paste makes a good flux for brass welding.

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



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

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

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

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

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

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

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

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

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

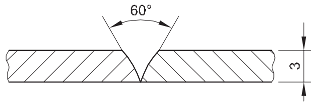
Welding procedure:

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

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

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

Table 1

Thickness	Preparation	Assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1mm	Square edge	No gap	20	1	1.2mm
1.2mm	Square edge	No gap	20	2	1.2mm
1.5mm	Square edge	No gap	25	2	1.6mm
3mm		No gap	45	5	3mm

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

Fig 1

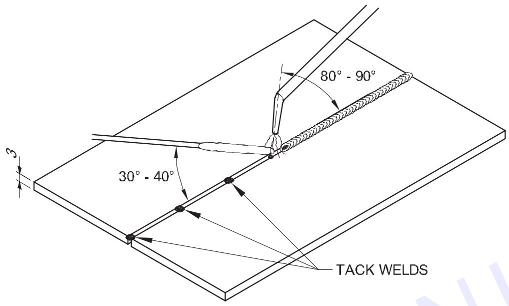
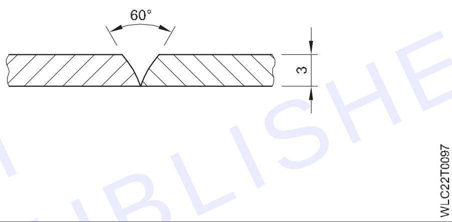


Fig 2



Add the filler rod by holding it close to the cone of the flame. upon withdrawing it from the puddle remove it entirely from the flame until you are ready to tip it back into the puddle.

Care must be taken not to direct too much heat on the end of the filler rod to avoid easy melting and flowing.

Complete the weld in one pass on one side and avoid multi-pass welding so as to reduce the effect of heat on the weldment.

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.

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.

Development drawing for pipe Elbow joint

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

- develop and layout the pattern for 90° elbow joining two equal diameter pipe by parallel line method.

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

Draw plan as shown in Fig 1.

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

Fig 1

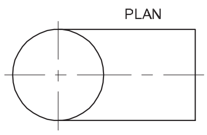
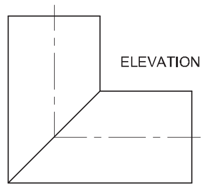
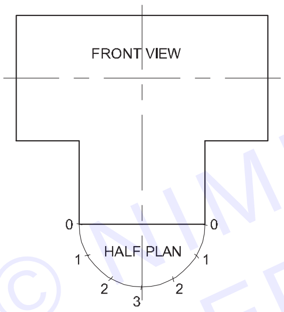


Fig 2



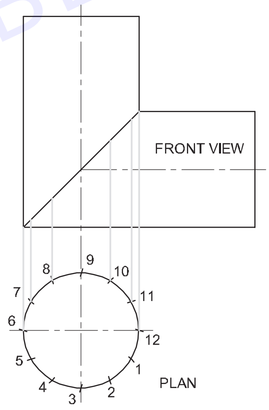
Divide the circle in the plan into twelve equal parts and number the points 0 to 12 as shown in Fig 3.

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



Development drawing for pipe "T" joint

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

- develop and layout the pattern for 90° "T" pipe of equal diameter by parallel line method.

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

Draw the front view as shown in Fig 1.

Draw the side view as shown in Fig 2

Fig 1

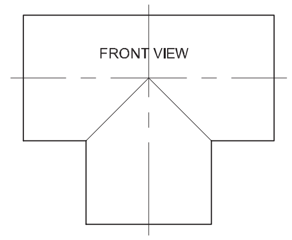
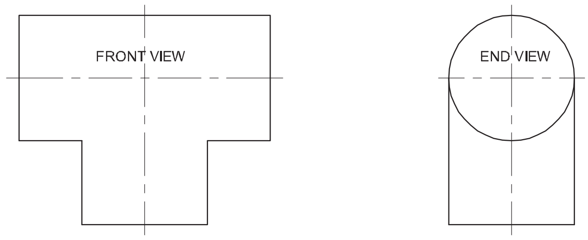
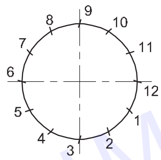


Fig 2



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

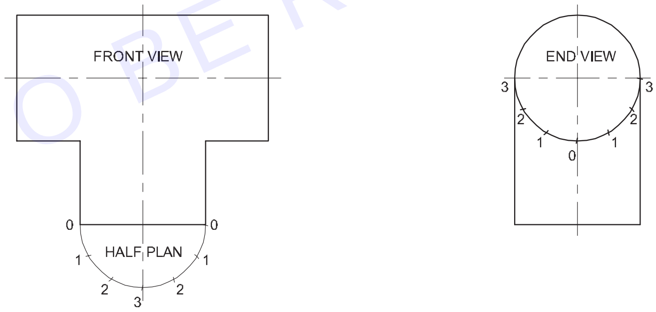
Fig 3



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

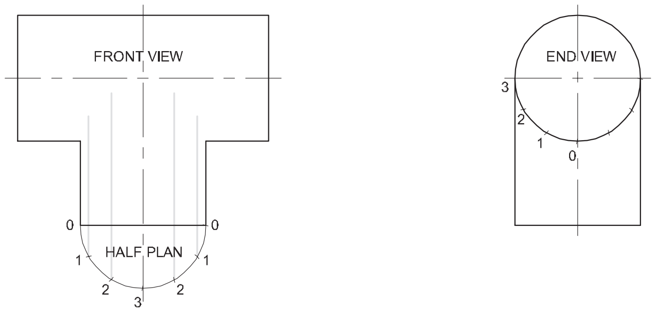
Divide a semi-circle in side view into six equal parts and number as 3, 2, 1, 0, 1, 2, 3 as shown in Fig 4.

Fig 4



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

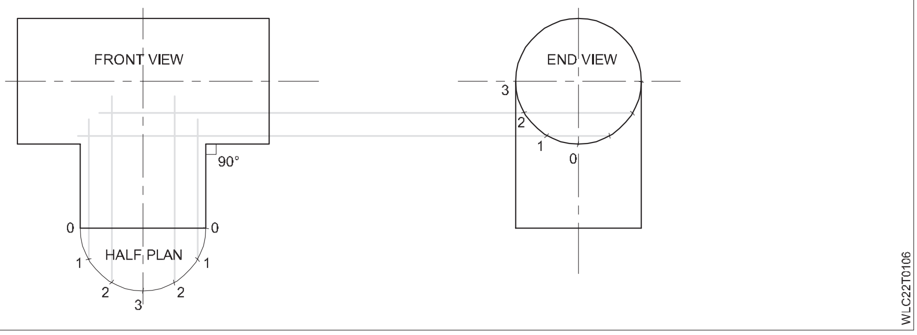
Fig 5



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

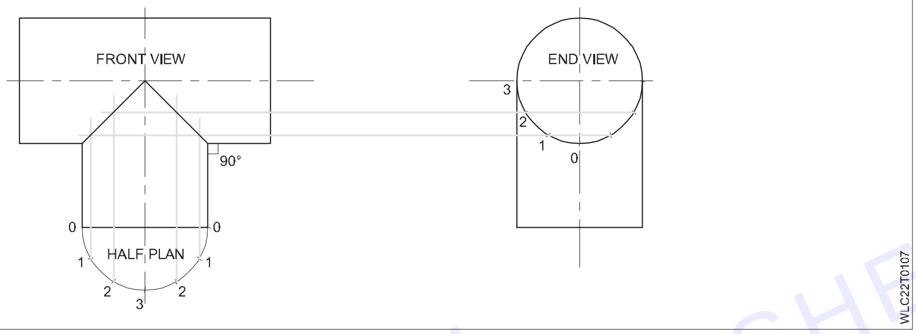
Now the vertical lines of the front view and the horizontal lines of side meet at their respective points.

Fig 6



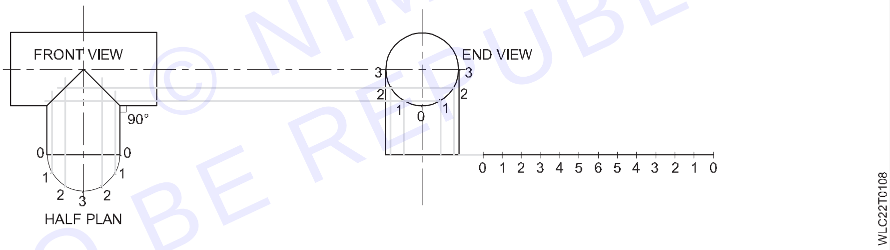
Join these points to get the line of intersection of “T” pipe as shown in Fig 7.

Fig 7



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

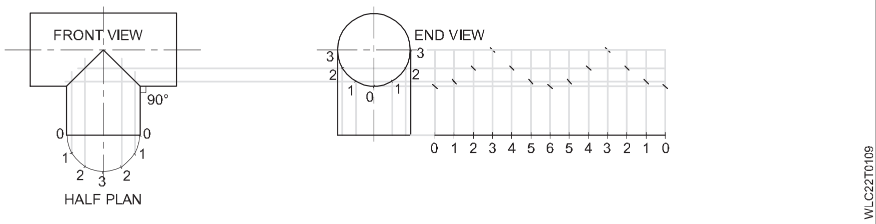
Fig 8



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

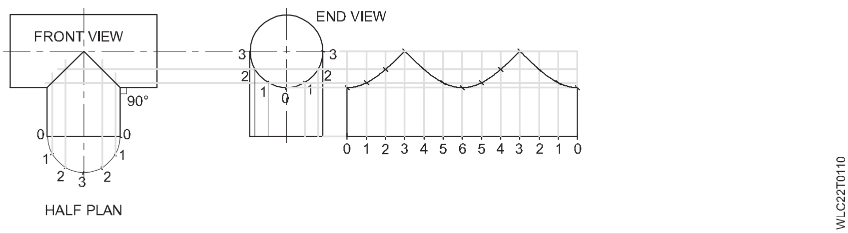
Draw perpendicular lines from these points and draw horizontal lines from the points on the line of intersection of “T”. These line meet at their respective points. (Fig 9)

Fig 9



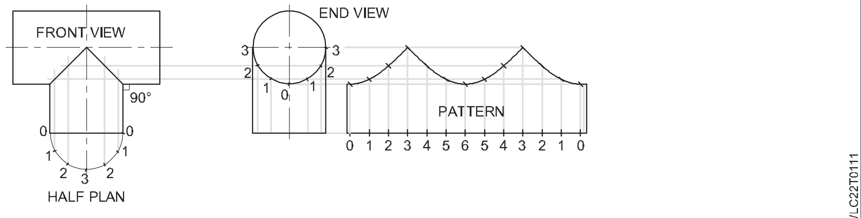
Join these points by free hand curve. (Fig 10)

Fig 10



Provide locked grooved joint allowance as shown in Fig 11.

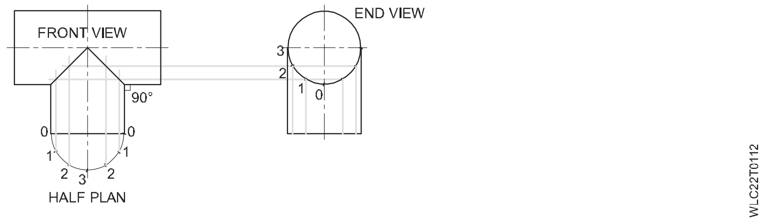
Fig 11



Check the pattern once again and cut. Thus you get the pattern for branch pipe.For main pipe, develop and layout the pattern as follows:

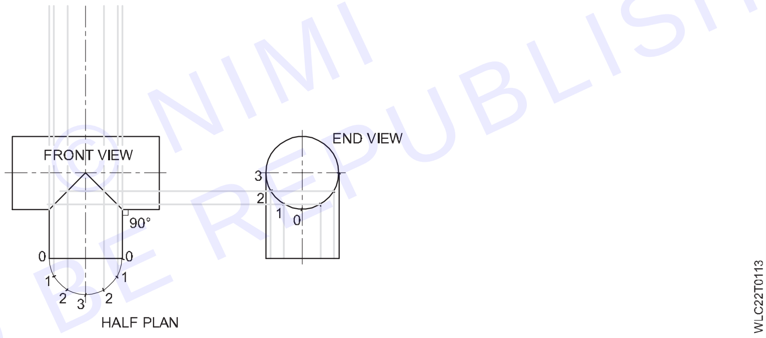
Draw the front view and end view. (Fig 12)

Fig 12



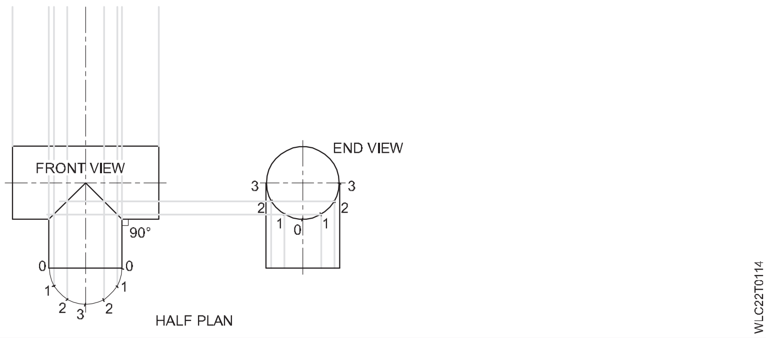
Extend the vertical lines 0, 1, 2, 3, 1, 0 of branch pipe from the front view as shown in Fig 13.

Fig 13



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

Fig 14



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

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

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

Provide the locked grooved joint allowances as shown in Fig 17

Fig 15

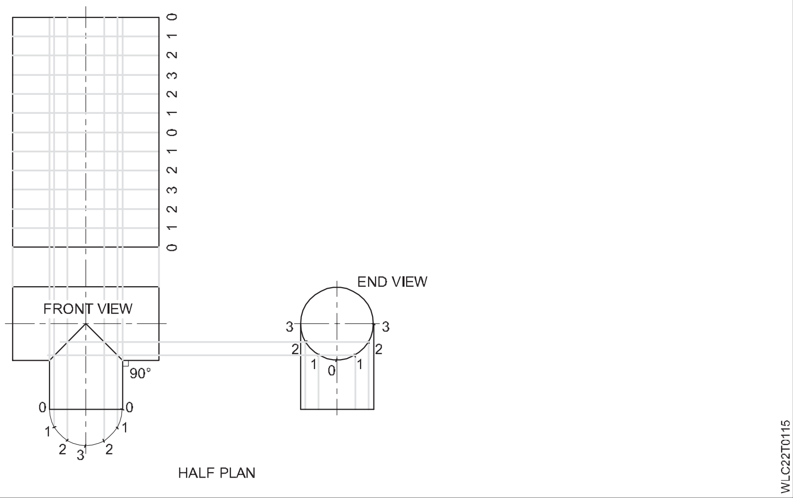


Fig 16

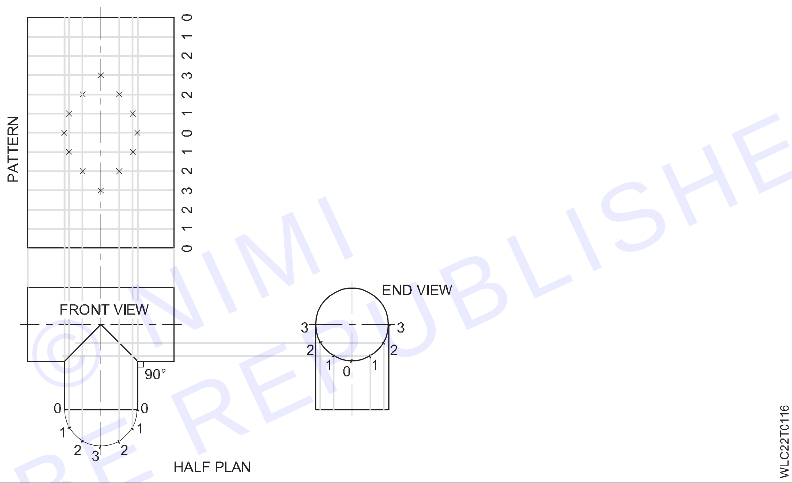
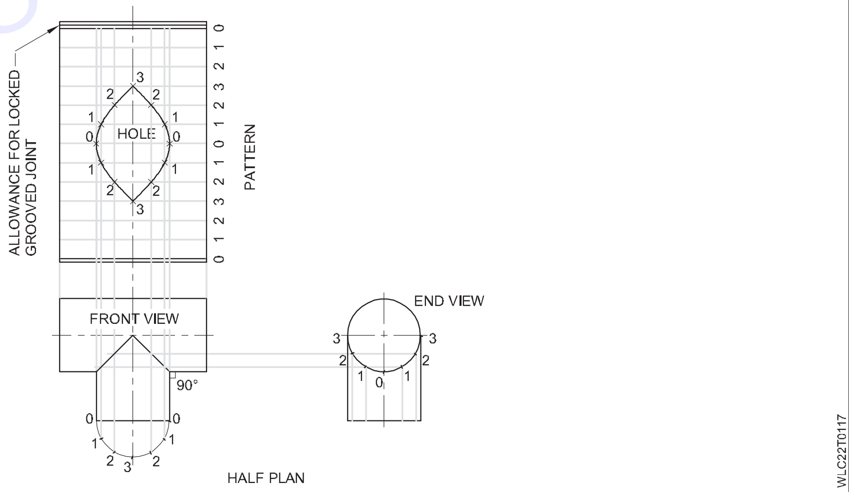


Fig 17



Development drawing for pipe Branch "Y" joint

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

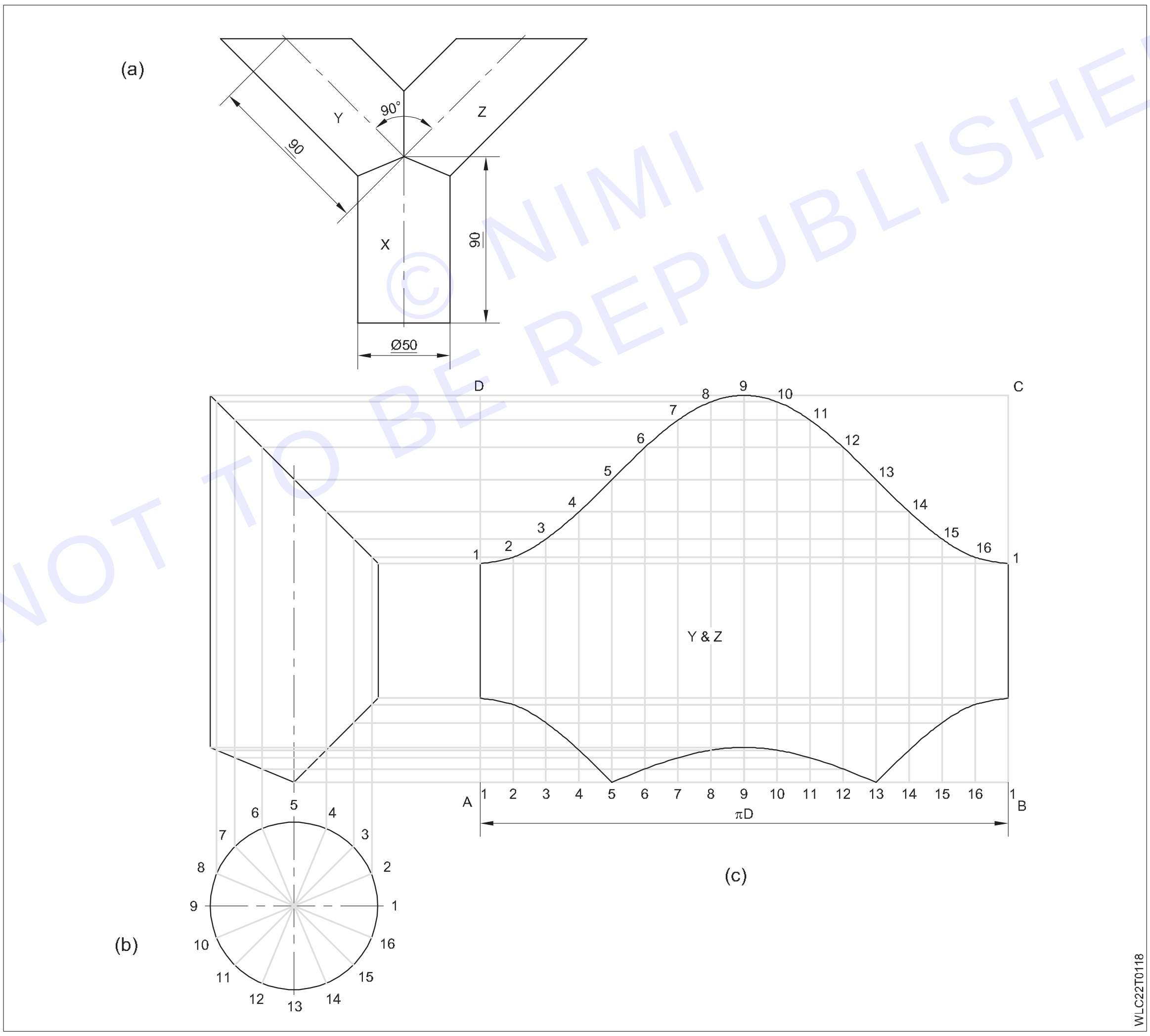
- develop and able to layout the pattern for "Y" joint pipes intersecting at 120°
- develop and layout the pattern for "Y" joint pipes branching at 90°.

Development of 'Y' joint 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.



◆MODULE 4: Repair and Maintenance◆

LESSON 27 - 30 : Electrode - Types - Function flux, types of flux, coating factor, size of electrode

Objectives

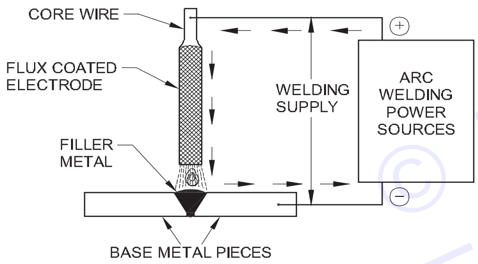
At the end of this lesson you shall be able to

- 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.

1 Electrode

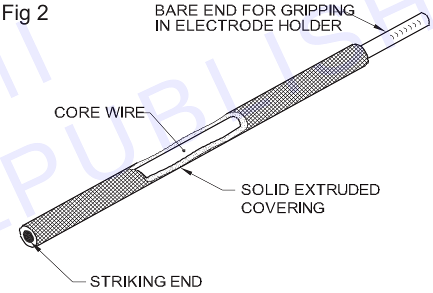
Introduction: An electrode is a metallic wire of standard size and length, generally coated with flux (may be bare or without flux coating also) used to complete the welding circuit and provide filler material to the joint by an arc, maintained between its tip and the work. (Figs 1 & 2)

Fig 1



FLUX COATED METALLIC ELECTRODE IN THE WELDING CIRCUIT

Fig 2



2 Types of Electrode

a Cellulosic electrode: (Pipe welding electrode e.g. E6010)

Cellulosic electrode coatings are mainly made of materials containing cellulose, such as wood pulp and flour. The coating on these electrodes is very thin and the slag is difficult to remove from deposited welds. The coating produces high levels of hydrogen and is therefore not suitable for high-strength steels. This type of electrode is usually used on DC+ and suited to root pass welding of high pressure pipes.

b Rutile electrodes: (General purpose electrode e.g. E6013)

Rutile electrodes, are general-purpose electrodes have coatings based on titanium dioxide. These electrodes are widely used in the CG & M industry as they produce acceptable weld shape and the slag on deposited welds is easily removed. Strength of deposited welds is acceptable for most low-carbon steels and the majority of the electrodes in this group are suitable for general purpose CG & M.

c Iron powder electrodes: (E7018)

Iron powder electrodes get their name from the addition of iron powders to the coating which tend to increase efficiency of the electrode. For example, if the electrode efficiency is 120%, 100% is obtained from the core wire and 20% from the coating. Deposited welds are very smooth with an easily removable slag; welding positions are limited to horizontal, vertical fillet welds and flat or gravity position fillet and butt welds.

d Basic or hydrogen-controlled electrodes: (Low hydrogen electrode e.g. E7018)

Basic or hydrogen controlled electrode coatings are based on calcium fluoride or calcium carbonate. This type of electrode is suitable for welding high-strength steels without weld cracks and the coating have to be dried. This drying is achieved by backing at 450°C holding at 300°C and storing at 150°C until the time of use. By maintaining these conditions it is possible to achieve high strength weld deposits on carbon, carbon manganese and low alloyed steels. Most electrodes in this group deposit welds with easily removable slags, producing acceptable weld shape in all positions. Fumes given off by this electrode are greater than with other types of electrodes.

Types of electrodes: Electric arc welding electrodes are of three general types. They are

a Carbon electrodes

b Bare electrodes

c Flux coated electrodes

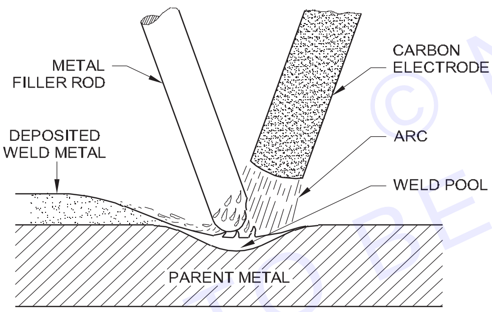
a Carbon electrodes

Carbon electrodes are used in the carbon arc welding process (Fig 3). The arc is created between the carbon electrode and the job. The arc melts a small pool in the job and filler metal is added by using a separate rod. Normally the carbon arc has very little use of welding. Its main application is in cutting and gouging operations.

b Bare electrodes

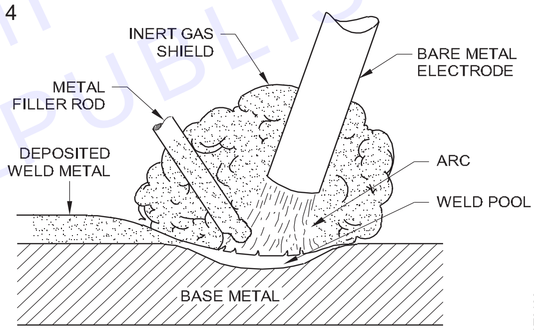
Bare electrodes are also used in some arc welding processes (Fig 4). An inert gas is used to shield the molten weld metal and prevent it from absorbing oxygen and nitrogen. Filler metal is separately added through a filler rod. Usually tungsten is used as one of the bare wire electrode. In Co2 welding and submerged arc welding processes the mild steel bare wire electrode is also used as a filler wire.

Fig 3



CARBON ARC PROCESS

Fig 4



PROCESS USING BARE ELECTRODE & GASEOUS SHIELD

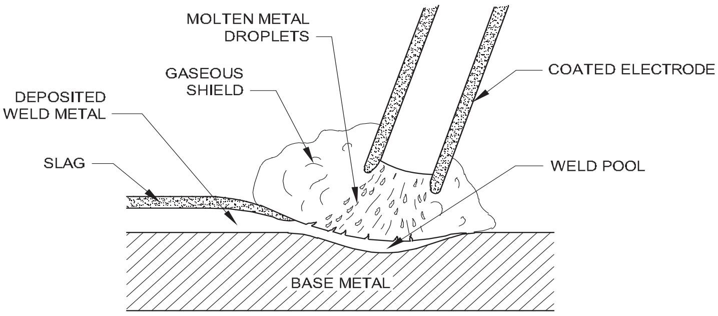
WLC22T0120

c Flux coated electrodes

Flux coated electrodes are used in the manual metal arc welding process for welding ferrous and non-ferrous metals. (Fig 5)

The composition of the coating provides the flux, the protective shield around the arc and a protective slag which forms over the deposited weld metal during cooling.

Fig 5



PROCESS USING FLUX COATED ELECTRODE

WLC22T0239

3 Function of flux

1. **Arc stabilizing substances:** These are carbonates known as chalk and marble. These are used for the stabilisation of the arc.
2. **Deoxidizers:** These substances prevent porosity and make the welds stronger. The deoxidising substances are iron oxide, lamitite, magnetite.
3. **Slag forming substances:** These substances melt and float over the molten metal and protect the hot deposited weld metal from the atmospheric oxygen and nitrogen. Also due to the slag covering, the weld metal is prevented from fast cooling. The slag forming substances are clay, limestone.
4. **Fluxing/cleaning substances:** These substances remove oxides from the edges to be welded and controls the fluidity of the molten metal. The cleaning substances are lime stone, chlorides, fluorides.
5. **Gas forming substances:** These substances form gases which aid the transfer of metal. They also shield the welding arc and weld pool. The substances are: wood flour dextrin and cellulose.
6. **Binding and plasticizing substances:** These sub- stances help the applied coating to grip firmly around the core wire of the electrode.

These are: sodium and potassium silicates.

Purpose or function of flux coating: During welding, with the heat of the arc, the electrode coating melts and performs the following functions.

a It stabilizes the arc.

b It forms a gaseous shield around the arc which protects the molten weld pool from atmospheric contamination.

c It compensates the losses of certain elements which are burnt out during welding.

d It retards the rate of cooling of the deposited metal by covering with slags and improves its mechanical properties.

e It helps to give good appearance to the weld and controls penetration.

f It makes the welding in all positions easy.

g Both AC and DC can be used for the welding.

h Removes oxide, scale etc. and cleans the surfaces to be welded.

i It increases metal deposition rate by melting the additional iron powder available in the flux coating.

4 Types of flux Coating

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

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

c Iron powder (e.g. E7018)

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

5 Method of flux coating:

a Dipping

b 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. This method is used by all the electrode manufacturers.

Coating factor (Fig 6): The ratio of the coating diameter to the core wire diameter is called the coating factor -

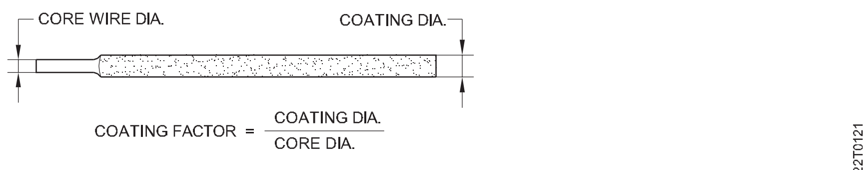
$$= \frac{\text{Coating diameter}}{\text{Coating wire diameter}}$$

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 6



COATING FACTOR

6 Size of electrode

a 1.6mm
b 2.0mm
c 2.5mm
d 3.15mm
e 4.0mm
f 5.0mm
g 6.0mm
h 6.3mm
i 8.0mm
J 10.0mm

Standard length of electrodes: The electrodes are manufactured in two different lengths, 350 or 450mm

Coding of electrode as per BIS and AWS Criteria selection of electrode

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

- explain the necessity of coding electrodes
- describe the electrode coding as per BIS, AWS and BS.

a Coding of electrode as per BIS

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

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

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

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

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

b a letter indicating the type of covering;

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

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

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

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

Example 1

The classification for the electrode EB 5426H1JX

E B 5 4 2 6 H1 J X

- Covered electrode (E)
- Type of covering (Basic) (B)
- Strength characteristics (UTS = 510–610 N/mm2 and YS = 360 N/mm2 min.) (5)
- Elongation and impact properties (Elongation = 20% min. and IMPACT = 27 J min. at – 30°C) (4)
- Welding position (all positions except vertical down) (2)
- Welding current and voltage condition (D + and A 70) (6)
- Hydrogen controlled electrodes (15 ml max.) (H1)
- Increased metal recovery (110 – 129%) (J)
- Radiographic quality electrode (X)

Example 2

The classification for the electrode ER 4211

E R 4 2 1 1

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

b AWS codification of carbon and low alloy steel coated electrodes

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

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

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

The third digit indicates the welding positions.

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

CHART 1

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

Electrode

E

First digit | Second digit | Third digit | Fourth digit

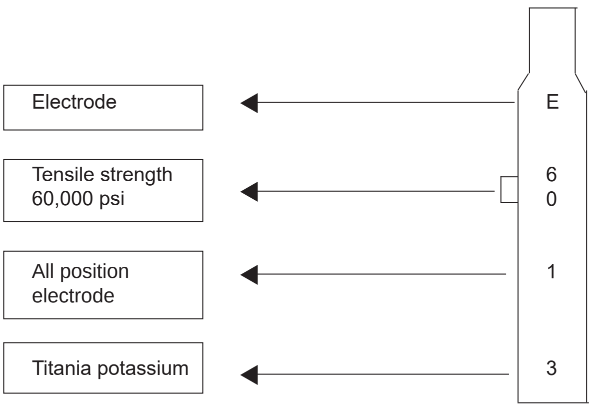
First two digits indicate tensile strength of the deposited weld metal in 1000 PSI

Third digit indicates the welding positions for electrodes.
1 All position
2 Flat & horizontal
3 Flat & down hand

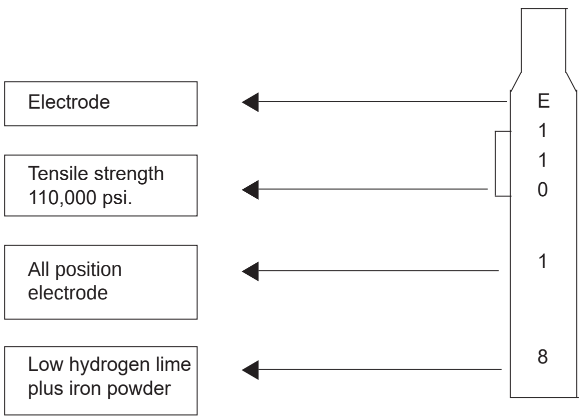
Fourth digit (0 to 8) indicate the type of flux coating.
0 Cellulose sodium, or iron oxide mineral
1 Cellulose potassium
2 Titania sodium
3 Titania potassium
4 Iron powder titania
5 Low hydrogen lime - sodium
6 Low hydrogen lime - potassium
7 Iron oxide plus iron powder
8 Low hydrogen lime plus iron powder
9 A number left over for peculiar coating. This number is rarely used.

FOUR DIGITS CODIFICATION

EXAMPLE : AWS – E 6013.



FIVE DIGITS CODIFICATION



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

Effects of moisture pickup and backing of electrode

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

- explain about special purpose electrodes and their application
- state the necessity of baking a coated electrode
- store and handle the electrode properly for better weld quality.

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

a Keep electrodes in unopened packets in a dry store.

b Place packages on a duckboard or pallet, not directly on the floor.

c Store so that air can circulate around and through the stack.

d Do not allow packages to be in contact with walls or other wet surfaces.

e The temperature of the store should be about 5°C higher than the outside shade temperature to prevent condensation of moisture.

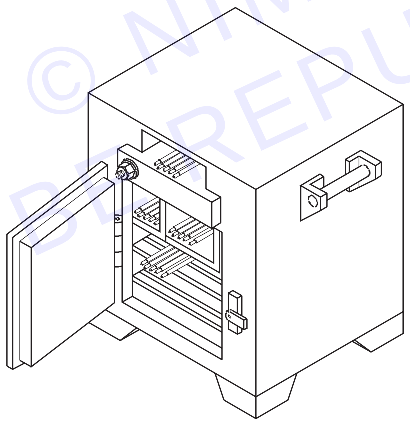
f Free air circulation in the store is as important as heating. Avoid wide fluctuations in the store temperature.

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

a Porosity in the weld

b Cracking in the weld.

Indications of electrodes affected by moisture are:

a White layer on covering.

b Swelling of covering during welding.

c Disintegration of covering during welding.

d Excessive spatter

e 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:

a has rusty stub end.

b has white powder appearance in coating.

c produces porous weld.

Always pick up the right electrode that will provide:

a good arc stability

b smooth weld bead

c fast deposition

d minimum spatters

e maximum weld strength

f easy slag removal.

LESSON 31 & 32 : Brazing - Principal, Types of brazing, Application

Objectives

At the end of this lesson you shall be able to

- describe the method of brazing
- describe the types brazing
- explain the application of brazing.

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

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

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

Brazing is employed where a ductile joints is required.

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

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

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

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

Various methods of brazing

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

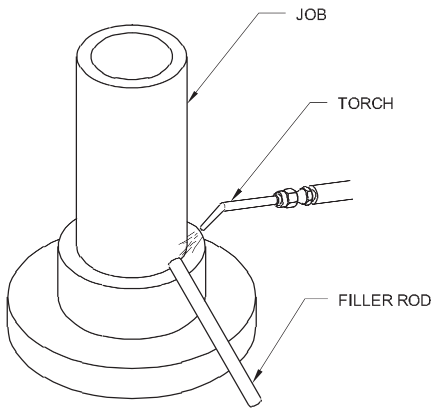
Furnace brazing: The parts to be brazed are aligned with the brazing material placed in the joint. The assembly is kept in the furnace. The temperature is controlled to provide uniform heating. (Fig 2)

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

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

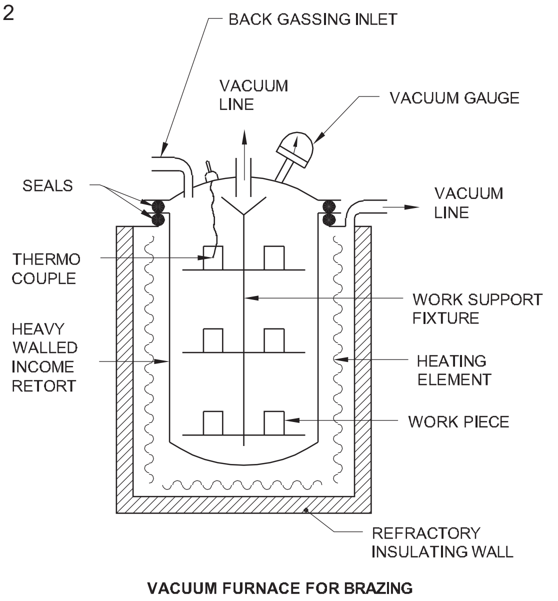
Silver brazing: Silver brazing is also sometimes called silver soldering. It is one of the best methods used to connect/join parts which are to be leak proof and has to give maximum strength of the joint. It is a very useful and easy process for joining copper brass, bronze parts as well as for joining dissimilar metal tubes like copper to stainless steel tubes etc. The melting point of silver brazing alloy filler rods will be around 600 to 800°C which is always less than that of the base metals joined. Fig 5 shows silver brazing of stainless steel tube to be with a copper tube.

Fig 1



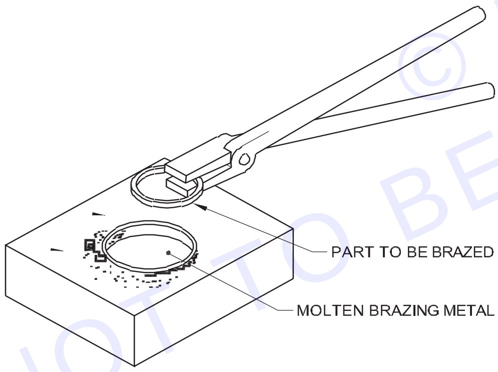
TORCH BRAZING

Fig 2



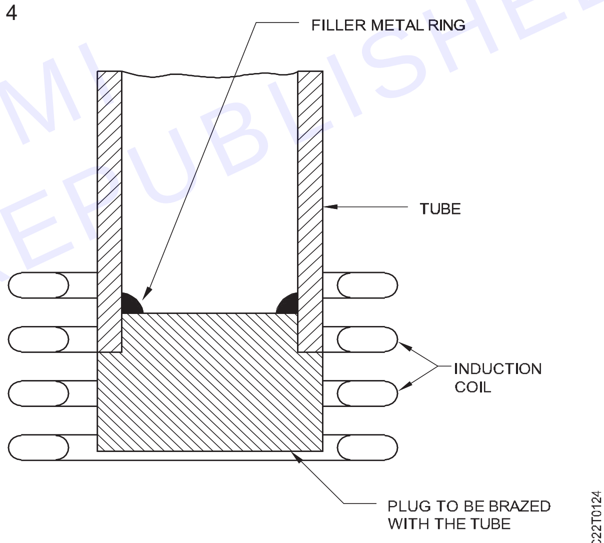
VACUUM FURNACE FOR BRAZING

Fig 3



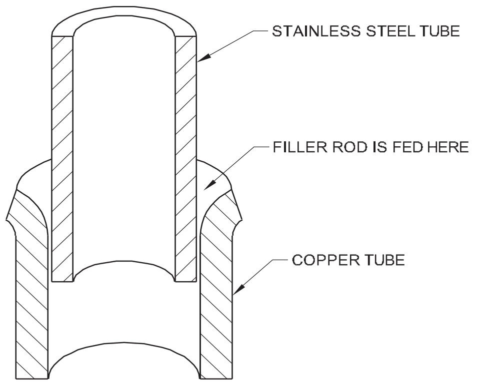
DIP BRAZING PROCESS

Fig 4



INDUCTION BRAZING

Fig 5



SILVER BRAZING OF STAINLESS STEEL TUBE WITH COPPER TUBE

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

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

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

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

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

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

Clean the joint thoroughly to remove all residual flux.

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

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

The American Welding society defines these processes as follows:

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

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

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

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

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

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

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

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

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

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

Brazing filler road and fluxes, necessity of cleaning, brazing parameter, Brazing techniques and cleaning

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

- describe the brazing filler and flux
- describe the brazing parameter
- explain the of brazing techniques and cleaning.

Brazing Filler Rod: Brazing is a process in which a non–ferrous filler alloy metal (copper + zinc) is used for joining and having a melting point above 427°C.

Brazing filler wire melting point is the lower than base metal.

It is melted and made to flow between closely fitted surface by capillary attraction/capillary action.

No direct melting of Base metal (only preheating).

a (non – ferrous alloy metal)

b Brass filler wire - copper + zinc alloy.

c Aluminum + silicon alloy .

d Heat –resisting brazing alloys and

e Silver Brazing filler wire (silver + copper + zinc)

Brazing Flux

The following list of chemical compound includes the most common ingredients of fluxes.

1 Sodium

2 Potassium

3 Lithium

4 Borax, boric

5 Wetting agents

A flux is a chemical compound used in brazing.

Fluxed main work

1 Used to dissolve the oxide on the job and clean the surface.

2 During brazing flux to prevent atmosphere contents–air /Oxidation.

3 Brazing flux formed the slag and cover the bead and prevent the atmosphere contamination and cool the job slowly, Control the temperature.

The common commercial fluxes

a Paste form

b Liquid form

c Powder form

Brazing Techniques: Clean the job and filler wire - free from oxides, oil, grease, dust, paint, moisture by using wire brush. Filling, Grinding and acid cleaning/solvent cleaning/Alkaline cleaning.

1 Fluxing both the base metal and filler metal.

2 Alignment the base meat parts to be joined.

3 Heating the joint by gas flame (high pressure system/low pressure system),use oxidizing flame.

4 Heating the filler wire and deep the flux.

5 Applying brazing filler wire in to joint.

6 Cooling of the brazed joint Slowly.

7 Clean the joint.

LESSON 44 & 45 : Cast iron - Types - Properties and uses, welding methods of cast iron

Objectives

At the end of this lesson you shall be able to

- describe the types of cast iron
- explain the welding method of cast iron
- explain the cast iron filler welding.

Introduction

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.

a Grey cast iron

b White cast iron

c Malleable cast iron

d Nodular cast iron (or) spheroidal graphite iron

a **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.

b **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.

c **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.

d **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.

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.

Method of cleaning

There are two methods used for cleaning cast iron jobs.

a) Mechanical cleaning

b) 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.

Welding methods of cast iron

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 5mm 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 1

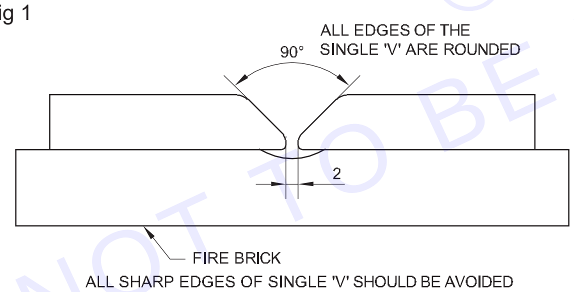


Fig 2

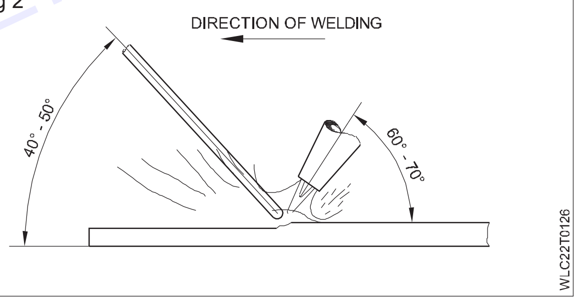


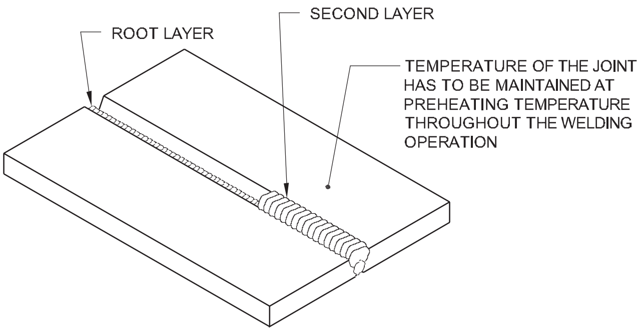
Table 1

Thickness 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

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:

a) 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)

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

c) Welding technique to be used (leftward or rightward).

Table 2

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

MODULE 5 : Pipe Welding

Lesson 33 - 43 : Introduction to pipe welding Difference between plate and pipe 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.

Introduction to pipe welding

Only high quality pipe welds are acceptable in modern industry because the failure of pipe welds due to poor quality will not only disrupt the operation of a plant, it can be the cause of a serious accident with the possible loss of life and property. For this reason, a pipe welder must be thoroughly qualified person in his craft.

To be successful pipe welder and achieve high quality pipe welds, require practice in welding pipe. It cannot be learned by reading a book alone. However if incorrect techniques are repeated, practices alone will never lead to successful pipe welding. A pipe welder must have through knowledge on pipe welding in addition to the skill.

When making the weld, the welder is confronted with the following primary tasks:

1 He must prepare to make the weld.

2 He must concentrate his entire attention on the welding operation.

3 In preparing to make the weld, the welder is concerned with the following matters.

i The type of metal to be welded.

ii The selection of correct welding electrodes.

iii The preparation and cleaning the edge or weld joint.

iv The fit up of the pipes to obtain the correct alignment.

After all of the preparations have been made the welder must

1 Give his completed attention to make the sound weld.

2 He must strike the arc and manipulate the electrode correctly in order to deposit a sound bead.

3 He must watch the, molten puddle and make instantaneous adjustment in his welding technique and

4 He must watch and maintain key hole constantly when welding root bead.

Difference between plate 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.

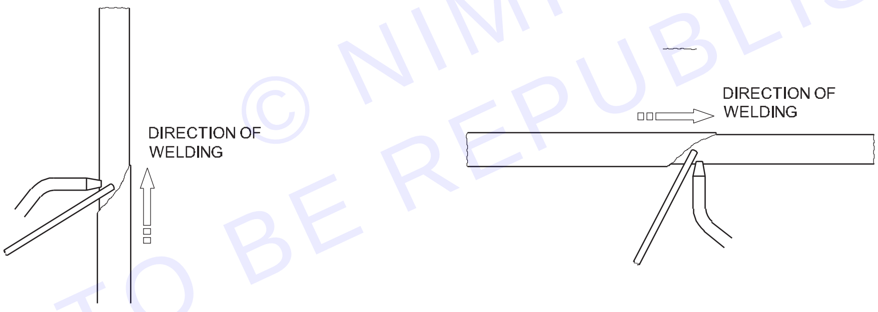
Pipe welding: When welding the circumference of a mild steel pipe, the angles of the rod and the blowpipe are given in relation to the tangent to the pipe at the point of welding.

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



ALL POSITION RIGHTWARD WELD

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
Leftward or rightward	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

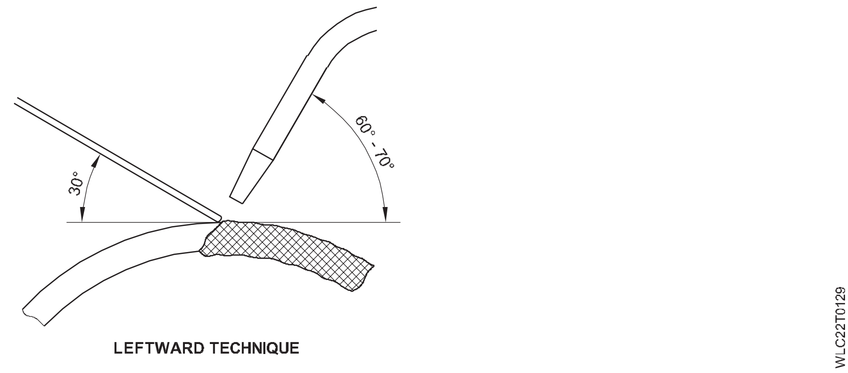
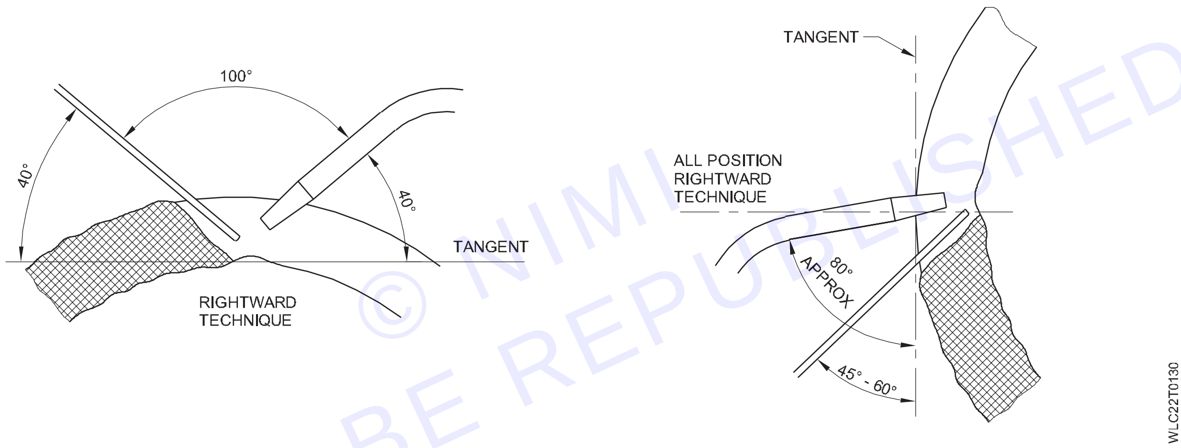


Fig 3

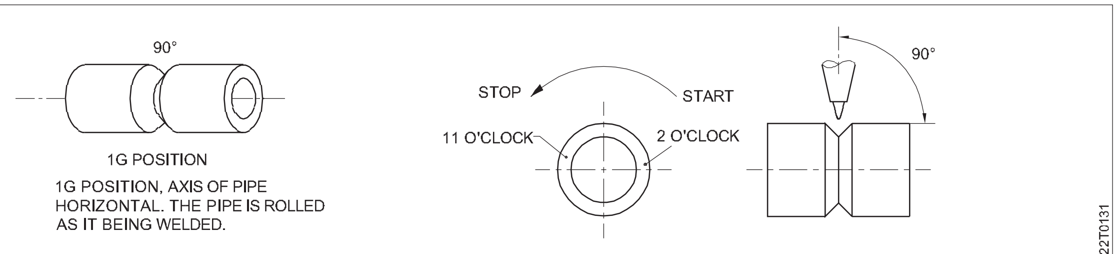


Differences between plate welding and pipe welding:

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.

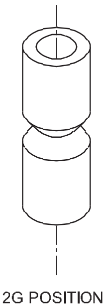
In plate welding, the line of weld is in only one position. In pipe welding, welding can be done in one position when it can be rotated. (Fig 4) Otherwise all-position welding can be done in the pipe when the pipe is in fixed position. (Fig 6) Sometimes the pipe may be in a fixed position and only one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

Fig 4



WELDING PIPE IN THE 1G POSITION

Fig 5



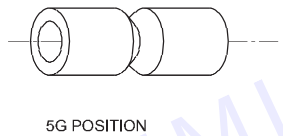
2G POSITION, AXIS OF PIPE VERTICAL

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 HORIZONTAL FIXED AND CANNOT BE ROOLED IN THE WELDING PROCESS.

Topic - Types of pipe and pipe schedule, preparation work before

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

- describe types pipe
- explain pipe schedule.

Introduction

Pipelines play an indispensable role in the oil and gas industry, serving as the backbone for fluid transport. From crude oil to natural gas, pipe infrastructure ensures that these industry essentials are securely conveyed from extraction sites to refineries and, finally, consumers. Each kind of pipe possesses certain qualities making it suitable for specific applications. Following are the 10 different types of pipes used in Oil and Gas Industry.

1 Stainless Steel Pipes

Stainless Steel Pipes are of high use in the oil and gas industry due to their corrosion resistance ability. With the availability of different grades like 304, 310, 316, and 410, they cater to different use cases – for instance, the 316 grade is ideal for high-temperature, high-pressure applications given its enhanced resistivity. Its structural integrity serves in applications like water transport and petroleum industries.

Stainless Steel Pipes 304 pipe

Stainless Steel Pipes 310 pipe

2 Carbon Steel Pipes

Carbon Steel Pipes, with their impressive durability and tensile strength, are perfect for transporting oil and gas within refineries or to consumer endpoints. Grades gauge the percentage of carbon - from low to high carbon steel – affecting flexibility and hardness. Their selection depends on the degree of stress they will endure.

3 Nickel Alloy Pipes

Given the high-temperature operations intrinsic to the oil and gas industry, Nickel Alloy Pipes are the ideal choice. These pipes are resistant to heat and provide corrosion resistance, making them essential for extreme environments. Variants like Inconel, Hastelloy, Monel, and Nitronic offer a range of functionalities for specific applications.

Nickel Alloy 200 Pipes

Inconel 625 pipe

4 Duplex Pipes

Duplex Pipes, a class of stainless steel, are well-suited for applications requiring high strength and good corrosion resistance, ideal for the oil and gas industry's chemical-laden environments. Grades like Duplex 2205 and Super Duplex 2507 are commonly used due to their resilience.

Duplex 2205 pipe

5 PVC Pipes

Lightweight, cost-effective, and easy to install, PVC Pipes are commonly used in oil and gas operations. Offering corrosion resistance and high strength, they prove ideal for low-pressure scenarios and are often used in saltwater disposal, chemical handling, and water flooding.

6 HDPE Pipes

The High-Density Polyethylene (HDPE) Pipes provide excellent resistance to rugged terrains, corrosion, and chemicals – perfect for cross-country pipelines transporting natural gas. Their light weight and ductility make them advantageous for seismic-prone areas.

7 Fiberglass Pipes

Fiberglass Pipes, owing to their lightweight, strength, and flexibility, are used extensively in oil field tubulars and casing for wells. Being resistant to corrosion and demanding less maintenance these pipes are used in application of oil and gas industry.

8 Copper Pipes

The use case for Copper Pipes extends to handling gases like propane and natural gases needing a tight seal. Its corrosion resistance and ability to withstand heat make it a perfect fit for this domain.

9 Polyvinylidene Fluoride (PVDF) Pipes

The high purity application of oil and gas makes the PVDF Pipes a viable option, owing to their resistance to most minerals and aqueous solutions. These pipes also exhibit high abrasion resistance and mechanical strength.

10 Galvanized Pipes

Galvanized Pipes, featuring a protective zinc coating preventing rusting, are effective in transportation of natural gas and other fluids. Once an industry standard, these pipes while still used, are gradually replaced by less corrosive materials.

Pipes used in the Oil and Gas industry have diverse properties as follows:

Pipe Types	Material	Common Uses	Advantages
Stainless Steel	Steel with Chromium	Water Transport, Petroleum Industries	Corrosion Resistance
Carbon Steel	Steel with Carbon	Transport within Refineries	Flexible, Durable
Nickel Alloy	Nickel and Chromium	Extreme Environments	Heat, Corrosion Resistance
Duplex	Stainless Steel	Chemical-Laden Settings	High Strength, Corrosion Resistance
PVC	Vinyl	Saltwater Disposal, Chemical Handling, Water Flooding	Lightweight, Cost-effective

Conclusion

HDPE	Polyethylene	Cross-Country Pipelines	Ductile, Lightweight
Fiberglass	Glass Fiber Reinforced Polymer	Oil Field Tubulars, Well Casing	Lightweight, Flexible
Copper	Copper	Handling Gases	Corrosion Resistance, Heat Withstanding
PVDF	Fluoropolymer	High Purity Applications	High Abrasion Resistance, Mechanical Strength
Galvanized	Zinc Coated Steel	Natural Gas Transportation	Rust Prevention

The material and construction of pipes greatly affect their complexity of usage in the oil and gas industry. While Stainless Steel and Carbon Steel pipes are commons in high-pressure, high-temperature situations, PVC and HDPE cater to lower pressure conditions. Copper and Nickel Alloy pipes prove their worth when heat resistance and tight sealing are required. On the other hand, Fiberglass and PVDF pipes exhibit their strengths in well casings and high purity applications, respectively. Finally, Galvanized pipes, with their rust prevention capabilities, find applications in fluid and gas transportation.

Pipe Schedules

PIPE SCHEDULECHART

STEEL PIPES - PIPE SCHEDULE CHART

NPS inches	N.D.	O.D. mm	10	20	30	STD	40	60	XS	80	100	120	140	160	XXS
1/8	-	10.3	1.24	-	1.45	1.73	1.73	-	2.41	2.41	-	-	-	-	-
1/4	6	13.7	1.65	-	1.85	2.24	2.24	-	3.02	3.02	-	-	-	-	-
3/8	10	17.1	1.65	-	1.85	2.31	2.31	-	3.2	3.2	-	-	-	-	-
1/2	15	21.34	2.11	-	2.41	2.77	2.77	-	3.73	3.73	-	-	-	4.77	7.47
3/4	20	26.67	2.11	-	2.41	2.87	2.87	-	3.91	3.91	-	-	-	5.56	7.82
1	25	33.4	2.77	-	2.90	3.38	3.38	-	4.55	4.55	-	-	-	6.35	9.09
1.1/4	32	42.16	2.77	-	2.97	3.56	3.56	-	4.85	4.85	-	-	-	6.35	9.7
1.1/2	40	48.26	2.77	-	3.18	3.68	3.68	-	5.08	5.08	-	-	-	7.14	10.16
2	50	60.32	2.77	-	3.18	3.91	3.91	-	5.54	5.54	-	-	-	8.74	11.07
2.1/2	65	73.02	3.05	-	4.78	5.16	5.16	-	7.01	7.01	-	-	-	9.52	14.02
3	80	88.9	3.05	-	4.78	5.49	5.49	-	7.62	7.62	-	-	-	11.12	15.24
3.1/2	90	101.6	3.05	-	4.78	5.74	5.74	-	8.08	8.08	-	-	-	-	16.15
4	100	114.3	3.05	-	4.78	6.02	6.02	-	8.56	8.56	-	11.12	-	13.49	17.12
5	125	141.3	3.40	-	-	6.55	6.55	-	9.52	9.52	-	12.7	-	15.87	19.05
6	150	168.3	3.40	-	-	7.11	7.11	-	10.97	10.97	-	14.27	-	18.26	21.95
8	200	219.1	3.76	6.35	7.04	8.18	8.18	10.31	12.7	12.7	15.08	18.26	20.63	23.01	22.22
10	250	273	4.19	6.35	7.80	9.27	9.27	12.7	12.7	15.08	18.26	21.44	25.4	28.57	25.4
12	300	323.9	4.57	6.35	8.38	9.52	10.31	14.27	12.7	17.47	21.44	25.4	28.57	33.32	25.4
14	350	355.6	6.35	7.92	9.53	9.52	11.12	15.09	12.7	19.05	23.82	27.79	31.75	35.71	-
16	400	406.4	6.35	7.92	9.53	9.52	12.7	16.66	12.7	21.44	26.19	30.96	36.52	40.49	-
18	450	457.2	6.35	7.92	11.13	9.52	14.27	19.05	12.7	23.82	29.36	34.92	39.67	45.24	-
20	500	508	6.35	9.53	12.70	9.52	15.08	20.62	12.7	26.19	32.54	38.1	44.45	50.01	-
22	550	558.8	6.35	9.53	12.70	9.52	15.87	22.22	12.7	28.57	34.92	41.27	47.62	53.97	-
24	600	609.6	6.35	9.53	12.70	9.52	17.47	24.61	12.7	30.96	38.89	46.02	52.37	59.54	-
26	650	660.4	7.92	12.70	-	9.52	-	-	12.7	-	-	-	-	-	-
28	700	711.2	7.92	12.70	15.88	9.52	-	-	12.7	-	-	-	-	-	-
30	750	762	7.92	12.70	15.88	9.52	-	-	12.7	-	-	-	-	-	-
32	800	812.8	7.92	12.70	15.88	9.52	17.47	-	12.7	-	-	-	-	-	-
34	850	863.6	7.92	12.70	15.88	9.52	17.47	-	12.7	-	-	-	-	-	-
36	900	914.4	7.92	12.70	15.88	9.52	19.05	-	12.7	-	-	-	-	-	-
40	1000	1016	-	-	-	9.53	-	-	12.7	-	-	-	-	-	-

Basic Pipe Welding Procedures uphill welding Downhill welding and horizontal welding pipe welding position 1G,2G, 5G, 6G

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

- describe the basic pipe welding procedure.
- explain pipe uphill and downhill welding.
- explain the pipe welding position 1G,2G, 5G, 6G.

Basic Pipe Welding Procedures: Before starting to learn pipe welding, a pipe fitter should be proficient in welding in the four basic positions:

Flat, horizontal, vertical and overhead.

All of these positions are used to weld pipes. Since the pipe has a round shape, there is usually a gradual transition from one position to another.

When the pipe is in the 5G position, with its horizontal axis in position on the pipe, it can readily be identified by their likeness to the numbers on the face of a clock.

Pipe axis shall be horizontal and pipe is fixed in horizontal. Rotation of pipe is not possible in 5G fixed position. Welding is to be accomplished in the vertical position. Two different welding procedures are used when the pipe is in the horizontal position: downhill and uphill pipe welding.

Uphill welding: The weld is started from 6 O'clock to 12 O'clock position on the right side first and then again from the 6 O'clock to 12 O'clock position on the left side (Fig 1). This method is called uphill method or vertical up method. This uphill method is used to weld pipes of 5 mm and above wall thickness.

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

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

Fig 1

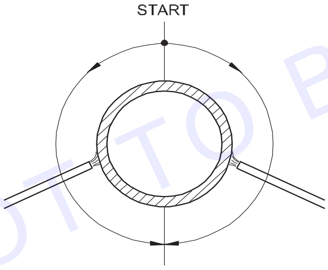
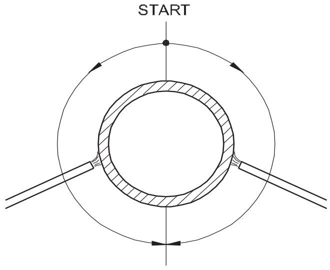
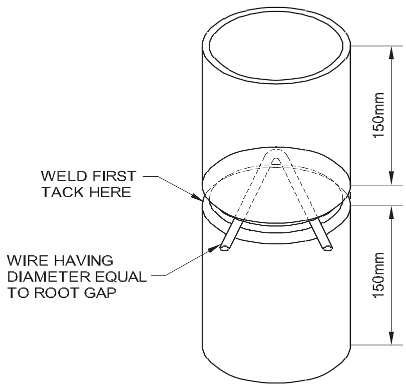


Fig 2



In the 6G position welding is usually done by using one of the methods i.e. uphill or downhill welding. (Fig 3)

Fig 3



USE OF BEND WIRE OF SPACER TO SET ROOT GAP

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

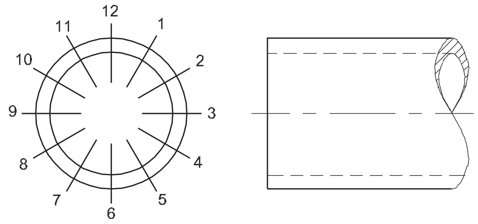
Downhill welding:

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

The top of the pipe is 12 O'clock position and the bottom is in 6 O'clock position. (Fig 4)

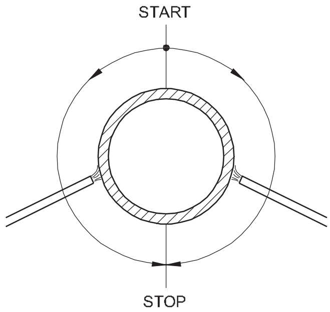
The weld is started from 12 O'clock position to 6 O'clock position on the right side vertically downwards. Then welding is done again from 12 O'clock to 6 O'clock position on the left side (Fig 5). This method is called down hill method and is normally used for thin walled pipes with wall thickness of 3 to 4 mm.

Fig 4



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

Fig 5



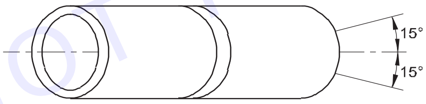
WLC22T0136

horizontal welding Pipe welding position 1G, 2G, 5G & 6G

The different positions used to weld pipe butt joints are named as 1G, 2G, 5G and 6G as shown in Fig 10 to Fig 13. These positions are decided based on the position of the pipe axis and whether the welding is done by rotating the pipe or by keeping the pipe fixed.

But in gas welding only 1G, 2G and 5G position are used. The 6G position welding is done by arc welding and it is usually used to test the skill/ability of a welder in pipe welding.

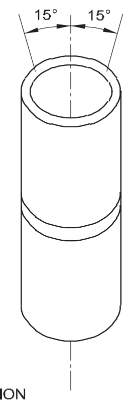
Fig 6



1G POSITION
PIPE HORIZONTAL ROLLED
WELD FLAT (±15°)

ROTATE PIPE AND DEPOSITE WELD AT OR NEAR THE TOP

Fig 7



2G POSITION
PIPE VERTICAL WELD HORIZONTAL (±15°)

PIPE SHALL NOT BE ROTATED DURING WELDING

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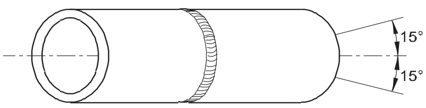
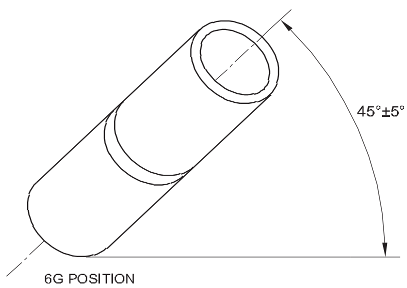
Fig 8



5G POSITION
PIPE HORIZONTAL FIXED (±15°)
WELD FLAT, VERTICAL, OVERHEAD

PIPE SHALL NOT BE ROTATED DURING WELDING

Fig 9



6G POSITION
PIPE INCLINED FIXED (45°±5°)
WELD FLAT, VERTICAL, OVERHEAD

PIPE SHALL NOT BE ROTATED DURING WELDING

WLC22T0138

Procedure for welding heavy wall pipes in 5G & 6G position welding

Welding heavy wall Procedure for pipes in 5G position weld

Welding Technique

Perhaps the most difficult position in which to weld pipe is in the 5G position. Once this is mastered, welding pipe in other positions is less difficult to learn. For this reason, it is best to start by learning how to weld in the 5G position.

Pipe size : OD 168 mm, 7.11 mm thickness

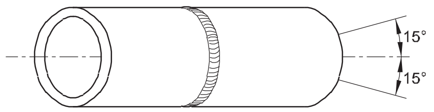
150 mm long - 2 nos.

Electrode : E 6010 - 3.20 mm Welding current : 80 - 110 amperes

Vertical up welding uses lower current and slower travel speed to produce a joint with fewer but heavier beads.

The slower travel speed of vertical-up welding and the high liquid pool melts out gas holes more effectively than vertical down welding (Fig 1)

Fig 1

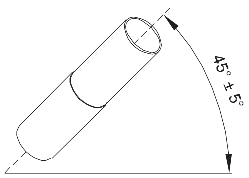


Pipe Clamps: One difficulty encountered in assembling pipe to be fabricated / installed, is the positioning of the pipe before tacking. External line up clamps are made to hold virtually any type of pipe joint. The use of clamps to secure proper alignment is highly recommended. The pipe joint should be clamped using the external line up clamp.

Welding in 6G position

6G position welding introduction: 6G is a welding position to which a welder / welding procedure is qualified to perform circumferential pipe (or tubular structure) weld with the pipe fixed and oriented on approximately 45° angle inclination. (Fig 2)

Fig 2



The letter "G" in "6G stands for the type of butt weld, called "groove weld" (another type of weld with letter "F" stands for "fillet weld") and the number :6 designates the position of the pipes welded. A groove weld is a joint in two metal pipes with joining edges prepared with angle bevel and the joining space in between them is deposited with the welding material.

In the 6G welding position, the pipes aligned with slopes at approximately 45° inclination from the horizontal from the horizontal (X) axis 45° from the vertical (Y) axis. The pipe is in a fixed position, so the welder must move around the pipe to perform the welding circumferentially. This is a difficult welding position involving horizontal, vertical and overhead position welding in a single joint welding that requires a great skill, competency, experience and technical expertise as the pipe / structure us immovable / rotatable.

So welder has to weld the test piece in that position to get qualification. Normally, the pipes are edge prepared with land (root face/weld face at the butt joint root) between 2mm and 3mm and joined with a 2 to 3mm root gap with proper alignment. The welder can use approximately 80 amps to start on a tack weld without sticking.

Note for knowledge purpose only: Another restricted weld position called as "6GR" in which the letter "R" indicated that 6G positioned test coupon fitted with a restriction ring to restrict the welding holder movement / position. 6GR position qualification is mandatory for welder / procedure qualification of TKY joints in tubular structural construction. The difference with the 6G and 6GR position is the restriction ring. 6GR position is applicable only for welding tubular structures and not for process / power or oil and gas piping.

Equipment and consumables requirement: Welding machine, grinding machine with grinding disc., welding consumables (electrode in case of SMAW and "filler metal & shielding gas normally argon" in case of TIG (also called as GTAW process) welding, try square / right angle, measuring tape / scale, chipping chisel, wire brush, PPE including welding helmet.

Work instruction

1 Always comply to work instruction and relevant welding procedure specification (WPS) and all safety requirements;

2 Verify based metal type and grade supplied as per WPS;

3 Verify consumable supplied as specified in WPS;

4 Check SMAW/TIG welding equipment and accessories functionality;

5 Cut the pipe and perform edge preparation of the pipe as per specification; normally, 32 to 38° for 6" MB pipe with sch 60 or sch 80 thickness pipes. Edges shall be prepared as per WPS; normally with 2 to 3mm root face and 2 to 3mm root gap.

6 Grind the edges to get smooth surface and clean & remove the mill scale up to 25mm from the joining edges of the pipe.

7 Perform pipe to pipe butt joint the fit-up duly maintaining the specified root face root gap as per WPS. Pipe edges misalignment shall not exceed 1.5mm.

8 Preheating is not required if atmospheric temperature is above 20°C. If WPS required preheat, joint shall be preheated to the specified temperature using propane gas with rose bud torch. Otherwise, small warm up heat (about 50°C) is enough; but not mandatory unless required by WPS.

9 Welding electrodes / Filler metal specification and grade will wary with respect to base material quality / specification. Approved WPS shall be referred. Normally, E 6013 / E 7018 for low carbon steel base metal welding with SMAW process and ER 70 - S2 / S6 series for GTAW weld process.

10 Tack welding can be performed; but preformed; but preferred bridge tacking.

11 Whenever you start and stop pipe welding, always do so no the side wall - never in the root gap. Start the arc, wait for the weld pool to form, then slowly and gently move across the open root to the other side. Slowly zigzag your way along the open root for the first section of the pipe until you have to change your position.

12 Inter pass temperature shall not exceed the limit specified in the WPS (normally, interpass temperature will be 250°C maximum for carbon steel base metal.

13 Think of the pipe in terms of a clock face, and divide it up into sections. Start at the 12 0' clock position, and work round to 3 0'clock then stop and make sure you're comfortable and prepared for the next section, and repeat this process until you've completed the entire weld.

14 Stagger these welding start and stop points for each weld layer rather than keeping them all at the same point around the pipe.

15 Perform and complete SMAW / GTAW welding process welding as per the WPS with appropriate current, voltage, travel speed for the respective electrode filler meta sixes and respective weld passes (root, hot, intermittent and fill passes) within the permissible heat input limitation as specified in the WPS for the respective weld passes as per WPS.

16 In case of TIG / GTAW welding, shielding gas flow rate shall be maintained as per WPS.

17 Ensure that welding is performed with proper fusion and penetration. Excess penetration more than 1.5mm shall be avoided.

18 Similarly welding shall be completed without excess weld reinforcement (In general - 2mm maximum weld reinforcement.) At the same time welding shall not be under-flush with pipe base-metal surface.

19 Perform visual inspection and sent for necessary NDT and mechanical testing (destructive test).

20 Mechanical testing for welder performance qualification will be normally - Bend test (root bend & face bend or side bend and number of bends, depending on applicable codes / standard requirements.)

21 The order, location / position of mechanical test specimen cutting and removal shall be as per applicable specification, code or governing standard.

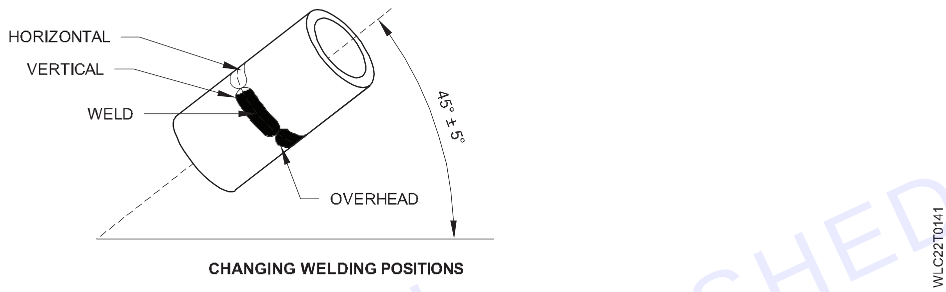
22 Bend testing shall be performed with required radius of bend (normally bend radius - 2 times the specimen thickness.)

23 Some standards require only NDT (normally visual and radiography testing) for welder performance qualification. Some specification requires only mechanical testing (bend test). Some customer require both NDT and mechanical testing.

6G position arrangement

Welders performing the 6G qualification testing, will weld in all positions including horizontal, vertical and overhead. Hence, if a welder pass 6G test, he will automatically qualifies for welding in all position. (Fig 3)

Fig 3



CHANGING WELDING POSITIONS

Importance of pre-heating, post- heating and maintenance of inter pass temperature, use of temperature indicating crayons

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

- describe the important of pre-heating and post heating.
- explain the inter pass temperature.
- explain the indicating CRAYONS.

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

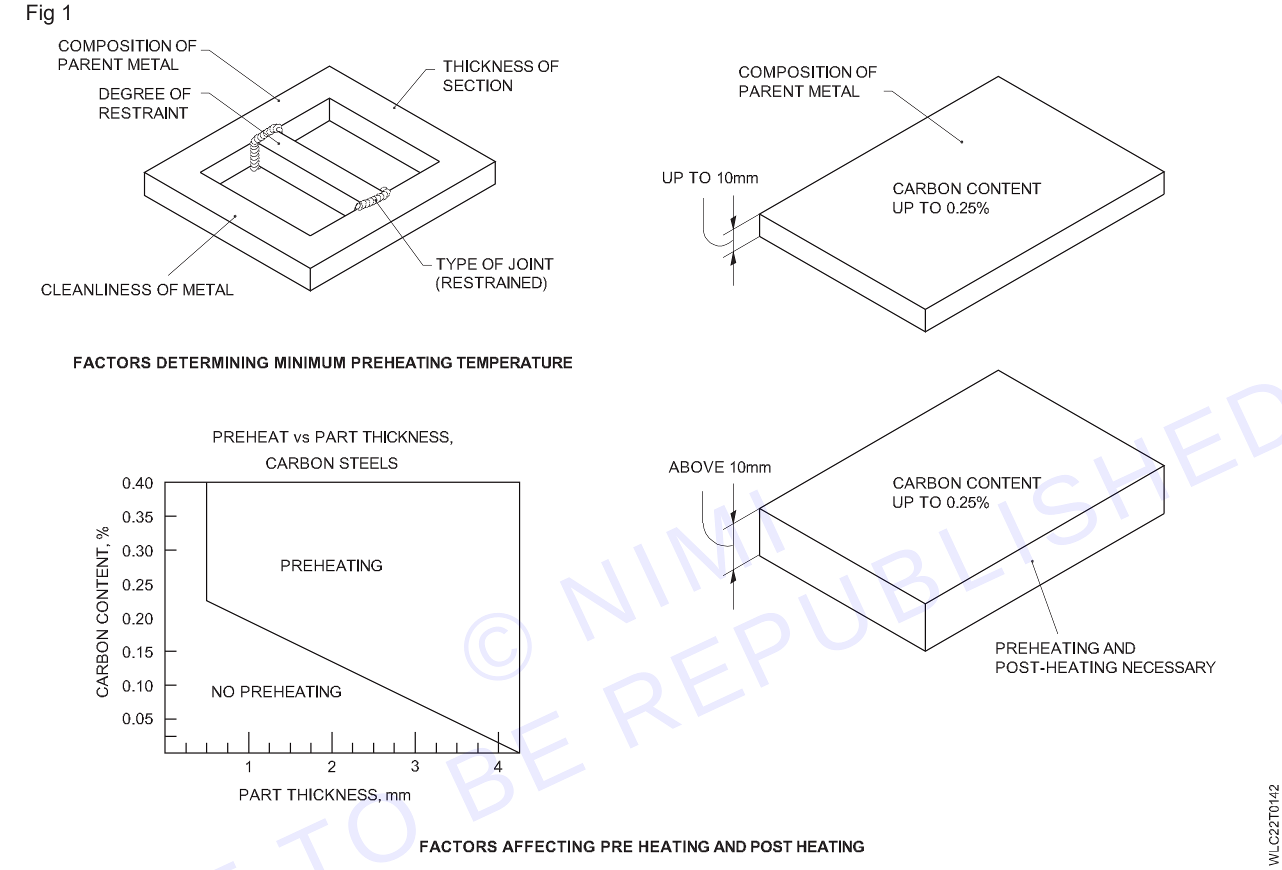
Preheating of various Metals

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)

Fig 1



a Type of metal

b Composition and properties of the parent metal

c Thickness of the plate

d Type of joint

e Degree of restraint of the joint

f Rate of heat input.

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

The preheating temperature can be checked by temperature indicating crayons. (Fig 2)

If the job and area to be preheated are large, then it is done in a preheating furnace (Fig 3).

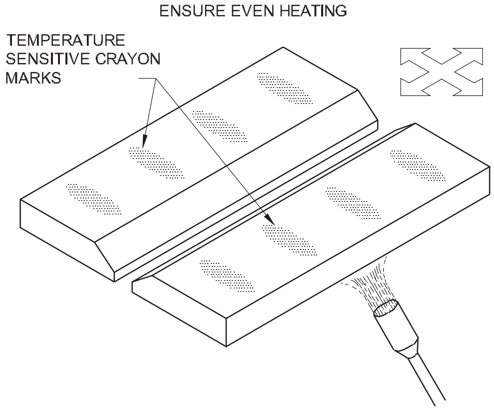
If it is small localised preheating is applied to the joint area only. This is called local preheating. (Fig 4)

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:

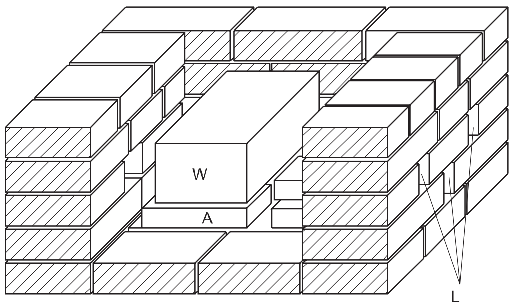
a the rate of heating

Fig 2



PREHEAT PLATES TO 200°C USING TORCH OR FURNACE AND USE OF CRAYONS

Fig 3



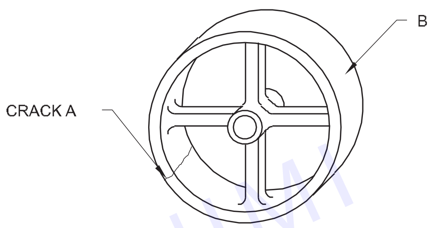
A - SUPPORTING BRICKS, W - WELDED JOB, L - AIR VENTS

TEMPORARY BRICK FURNACE FOR REPAIR WORK

WLC22T0143

Fig 4

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



TECHNIQUE OF LOCAL PREHEATING

WLC22T0144

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

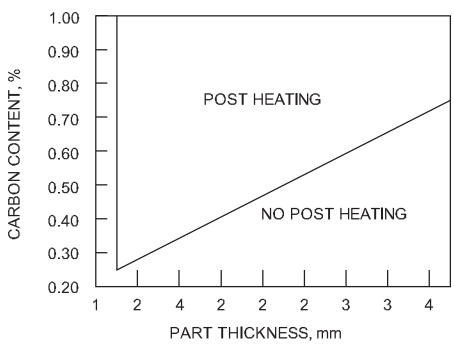
c holding time in the furnace

d 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

NEED FOR POSTHEAT vs PART THICKNESS
CARBON STEELS



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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 brittle- ness 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-relieve

TABLE 2

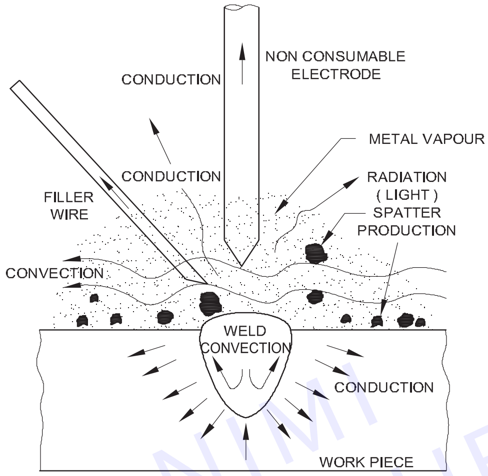
Preheating temperatures for plain and alloy steels

	Approximate composition (percentage)			**Recommended preheating temperature**	
	% Carbon			**°C**	**°F**
PLAIN CARBON STEELS Plain carbon Plain carbon Plain carbon Plain carbon	C Below 0.20 0.20 to 0.30 0.30 to 0.45 0.45 to 0.80			Up to 95 95 to 150 150 to 280 260 to 425	Up to 200 200 to 300 300 to 500 500 to 800
CARBON MOLYBDENUM STEELS Carbon molybdenum Carbon molybdenum Carbon molybdenum	C 0.10 to 0 .20 0.20 to 0.30 0.30 to 0.35	Mo 0.50 0.50 0.50		150 to 260 200 to 315 260 to 425	300 to 500 400 to 600 500 to 800
MANGANESE STEELS Silicon structural Medium manganese SAE T 1330 SAE T 1340 SAE T 1350 12% Manganese	C 0.35 0.20 to0 .25 0.30 0.40 0.50	Mn 0.80 1.0 to 1.75 1.75 1.75 1.75 1.25	Si 0.25	150 to 260 150 to 260 200 to 425 260 to 425 315 to 480 Usually not required	600 to 900 Usually not required
NICKEL STEELS SAE 2015 SAE 2115 2"% Nickel SAE 2315 SAE 2320 SAE 2330 0SAW 2340	C 0.10 to 0.20 0.10 to 0.20 0.10 to 0.20 0.15 0.20 0.30 0.40	Ni 0.50 1.50 2.50 3.50 3.50 3.50 3.50		Up to 150 95 to 150 95 to 200 95 to 260 95 to 260 150 to 315 200 to 370	Up to 300 200 to 300 200 to 400 200 to 500 200 to 500 300 to 600 400 to 700
LOW CHROME MOLYBDENUM STEELS 2% Cr. "% Mo 2% Cr. "% Mo 2% Cr. 1% Mo 2% Cr. 1% Mo	C Up to .15 0.15 to 0.25 Up to 0.15 0.15 to 0.25	Cr 2.0 2.0 2.0 2.0	Mo 0.5 0.5 1.0 1.0	0 C 200 to 315 260 to 425 260 to 370 315 to 425	0 F 400 to 600 500 to 800 500 to 700 600 to 800
MEDIUM CHROME MOLYBDENUM STEELS 5% Cr. "% Mo 5% Cr. "% Mo 8% Cr. 1% Mo	C Up to 0.15 0.15 to 0.25 0.15 Max.	Cr 5.0 5.0 8.0	Mo 0.5 0.5 1.0	260 to 425 315 to 480 315 to 480	500 to 800 600 to 900 600 to 900
PLAIN HIGH CHROMIUM STEELS 12 to 14% Cr TYPE 410 16 to 18% Cr TYPE 430 23 to 30% Cr TYPE 446	C 0.10 0.10 0.10	Cr 13.0 17.0 26.0		150 to 260 150 to 260 150 to 260	300 to 500 300 to 500 300 to 500

Maintenance of Inter pass temperature:

Introduction: During welding, the parent metal is heated to melting point and after that it is allowed to cool rapidly. The adjacent portion to the welded zone is also heated by to a lower temperature. This causes certain phase transformations and on rapid cooling, due to heat transfer through the colder portion of parent metal and atmosphere, the materials hardness and hence mechanical properties are also affected. The width of parent metal that is affected due to the above cycle is called 'Heat Affected Zone'. It is quite clear that the hardness depends on rate of cooling. Higher the cooling higher will be the hardness. In order to control the cooling rate pre-heating and interpass temperature controls are adopted. In order to relieve the welding induced stresses and to achieve better metallurgical structure to meet service conditions, post - weld heat treatment is followed. Heat input: The energy supplied by the welding arc in a fusion welding process is called arc energy and is calculated from current voltage and welding speed. However all the arc energy is not utilized for welding; some of it is invariably lost as shown in Fig 6.

Fig 6



LOSS OF ARC ENERGY

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

The heat input of a single pass weld is calculated by multiplying the efficiency of the welding process and arc energy. Therefore heat input at best can serve as a rough guide to the amount of heat supplied to the workpiece. Temperature changes in welding: Heat moves from one area to another whenever there is a difference in temperature. Just as water flows downhill, so that flows down the temperature hill, warning cold objects at the expense of warmer ones. When the source is moved away, the heat in the weld is conducted outward into the plate. The temperature of the weld has fallen, while the plate temperature near the weld is rising. The weld has cooled still further and the plate temperature is still rising. The metal reaches a maximum temperature less than the melting point of the weld metal, and cooling sets in.

Use of temperature indicating CRAYONS

Although there are many other uses for measuring high temperatures, it's critical to get accurate temperature readings during the preheat stage of welding.

Whether you are using TIG (GTAW) welding, automatic welding or gas metal arc welding (MIG), many base materials, like certain Quench and Tempered Steels, require you to raise the temperature in order to prevent hardness in the heat affected zone and prevent hydrogen assisted cold cracking in joints of larger thicknesses. With Q&T materials the maximum inter pass temperature must be monitored to ensure it is not over-tempered (softened) this is result in loss of tensile strength. Otherwise, your welding joint may not have the required mechanical properties.

There are other critical factors to achieving mechanical properties, such as the consumable electrode type. Thermo crayons, however, are designed to help with temperatures indication and can be purchased for a specific temperature. Normally you need a series of temperatures 50C, 75C and 100C. The temperature you need depends on the base material type, thickness, welding process, and consumables.

They mark almost any base material, from steel, brass and aluminium. This temperature indication technology is clearly useful when welding.

Discover some of the pros and cons and determine for yourself whether thermo crayons are outdated or still useful for modern welding.

Advantages of Thermo Crayons

There are a number of positive benefits to using thermo crayons instead of other temperature reading alternatives.

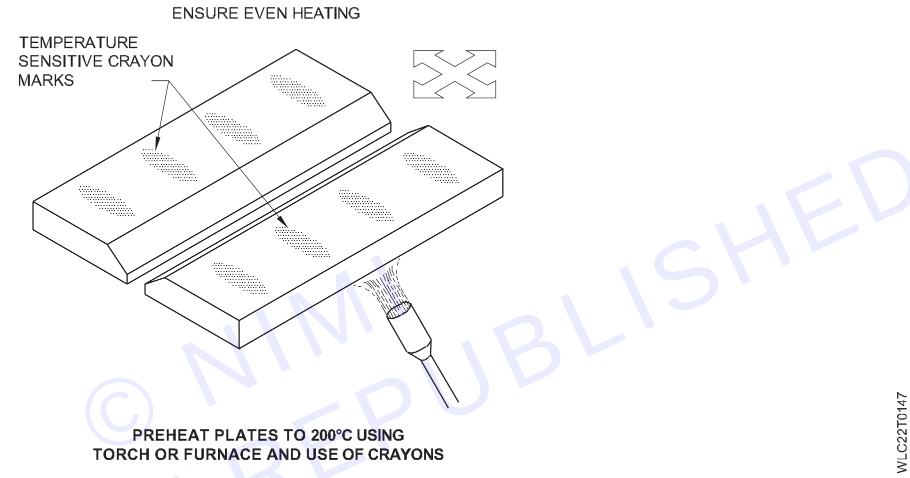
Some of the advantages of using a thermo crayon include:

Affordable: Premium digital thermometers can easily cost up to ten times the amount of a thermo crayon. If you are looking for a cost-effective way to reach a set temperature point, thermo crayons are the most affordable option.

Hands-Free: Simply make a mark and begin heating the material. Because you don't have to constantly hold a thermometer to the material, you'll be able to work on another project or use both hands to operate a heating torch while you heat the project.

Accurate: Thermo crayons are typically rated to be accurate within 3 degrees Celsius.

Fig 7



Welding symbols as per BIS & AWS. Reading of assembly drawing

Objectives ; At the end of this lesson you shall be able to
- describe the welding elementary symbols
- explain the reference line, arrow-head
- explain the welding symbols.

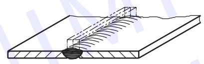
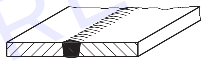
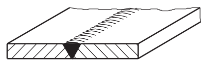
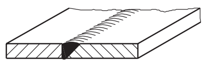
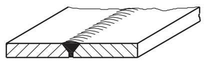
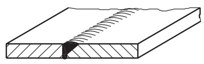
Necessity: For conveying the information required for welding for designers and welders, standard symbols are used. The symbols described below provide the means of placing on drawing the information concerning type, size, location of weldment.

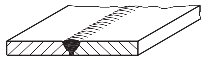
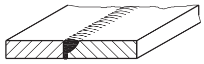
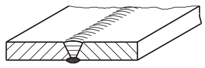
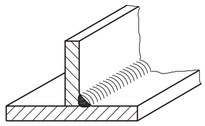
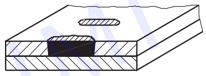
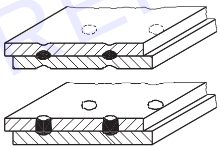
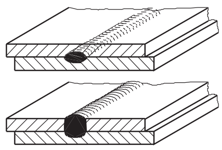
Elementary symbols (As per IS 813 - 1986): The various categories of welds are characterized by a symbol which in general is similar to the shape of the weld to be made. (Table 1)

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

TABLE 1

Elementary symbols

Sl.No	Designation	Illustration	Symbol No
1	Butt weld between plates with raised edges (the raised edges being melted down completely)		
2	Square butt weld		
3	Single V butt weld		
4	Single bevel butt weld		
5	Single V butt weld with broad root face		
6	Single bevel butt weld with broad root face		

7	Single U butt weld (Parallel or sloping sides)		
8	Single J butt weld		
9	Backing run; back or backing weld		
10	Fillet weld		
11	Plug weld; Plug or slot weld/USA		
12	Spot weld		
13	Seam weld		

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

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

1 Reference line

2 Arrow

3 Welding elementary symbols

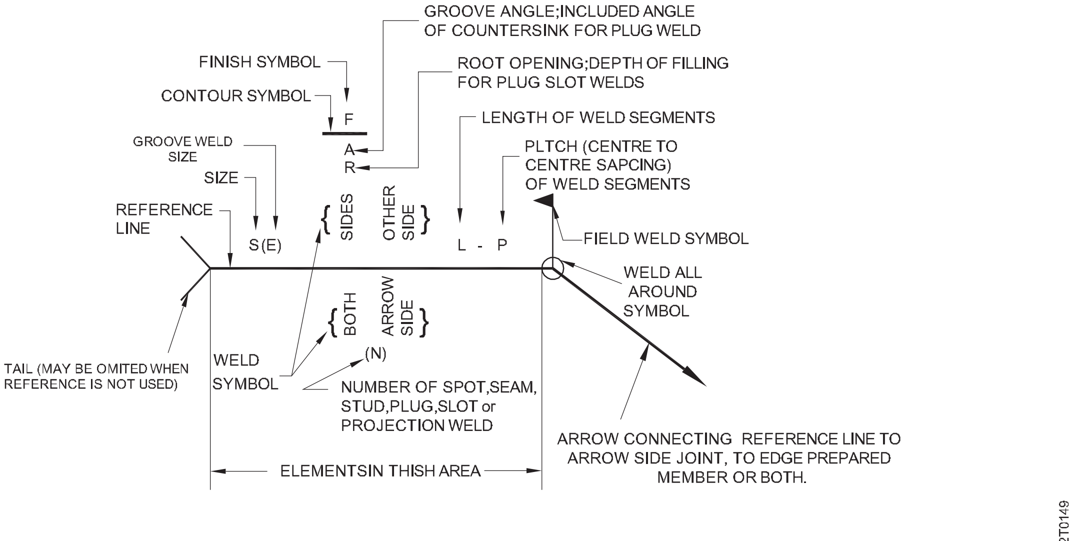
4 Dimensions and other details

5 Supplementary symbols

6 Finish symbols

7 Tail (Specification, process)

Fig 1



STANDARD LOCATION OF ELEMENTS OF A WELDING SYMBOL

Lesson 46 - 48 : Requirement for qualification in different codes Qualification procedure under various codes Different tests and inspection involved in qualification Pressure welding codes and standards (IBR, ASME etc.) Writing procedure for WPS and PQRs

Objectives

At the end of this lesson you shall be able to

- describe the welding, qualification and code
- explain the welder performance qualification
- explain the weld procedure specification.

Welding procedure, Performance, Qualification and codes

Introduction

Code' is any set of standards set forth and enforced by a local government for the protection of public safety, health etc.. as in the structural safety of building, (building code) health requirements for plumbing, ventilation etc.... (Sanitary or health code) and the specifications for fire escapes or exits (Fire code) 'Standard' is defined as 'something considered by an authority or by general consent as a basis of comparison, an approved model'. As a practical matter, codes tell the user what to do and when and under what circumstances to do it. Codes often legal requirements that are adopted by local jurisdictions that then enforce their provisions. Standards tell the user how to do it and are usually regarded only as recommendations that do not have the force of law. The uses of welding in Engineering Industries are Boilers, Heat Exchangers, Pressure Vessels, Bridges, Ships, Pipelines, Reactors, Storage tanks, Construction Structures and Equipment etc. When a design engineers designs a welding structure, the function of production & Quality control personnel is to translate that design in to a real component. From a design point of view properties of the weld joint are designed as-

1 Physical soundness (free from discontinuities)

2 Related Theory for Exercise 2.6.06 Metallurgical compatibility (Chemistry of weldment, base metal, gas etc.)

3 Mechanical Properties The welding Procedure Specification (WPS) is written exactly to translate these property requirements on to relevant welding variables.

The procedure has to be testified on a test piece for its intended performance by a qualified welder. To draw a correct weld procedure, performance methods and qualification criteria, there are popular codes and standards are available. All the codes specifies the rules for the preparation of welding procedures specification and the qualification of welding procedures, welders and welding operators. This code specifies the rules for all manual and machine welding processes. Reading of Welding Procedure specifications (WPS) & Reading of Procedure Qualification Record (PQR) Government as well as private organizations develop and issue standards that apply to a particular area of interest. Many standards with regard to the welding industry are prepared by the American Welding Society (AWS). Many countries have their own national standards on the subject of welding. The following are examples of the various standards, and the bodies responsible for them.

There is also the International Organization for Standardization (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.

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

Weld procedure specification: A WPS is deemed to have been qualified if through tests that are conducted on the weld test coupon meeting the requirements or the acceptance criteria. Acceptance criteria and the specification format may vary depending on the code of design and manufacture. The tests that are carried out on the weld test coupon are destructive tests, and they help to evaluate the mechanical properties of the weldment carried out in accordance with WPS. The results of this qualification are generally recorded in a format and these are generally recorded in a particular format and this is usually referred to as an Procedure Qualification Record (PQR). Thus for every WPS there has to be at least ONE PQR and vice versa. A performance qualification is generally done to evaluate the performance of a welder on a welding operator. It is done to evaluate the ability of a welder or operator to perform consistently and deliver sound and good quality welds. As this is done to a WPS which has already been qualified most codes of practice generally permit the evaluation to be done by the use of non destructive tests viz, radiography. Welders and operators who fulfill the requirements are deemed to be certified for welding to the specific WPS/WPSs.

ASME sections IX, AWS B2.1, API 1104 are some of the popular American codes specifying welding procedures and welder performance qualification. BS 2633, BS 4870/4871, BS 4872, DIN 8560, AD Merkblatt HP 2 and HP 3, eN 288-2 and EN 287-1 are some of the European standards for welding procedures and performance qualification.

IBR chapter 13, IS 2825, IS 7307, IS 7310, IS 7318 are the major Indian codes on welding qualifications.

Weld procedure specifications, variables and logic for requalification

A WPS (Weld Procedure Specification) is a document which lists out all the essential characteristics for performing a weld. For purposes of qualifying for the WPS, a test coupon is welded adhering to all parameters as stated/ listed in the WPS. A WPS is valid only when supported by a relevant PQR.

The characteristics listed in the WPS, those in this chapter, are otherwise known as variable. As the term signifies, these characteristics may be changed or varied. When these "variables" are changed we have a new WPS. Whenever a change in a particular "variable" is bound to influence the mechanical properties of the weld, then that "variable" is termed as an ESSENTIAL variable. The variable which do not have any impact on the mechanical properties of the weld are generally termed as NON-ESSENTIAL variables. However, under certain conditions, some of the variables could influence the mechanical properties of the weld. Such variables are termed as supplementary essential variables. A more detailed treatment of these is made in the code of manufacture and the same could be referred to.

Similarly those variable that have an influence on the welder's ability to produce sound welds are referred to as essential variables for purposes of Welder Performance Qualification. An example that comes to one's mind right way would be the position in which a weld is made.

Introduction to ASME Sec.IX: Welding procedure and performance qualification Section IX of the ASME code specifies the rules for the preparation of welding procedure specification and the qualification of welding procedures, welders and welding operators. This code specifies the rules for all manual and machine welding processes.

Materials: All the materials that can be used for pressure vessel manufacture have been grouped (Table 1) under different 'P' numbers. The object of grouping the base materials is to reduce the number of qualifications required. The 'P' numbers grouping of materials is based essentially on comparable metal characteristics such as composition, weld ability and mechanical properties.

Table 1

'P' Number grouping

P1 to P11	Steel and steel alloy
P21 to P30	Aluminum and aluminum based alloys
P31 to P35	Copper and copper based alloys
P43 to P47	Nickel and nickel based alloys
P51 to P52	Titanium and titanium based alloys.

Filler metals: The filler metals are grouped as both "F" numbers and "A" numbers.

"F" numbers All the electrodes and filler metals are grouped under different "F" numbers. The object of the "F" number grouping (Table 2) is to reduce the number of welding procedures and performance qualifications.

Table 2

"F" Number grouping

F1 to F6	Steel and steel alloys
F21 to F24	Aluminum and aluminum based alloys
F31 to F 37	Copper and copper based alloys
F41 to F45	Nickel and nickel based alloys
F51	Titanium and titanium alloys
F61	Zirconium and zirconium alloys
F71 to F72	Hard facing weld metal overlay.

The "F" number grouping is based essentially on their usability characteristics, with respect to coating. This fundamentally determines the ability of the welder to make a satisfactory weld with a given filler metal. For example, the low hydrogen electrodes have been grouped under "F" Number 4 and rutile steel electrode4s under "F" Number 2.

Obviously, a welder who is able to produce a sound weld with a E6013 (rutile) electrode may not be able to produce a sound weld with a low hydrogen lime powder coated electrode. The skill required to use these electrodes is definitely not the same. "F" Number 1 is thus the easiest (iron powder) electrode used only in downhand fillet/butt and horizontal fillet positions.

'A' Numbers: A part from classifying the filler metals under "F" numbers, they are again classified under 'A' number as shown in Table 3. 'A' number classification of the filler metals is based on the weld metal chemical analysis whereas the 'F; number classification is based on the usability, or rather operation characteristics. With these definitions of 'P' numbers and 'A' numbers, we shall now see what the code says regarding welding procedures and welders qualification.

Table 3

'A' number grouping

A 1	Mild steel
A 2	Carbon - Molybdenum
A 3 to A 5	Chrome - Molybdenum
A 6	Chrome - Martensitic
A 7	Chrome - Ferritic
A 8 to A 9	Chrome - Nickel
A 10	Nickel - 4%
A 11	Manganese-Molybdenum
A12	Nickel chrome-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, inter pass 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 inter pass cleaning, back gouging, single or multiple passes, root grinding etc., shall be written here. The test welding can be done either in a plate or pipe material and in any position. The maximum thickness for which the procedure is applicable is generally twice the thickness of the test plate or pipe. The welder who welds the test joint is also qualified for that procedure but only in that position in which he welds whereas the procedure is applicable to all positions. The results of the tests shall be recorded in the PQR including welding, NDT and mechanical test results.

Welder's qualification: The purpose of the welder's qualification is to determine the ability of the welder to make sound welds.

The welder may be qualified, based on the results of the mechanical test (two face bends and two root bend tests or four side bend tests) or by radiographic examination of a minimum length of 150 mm for a plate or the entire weld for a pipe. The position of the weld joint has been classified as 1G, 2G, 3G, 4G, 5G and 6G. Table 4 shows the positions qualifying for other positions.

Table 4

Range of positions qualified

Test position	Also qualifies
1G	1G
2G	1G
3G	1G
4G	1G & 3G
5G	1G & 3G
2G & 5G	All positions
6G	All positions

For positions 1G and 2G (flat and horizontal) qualification on a plate shall also qualify the welder in pipes. For all other positions, qualification on a pipe shall qualify for plate but not vice versa.

A qualification in a plate or pipe butt joint shall also qualify the welder for fillet welding in all plate thickness and pipe diameters.

Lesson 49 - 60 : Safety precautions pertaining to GTAW & GMAW

Objectives

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

- safety precautions in GTAW
- explain the welding environment safety rules
- explain the safety precaution in GMAW.

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

a never install fuses higher than specified

b always ground/earth the welding machine properly

c install electrical components as per the codes given by the electricity boards

d ensure electrical connections are tight

e never open a welding machine when it is operating

f lock primary voltage switches, open and remove fuses when working on electrical components inside the machine

g 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.

h keep the welding power supply dry

i keep the power cable, ground cable and torch dry

j do not weld in damp area. If you must, wear rubber boots and gloves

k make sure the ground clamp is securely attached to the power supply and the work piece

l high frequency components in some GTAW ma- chines 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 ampere- age 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, colorless 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 atmosphere that does not contain at least 18 % oxygen can cause dizziness, unconscious- ness 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.

Welding environment safety rules

a keep the welding area clean

b keep combustibles out of the weld area

c maintain good ventilation in the weld area

d repair or replace damaged power cables

e make sure the part to be welded is securely grounded/ earthed

f welding helmets should have no light leaks. Should not have scratches or cracks

g use the proper colored lens with correct shade number in the helmet

h wear safety glasses when grinding

i do not see the arc with bare eyes

j use safety screens or shields to protect your area

k wear proper clothing. Your entire body should be covered to protect you from arc radiation

l when welding on cadmium coated steels, copper or beryllium copper use special ventilation to remove fumes from the weld area.

Safety in GMAW:

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 galvanized 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

a keep the welding area clean

b keep combustibles out of the weld area

c maintain good ventilation in the weld area

d repair or replace damaged power cables

e make sure the part to be welded is securely grounded/ earthed

f welding helmets should have no light leaks. Should not have scratches or cracks

g use the proper coloured lens with correct shade number in the helmet

h wear safety glasses when grinding

i do not see the arc with bare eyes

j use safety screens or shields to protect your area

h wear proper clothing. Your entire body should be covered to protect you from arc radiation

Introduction to CO_2 welding - equipments - accessories, Description of CO_2 welding set with diagram

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

- describe the CO_2 welding power source
- explain the CO_2 welding CO_2 wire feeder
- explain the CO_2 welding gun.

Introduction to CO_2 welding: Fusion welding of metal plates and sheets is the best method of joining metals because in this process the welded joint will possess the same properties and strength as the base metal.

- Without a perfectly shielded arc and molten puddle, the atmospheric oxygen and nitrogen will get absorbed by the molten metal. This will result in weak and porous welds.
- In shielded metal arc welding (SMAW) the arc and molten metal are protected/shielded by the gases produced by the burning of the flux coated on the electrode.

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

Basic equipment for a typical GMAW semiautomatic setup: (Fig 1)

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

Other names

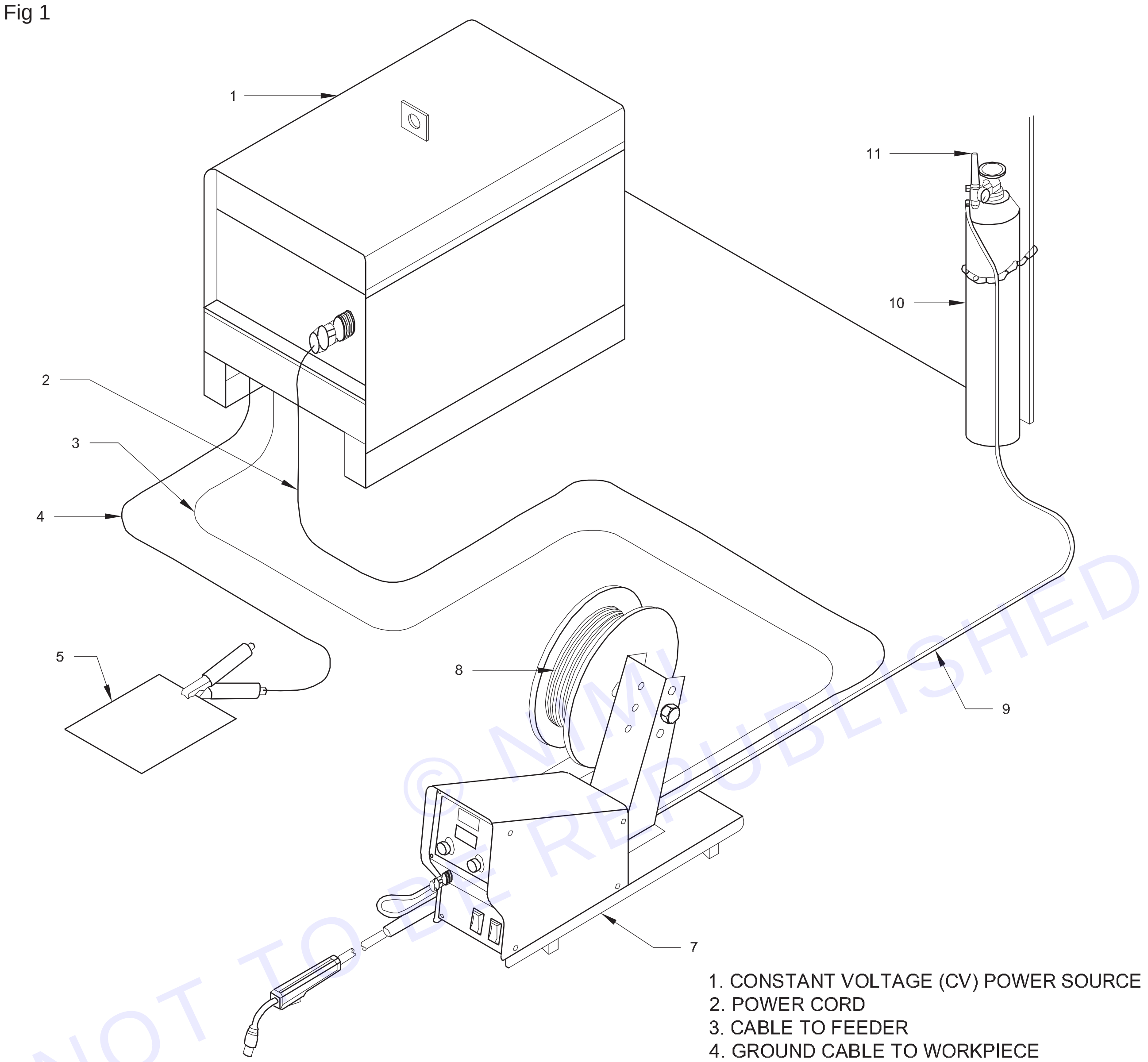
- MIG (Metal Insert Gas) welding,
- MAG (Metal Active Gas)/CO_2 Welding
- GMAW (Gas Metal Arc Welding)

GMAW can be done in three different ways:

- Semiautomatic welding - equipment controls only the electrode wire feeding. Movement of welding gun is controlled by hand. This may be called hand-held weld-ing.

Machine welding - uses a gun that is connected to a manipulator of some kind (not hand-held). An operator has to constantly set and adjust controls that move the manipulator.

Fig 1



1. CONSTANT VOLTAGE (CV) POWER SOURCE
2. POWER CORD
3. CABLE TO FEEDER
4. GROUND CABLE TO WORKPIECE
5. WORKPIECE
6. WELDING TORCH
7. CONSTANT SPEED WIRE FEEDER
8. ELECTRODE WIRE
9. GAS HOSE
10. SHIELDING GAS CYLINDER
11. GAS REGULATOR WITH FLOW METER

Constant voltage power source for CO_2 welding- Working principal, advantage & limitation of GMAW over other welding process

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

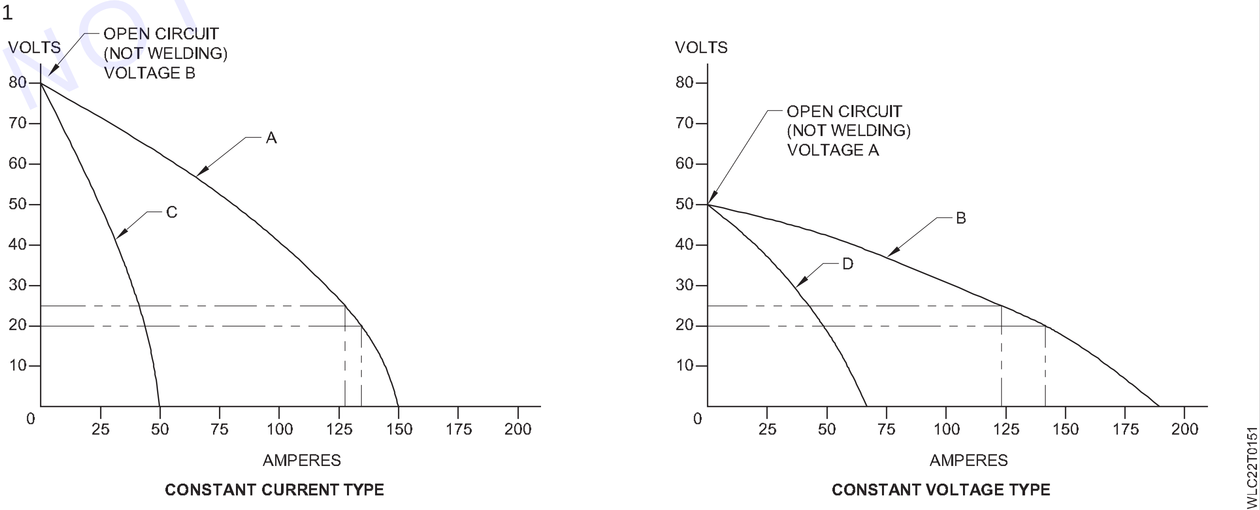
- describe the GMAW power source
- explain the principal of power source GMAW
- explain the GMAW power source advantage.

Mig Welding Power Source

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.

The characteristics volt, ampere curves (A & B) are shown in Fig 1. Curve A (For SMAW): On the output slope or volt ampere curve A, a change from 20 volts to 25 volts will result in a decrease in amperage from 135 amps to 126 amps. With a change of 25 percent in voltage, only a 6.7 percent change occurs in the welding current in curve A. Thus if the welder varies the length of the arc, causing a change in voltage, there will be very little change in the current and the weld quality will be maintained. The current in this machine, even though it varies slightly is considered constant. 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.

Fig 1

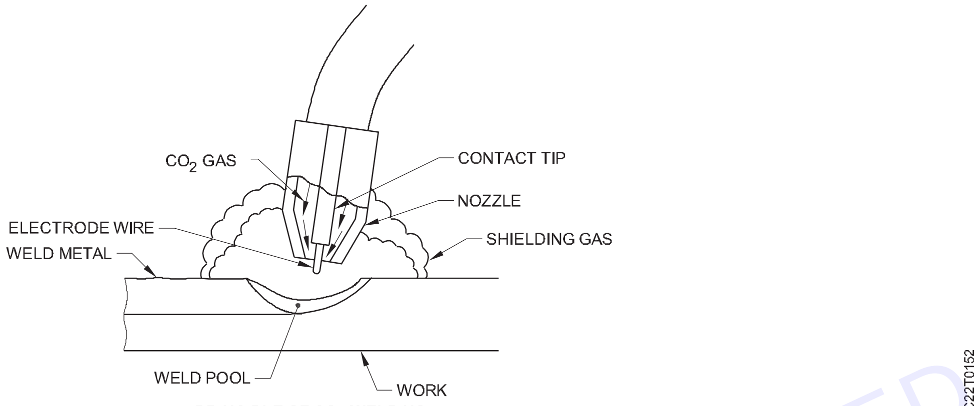


This type of power source is used in GMAW & SAW process. With a flatter output slope the welder can control the molten pool and electrode melt rate by making small changes in the arc length. Control of the molten pool and electrode melt rate are most important when welding in the horizontal, vertical and overhead positions.

Working 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/non inert gas passing through the welding torch/ gun. (Fig 2)

Fig 2



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

Advantage & Limitations of GMAW over other welding process-

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 and Limitation

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.

Wire feed units- types- application, limitation care and maintenance

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

- describe the wire feeder.
- explain the wire feeder application
- explain the wire feeder care maintenance.

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 work piece.

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.

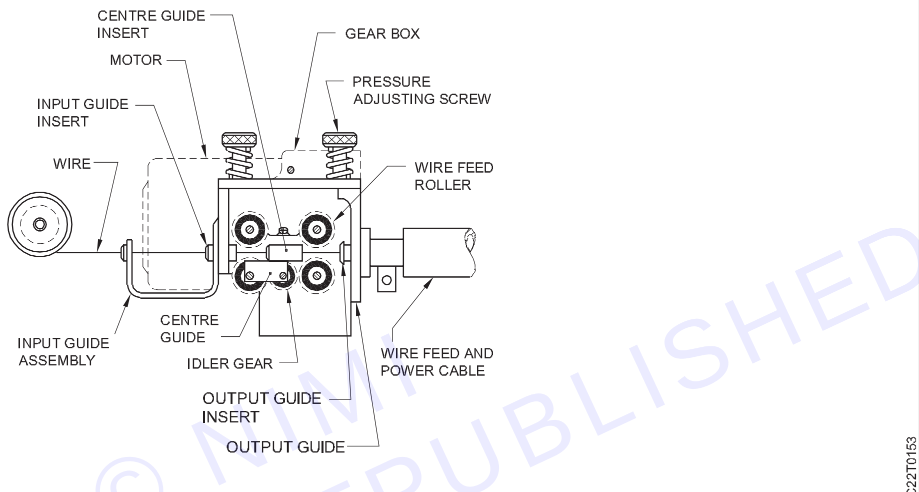
iii Provides gas flow control through a solenoid valve. The gas is fed down from the gas regulator to the weld area via the feeder and then the MIG welding torch.

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.

Fig 1



A SIMPLIFIED WIRE FEED MECHANISM FOR GMAW

Drive rollers: The drive rollers grasp the wire electrode and continuously feed the wire down the MIG torch into the welding arc (Fig 2 & 3). The rollers need to be selected by :

i the wire size

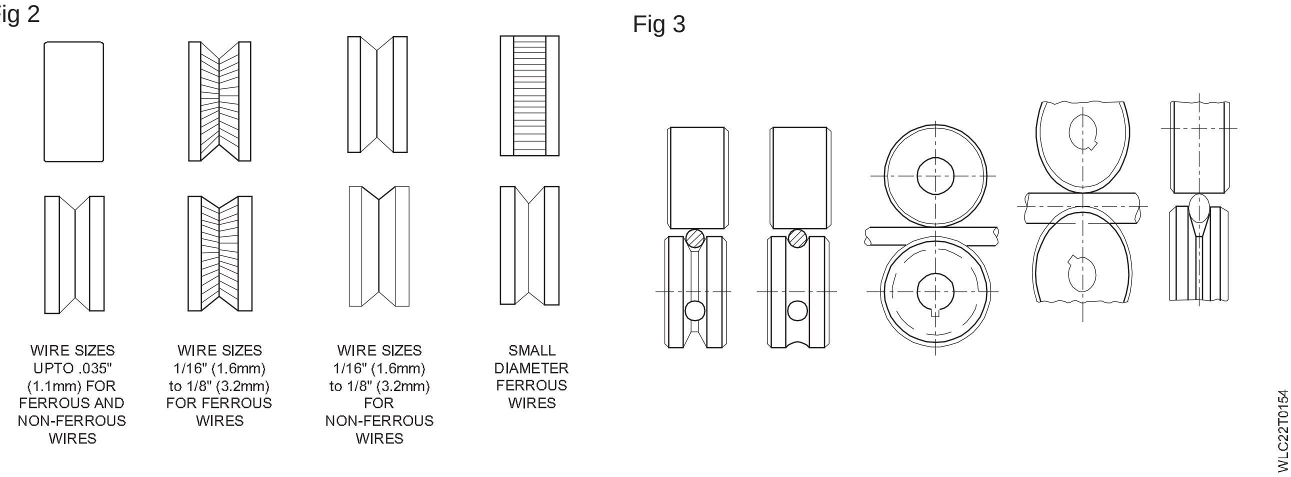
ii the type of wire to be fed. Each type of wire may need a different style of roller grooving

iii rollers for steel and other hard wires V-Knurled for Flux cored wire

iv U-Grooved for aluminium and other soft wires

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

Fig 2 Fig 3



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

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 weld piece); with the advantage of, the higher the amperage the thicker the material that can be welded.

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 weld pool and can be left stuck to the weld metal.

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

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.

Welding Gun- types, description of parts functions and maintenance.

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

- describe the MIG welding Gun.
- explain the MIG gun part function
- explain the MIG gun maintenance.

Introduction

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 the type of torch you need, including amperage rating 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 on to 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

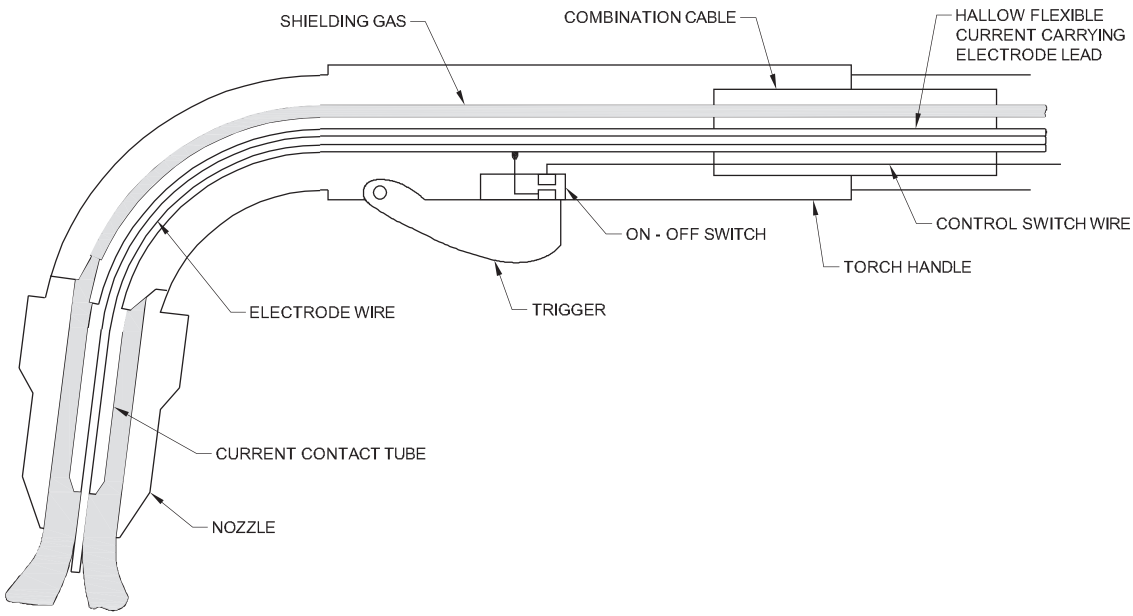
The MIG Torch is connected to the wire feeder, and its job is to deliver the wire electrode, shielding gas and the electrical welding current to the welding area. There are a lot of different shapes and styles of MIG Torch out in the marketplace but they all have things in common. (Fig 1 & 2).

1 Aircooled (less than 200 Amps) or water cooled (above 200 Amps) (Fig 1)

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.

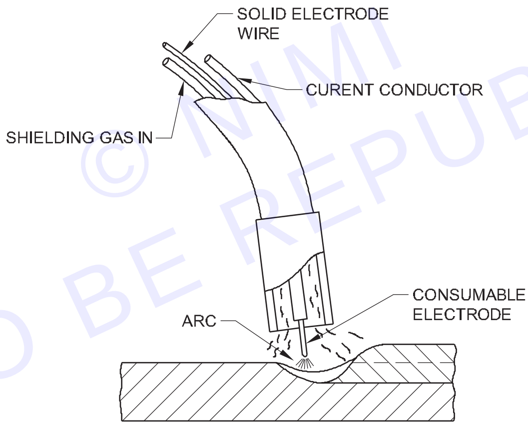
3 They all have parts that will wear out (consumables eg liners, tips, diffuser, nozzle, etc.) Let's take a look at each part (Fig 3)

Fig 1



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

Fig 2



TORCH ASSEMBLY

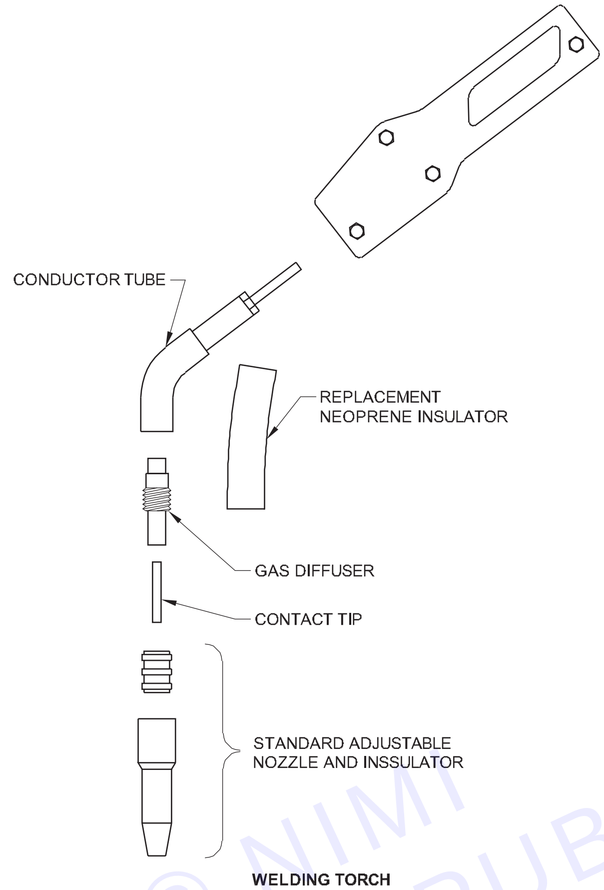
Liner: The liner causes the most problems. First, they have a life span that is approximately one to four rolls of MIG wire depending on the quality of the liner and wire.

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. 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 on the 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.

Fig 3



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.

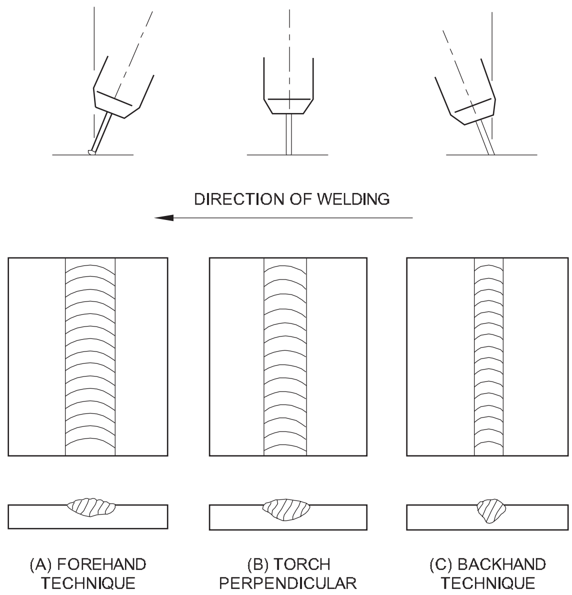
Nozzle: Guns are available with a straight or curved nozzle. The curved nozzle provides easy access to intricate joints and difficult-to-weld.

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 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 4. 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.

Fig 4



TORCH ANGLE

Model of metal transfer - Dip or short circuiting, transfer, Spray transfer (free fight transfer) and Globular transfer (intermitted transfer) and applications

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

- describe the modes of metal transfer spray transfer
- explain the modes of metal transfer globular transfer
- explain the modes of metal transfer short circuit 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.

a Spray transfer (Free flight)

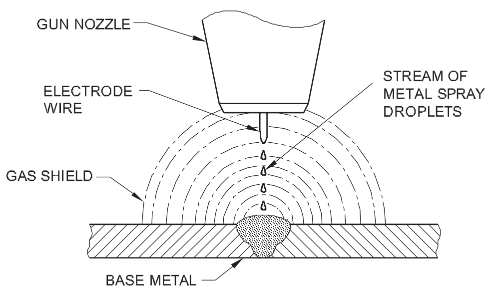
b Globular transfer (Intermediate)

c Short circuit or Dip transfer

d Pulsed transfer

The type of metal transfer that occurs will depend on the electrode wire size, shielding gas, arc voltage and welding current.

Fig 1



SPRAY TRANSFER OF METAL.

a **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).

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

a high deposition rates

b good travel speeds

c good looking weld appearance

d little weld spatter

e good weld fusion

f very good on heavy sections

g The disadvantages of the spray mode are

h higher capacity power source needed

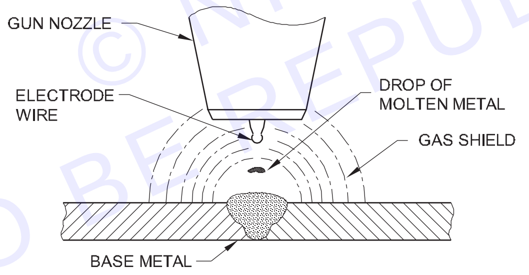
i weld position is limited to flat and horizontal fillet

j the cost of using a more expensive mixed gas

k higher radiated heat is produced so extra protection is needed

b **Globular transfer:- I**n globular transfer, only a few drops are transferred per second at low current values, while many drops are transferred at high current values. This transfer occurs when the welding current is low. (Fig 2). The voltage range is 23 to 27V.The spatter produced in this transfer is more and hence itis less preferred. But this is a good transfer method for using CO_2 gas as a shielding gas.

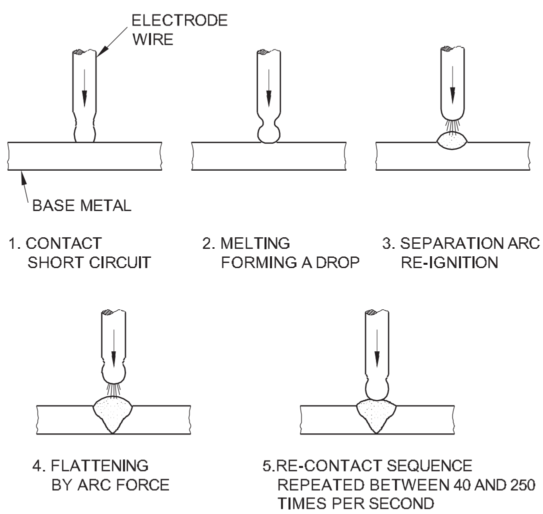
Fig 2



GLOBULAR TRANSFER OF METAL.

c **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

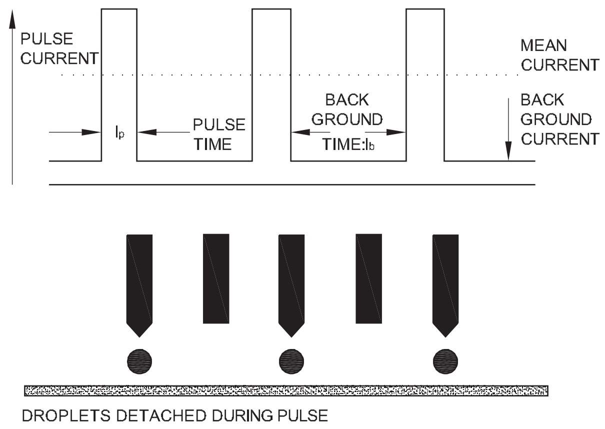


It permits welding thinner sections with greater ease, and is extremely practical for welding in all positions.

d Pulsed spray transfer (Fig 4)

Pulsed spray transfer has a steady stream of metal drop-lets crossing the welding arc. The pulsed power source supplies the welding arc with two types of welding current.

Fig 4



Peak current - this current allows the formation of metal droplets which then cross the welding arc.

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

a able to spray thinner metals

b less heat input

c stronger welds

d more weld control

e out-of-position welding

f Little spatters

Disadvantages

a higher set up costs

b needs operator training

c lower deposition rate

Welding parameters for GMAW M.S and Alloy steels-related Tables / data

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

- describe the welding parameter for GMAW
- explain the welding parameter for mild steel
- explain the welding parameter for alloy steels.

GMA welding process parameters/variables

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

Electrode size:

Rate of wire feed (Welding current) Arc voltage Stick out welding position Shielding gas Travel speed electrode position

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

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

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

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

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

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

The current varies as the wire feed varies.

Ranges of wire feed rate in CO_2 welding

(Current is shown in brackets)

Wire feed speed, m/min]

Wire dia. (mm)	Spray type arcs (28 - 32 V)	Short circuiting arcs (16-22 V)
0.8	5.0-15 (150-250 amps)	2.5-7.5 (60-160 amps)
1.2	5.0-15 (200-350 amps)	2.0-3.8 (100-175 amps)
1.6	5.0-8.8 (350-500 amps)	1.5-2.0 (120-180 amps)

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

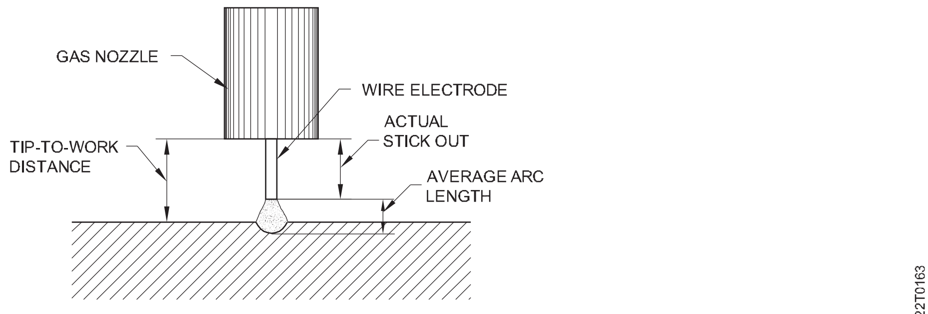
For details refer to the table of General Guide to Welding Conditions.

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

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

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

Fig 1



CORRECT WIRE STICK OUT IS IMPORTANT TO ACHIEVE SOUND WELDS

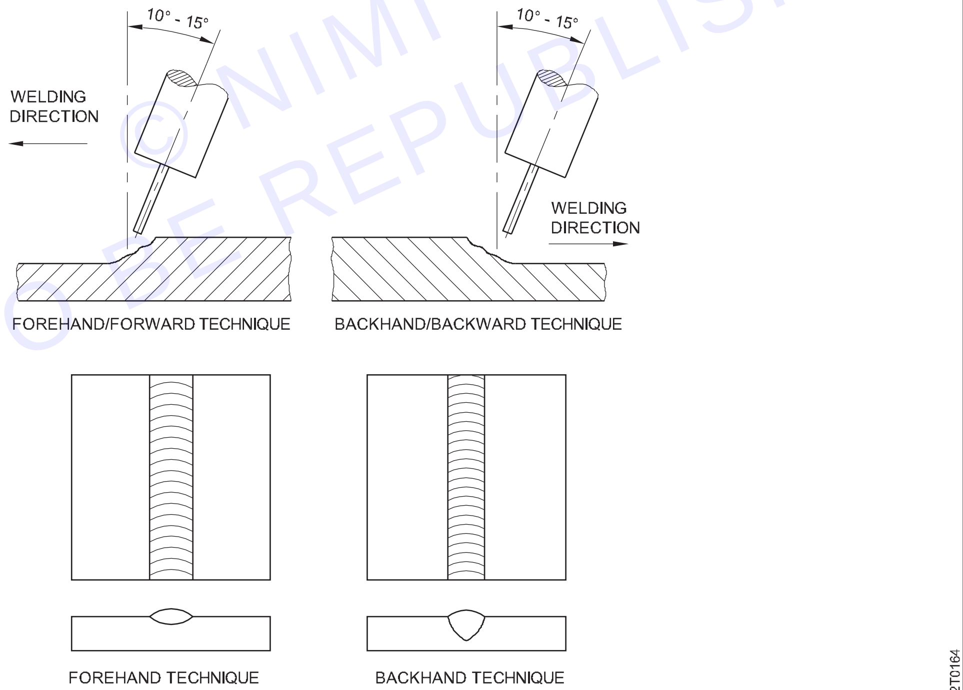
Too long a stick out results in excess weld metal being deposited at low arc heat, giving rise to badly shaped weld and shallow penetration.

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

Recommended stick out is 6 to 13 mm for a short circuiting arc, and 13 to 25 mm for the spray transfer arc.

Electrode position: In all welding processes, the position of the gun and electrode with respect to the joint affects the weld bead shape and penetration. The welding can be done either by using Forehand/Forward technique or by using Backhand/ Backward technique. The gun angles are usually maintained within 10 to 15° as shown in Fig 2.

Fig 2



ELECTRODE ANGLE AND ITS EFFECTS ON WELD BEAD

Preheating temperatures for plain and alloy steels	Approximate composition (percentage)			Recommended preheating temperature	
	% Carbon			°C	°F
PLAIN CARBON STEELS Plain carbon Plain carbon Plain carbon Plain carbon	C Below 0.20 0.20 to 0.30 0.30 to 0.45 0.45 to 0.80			Up to 95 95 to 150 150 to 280 260 to 425	Up to 200 200 to ¬300 300 to 500 500 to 800
CARBON MOLYBDENUM STEELS Carbon molybdenum Carbon molybdenum Carbon molybdenum	C 0.10 to 0 .20 0.20 to 0.30 0.30 to 0.35	Mo 0.50 0.50 0.50		150 to 260 200 to 315 260 to 425	300 to 500 400 to 600 500 to 800
MANGANESE STEELS Silicon structural Medium manganese SAE T 1330 SAE T 1340 SAE T 1350 12% Manganese	C 0.35 0.20 to0 .25 0.30 0.40 0.50	Mn 0.80 1.0 to 1.75 1.75 1.75 1.75 1.25	Si 0.25 12.0	150 to 260 150 to 260 200 to 425 260 to 425 315 to 480 Usually not required	300 to 500 300 to 500 400 to 600 500 to 600 600 to 900 Usually not required
NICKEL STEELS SAE 2015 SAE 2115 2"% Nickel SAE 2315 SAE 2320 SAE 2330 0SAW 2340	C 0.10 to 0.20 0.10 to 0.20 0.10 to 0.20 0.15 0.20 0.30 0.40	Ni 0.50 1.50 2.50 3.50 3.50 3.50 3.50		Up to 150 95 to 150 95 to 200 95 to 260 95 to 260 150 to 315 200 to 370	Up to 300 200 to 300 200 to 400 200 to 500 200 to 500 300 to 600 400 to 700
LOW CHROME MOLYBDENUM STEELS 2% Cr. "% Mo 2% Cr. "% Mo 2% Cr. 1% Mo 2% Cr. 1% Mo	C Up to .15 0.15 to 0.25 Up to 0.15 0.15 to 0.25	Cr 2.0 2.0 2.0 2.0	Mo 0.5 0.5 1.0 1.0	0 C 200 to 315 260 to 425 260 to 370 315 to 425	0 F 400 to 600 500 to 800 500 to 700 600 to 800
MEDIUM CHROME MOLYBDENUM STEELS 5% Cr. "% Mo 5% Cr. "% Mo 8% Cr. 1% Mo	C Up to 0.15 0.15 to 0.25 0.15 Max.	Cr 5.0 5.0 8.0	Mo 0.5 0.5 1.0	260 to 425 315 to 480 315 to 480	500 to 800 600 to 900 600 to 900
PLAIN HIGH CHROMIUM STEELS 12 to 14% Cr TYPE 410 16 to 18% Cr TYPE 430 23 to 30% Cr TYPE 446	C 0.10 0.10 0.10	Cr 13.0 17.0 26.0		150 to 260 150 to 260 150 to 260	300 to 500 300 to 500 300 to 500

Welding wires used in CO_2 welding, diameter, Specification

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

- describe the GMAW consumable wire
- explain the GMAW wire chemical composition
- explain the GMAW wire selection in welding.

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

a short circuit metal transfer on mild and low alloy steel

Electrode diameter(mm)	voltage range	Arc Amperage
0.8 1.2	16-22 17-22	80-190 100-225

b Approx. machine settings for spray arc transfer on mild and low alloy steel

Electrode diameter(mm)	voltage range	Arc Amperage
0.8 1.2 1.6	24-28 24-30 24-32	150-265 200-315 275-500

c Approx. machine settings for short circuit transfer on series 300 stainless steel

Electrode diameter(mm)	voltage range	Arc Amperage
0.8 1.2	17-22 17-22	50-180 100-210

d Approx. machine settings for spray transfer on series 300 stainless steel

Electrode diameter(mm)	voltage range	Arc Amperage
0.8 1.2 1.6	24-28 24-30 24-32	160-210 200-300 215-325

Chemical properties: Chemical compositions of the filler wire play a very important role. The main composition, apart from the major elements, in the case of mild steel welding, will contain deoxidisers like Si, Mn to take of care of porosity due to oxidation of carbon in the steel. Typical composition of mild steel filler wires are listed in the table. We are using ER70S-6 for most of our carbon steel fabrication.

Specification of electrode wires

The GMAW electrode specification as per AWS is as given below.

Eg: E 70S-2 or ER70S-2 or E70T-2

E - Electrode

ER - Electrode can also be used as a filled Rod in GTAW.

70 - 70 x 1000 PSI - Tensile strength of the weld metal

in pounds per square inch.

S - Solid wire / Rod

T - Tubular wire used in FCAW.

2 - Chemical composition of the wire.

Chemical composition, Weight percent

AWS classification	c	Mn	Si	P	S	Cu	Ti	Zr	Al
70S-2	0.07	0.90 to 1.40	0.40 to 1.40	0.025	0.035	0.5	0.05 to 0.15	0.02 to 0.12	0.05 to 0.15
70S-3	0.06 to 0.15	0.90 to 1.4	0.45 to 0.7						
70S-6	0.07 to 0.15	1.4 to 1.85	0.8 to 1.15						

Wire electrodes selection

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

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

2 the composition of the metal being welded

3 welding indoors or outdoors

4 joint design

5 cost

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

Shielding Gas & Gas mixture, and its application GMAW

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

- describe the GMAW shielding gas
- explain the GMAW gas mixture
- explain the application of GMAW.

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. There-fore helium is chosen for welding thicker metals as well as high conductivity metals like copper and aluminium.

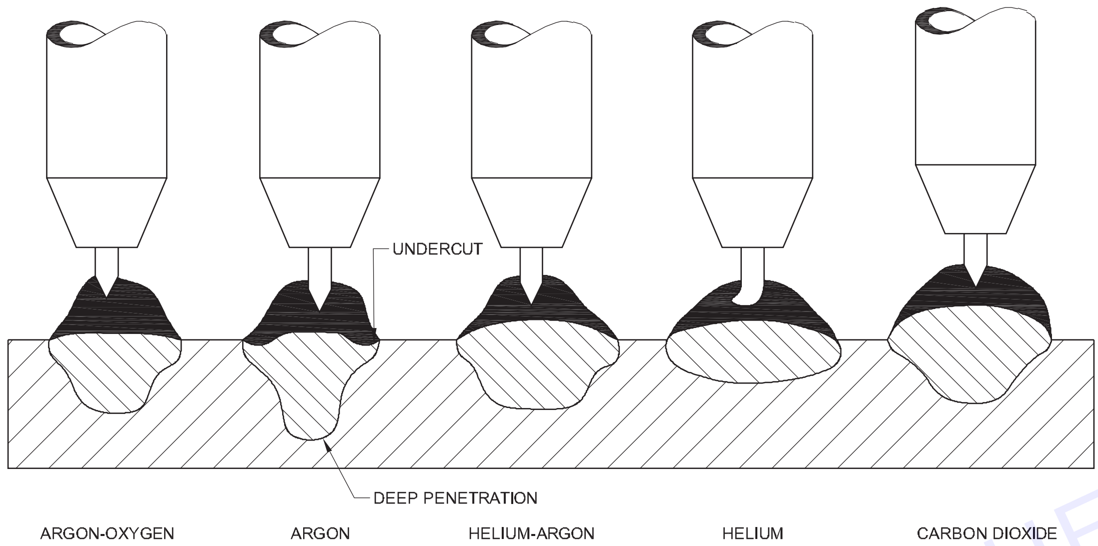
Argon used with the gas metal arc spray transfer process tends to produce deeper penetration through the center line of the bead. Spray transfer occurs more easily in argon than in helium.

Reactive gases and gas mixtures used in GMAW

Carbon-dioxide: 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 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 undercut 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).

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 amore 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

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

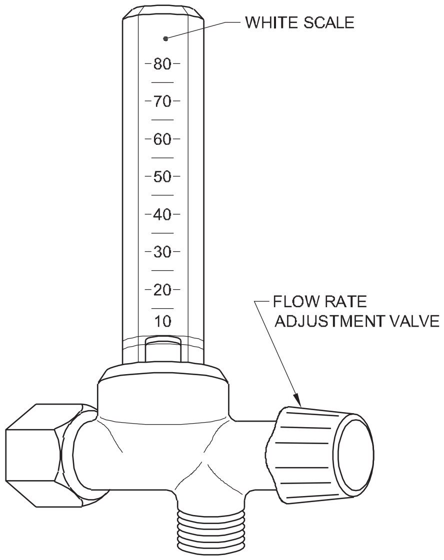
Too much gas flow can be just as bad as not having enough. The reason being that if the gas flow is too high it will come out of the MIG Torch.

Suggested gases and gas mixtures for use in GMAW spray transfer

CO_2 gas cylinder and regulator: The shielding gas required for GMAW/CO_2 welding is supplied from a gas cylinder through an outlet valve and regulator.

Gas flow meter: It is a unit which has graduations marked on the glass tube. A flow rate adjustment valve fixed to the flow meter controls the rate of flow of inert gas/CO_2 gas to the welding gun in litre per minute. Fig 2.

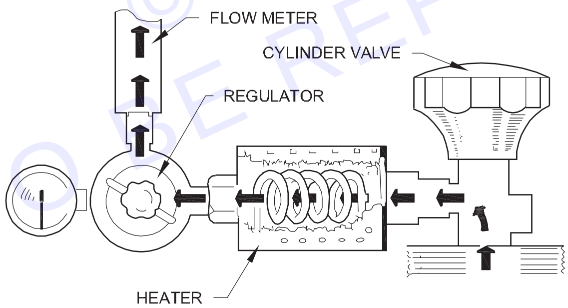
Fig 2



FLOW METER

Gas Preheater for CO_2 welding- (Fig 3): Carbondioxide is filled in cylinders in liquid form. i.e., the CO_2 at room temperature and high pressure condenses into liquid form. Therefore while welding the liquid CO_2 has to be in gaseous form as they enter into the welding torch. CO_2 liquid boils and expands into gas as it passes through the regulator. This causes the gas to cool. If moisture is present in the regulator inlet, it will condense and freeze in the regulator, causing blocking of the gas passage. Therefore to avoid cooling a gas heater is connected to the cylinder to increase the temperature of the gas leaving the cylinder. Hence a uniform gas flow is maintained during welding.

Fig 3



Edge preparation and fit up of various thicknesses of metals for GMAW.

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

- describe the base preparation of metal in GMAW
- explain the types of edge preparation of GMAW.
- explain the edge preparation single and double V in GMAW.

Base metal preparation: For GMAW/CO_2 welding the edges and the plate surfaces for welding of ferrous and nonferrous metals are cleaned similar to Shielded Metal Arc Welding process. The groove angle for single V butt joint in case of CO_2 welding is 40 to 45 only when compared to 60 used for shielded metal arc welding (Fig 1,2 & 3). The edge preparation required for the various types of welding process.

Fig 1

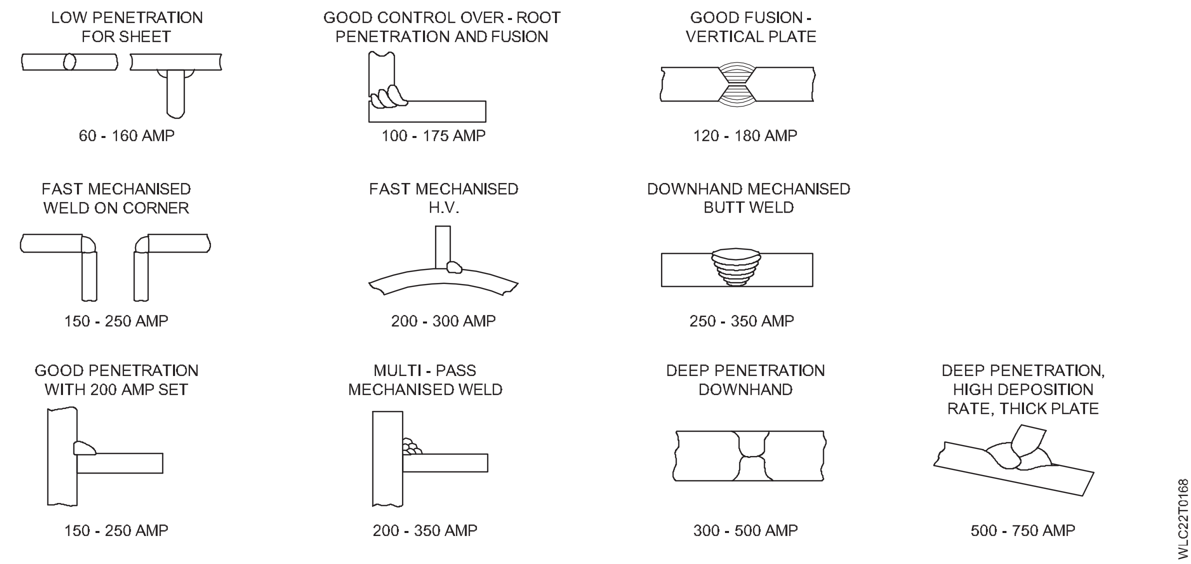

LOW PENETRATION FOR SHEET
60 - 160 AMP
GOOD CONTROL OVER - ROOT PENETRATION AND FUSION
100 - 175 AMP
GOOD FUSION - VERTICAL PLATE
120 - 180 AMP
FAST MECHANISED WELD ON CORNER
150 - 250 AMP
FAST MECHANISED H.V.
200 - 300 AMP
DOWNHAND MECHANISED BUTT WELD
250 - 350 AMP
GOOD PENETRATION WITH 200 AMP SET
150 - 250 AMP
MULTI - PASS MECHANISED WELD
200 - 350 AMP
DEEP PENETRATION DOWNHAND
300 - 500 AMP
DEEP PENETRATION, HIGH DEPOSITION RATE, THICK PLATE
500 - 750 AMP
WLC22T0168

Fig 2

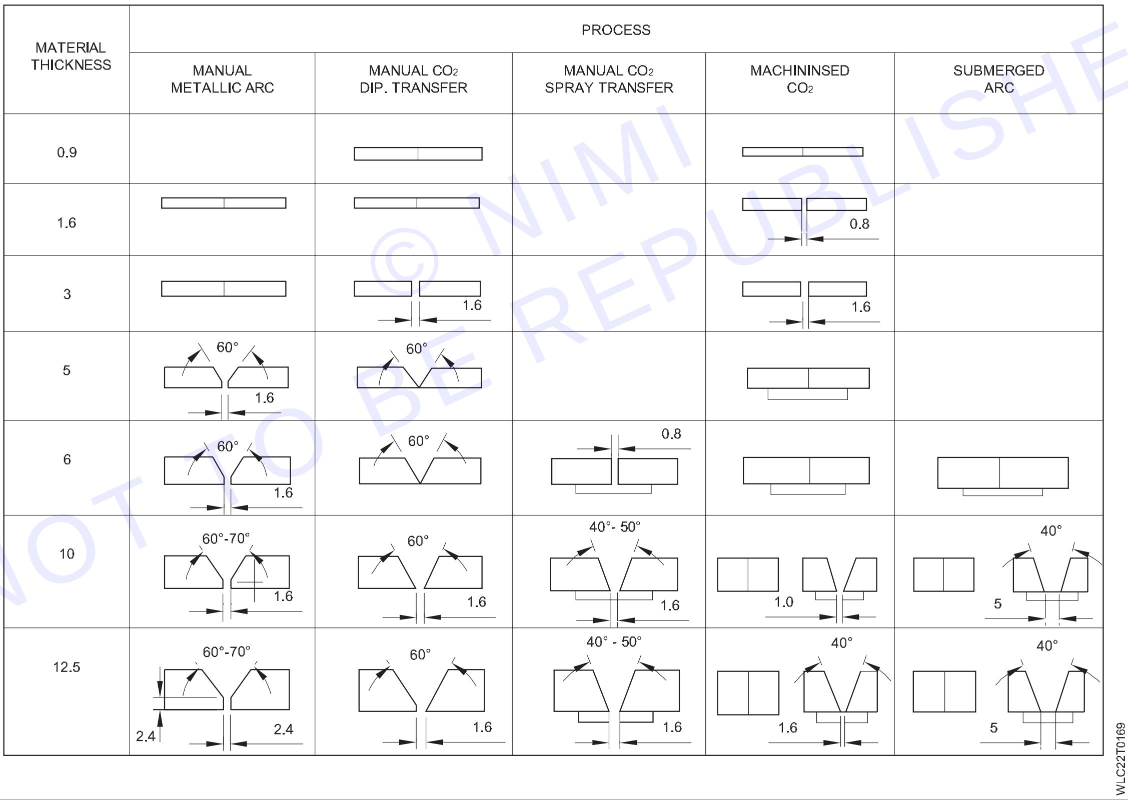
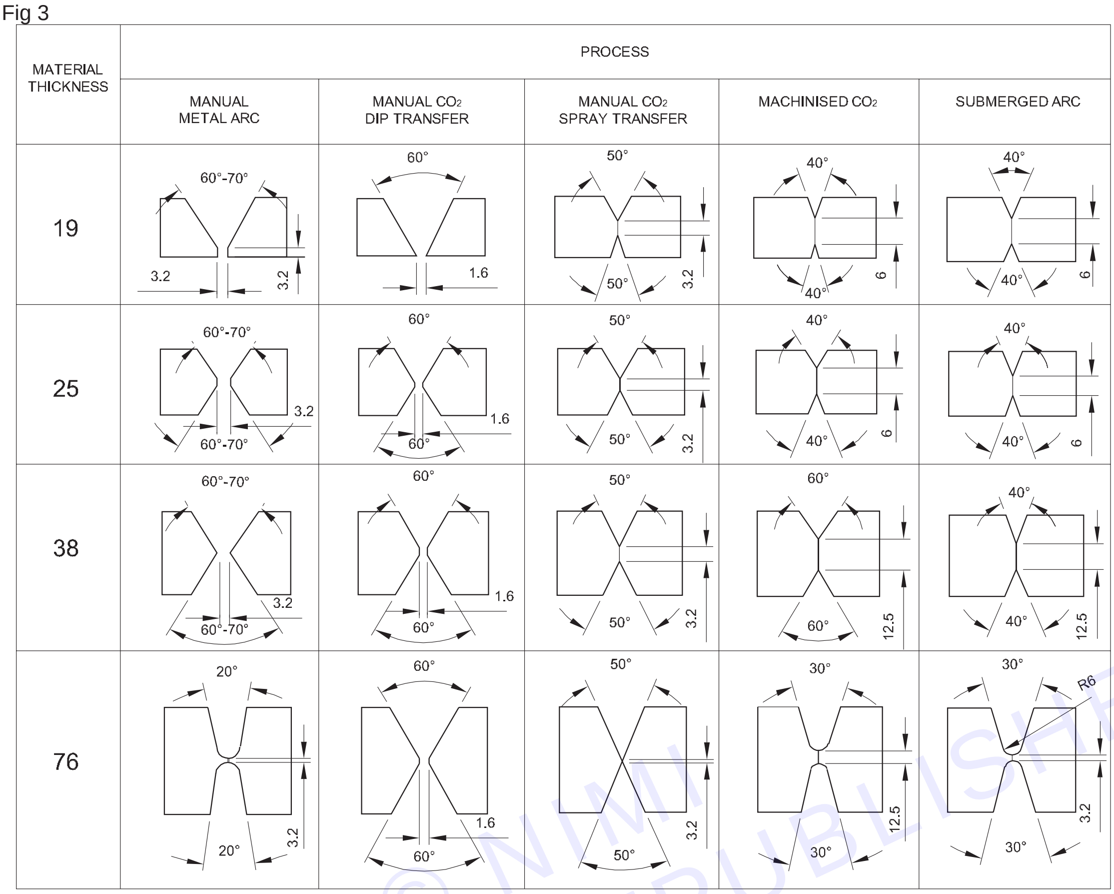

MATERIAL THICKNESS
PROCESS
MANUAL METALLIC ARC
MANUAL CO2 DIP. TRANSFER
MANUAL CO2 SPRAY TRANSFER
MACHININSED CO2
SUBMERGED ARC
0.9
1.6
3
5
6
10
12.5
0.8
1.6
60°
60°-70°
40°- 50°
40°
1.0
5
2.4
WLC22T0169

Fig 3



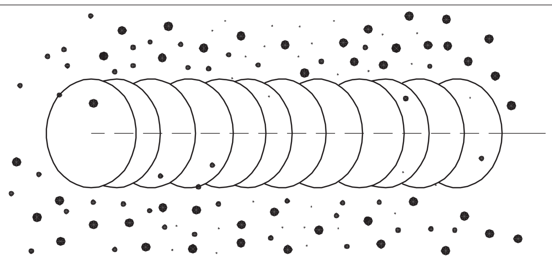
Types of weld defects, Causes and remedy in GMAW

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

- describe the types of weld defects
- explain the weld defects causes
- explain the defects remedy in GMAW.

1 Excessive spatter- scattering of molten metal particles that cool to solid form near weld bead.

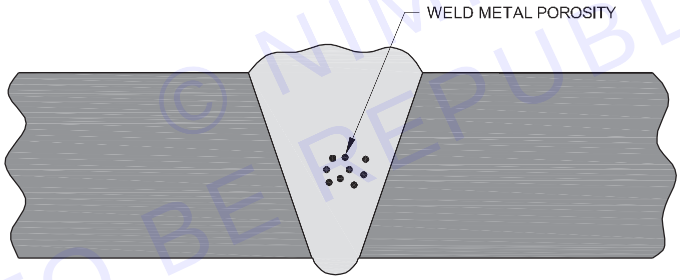
Fig 1



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

2 **Porosity** - small cavities or holes resulting from gas pockets in weld metal.

Fig 2

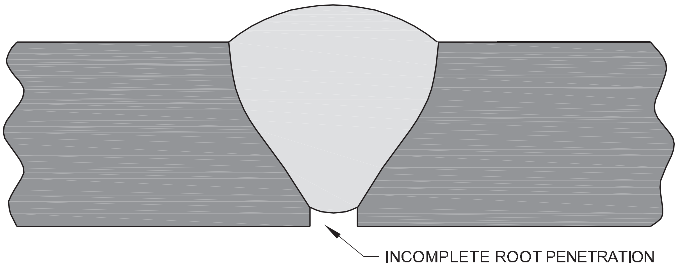


Causes	Remedy
Inadequate shielding gas coverage	Check for proper gas flow rate.
Wrong gas.	Remove spatter from gun nozzle.
Dirty welding wire	Check gas hoses for leaks.
Work piece dirty.	Eliminate drafts near welding arc.
Welding wire extends too far out of nozzle.	Hold gun near bead at end of weld until molten metal solidifies.
	Use welding grade shielding gas; change to different gas.
	Use clean, dry welding wire.
	Eliminate pick up of oil or lubricant on welding wire from feeder or liner.
	Remove all grease, oil, moisture, rust, paint, coatings, and dirt from work
	surface before welding.

	Use a more highly deoxidizing welding wire.
	Be sure welding wire extends not more than (13 mm) beyond nozzle.

3 **Incomplete fusion** - failure of weld metal to fuse completely with base metal or a proceeding weld bead.

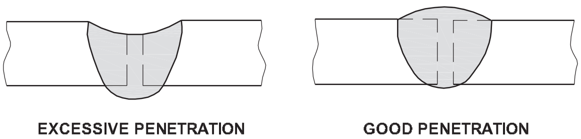
Fig 3



Causes	Remedy
Work piece 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

4 **Excessive penetration -** failure of weld metal to fuse completely with base metal or a proceeding

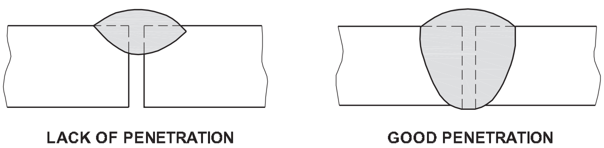
Fig 4



Causes	Remedy
Excessive heat input.	Select lower voltage range and reduce wire feed speed. Increase travel speed.

5 **Lack of penetration -** shallow fusion between weld metal and base metal

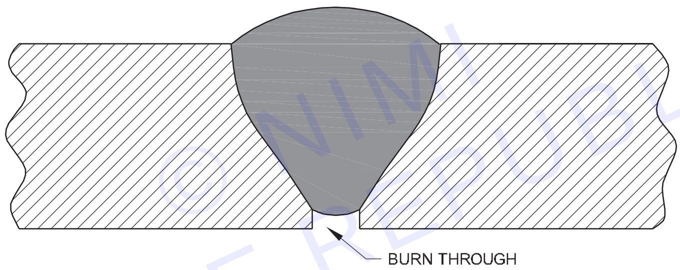
Fig 5



Causes	Remedy
Improper joint preparation.	Material too thick. Joint preparation and design must provide access to
Improper weld technique	bottom of groove while maintaining proper welding wire extension and arc
Insufficient heat input.	characteristics.
	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.
	Select higher wire feed speed and/or select higher voltage range.
	Reduce travel speed.

6 **Burn through -** weld metal melting completely through base metal resulting in holes where no metal remains.

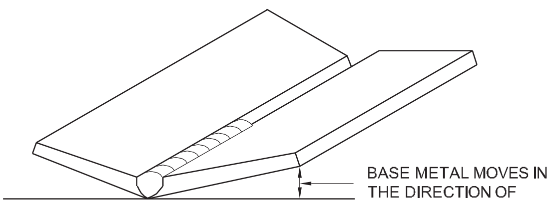
Fig 6



Causes	Remedy
Excessive heat input.	Select lower voltage range and reduce wire feed speed.
	Increase and/or maintain steady travel speed.

7 **Distortion -** contraction of weld metal during welding that forces base metal to move.

Fig 7



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

Flux cored arc welding - Description, advantage, welding wire for flux cored arc welding, types coding as per AWS and specification- Trouble shooting in MIG welding.

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

- describe the flux cored arc welding
- explain the flux welding MIG wire.
- explain the flux cored wire specification.

Introduction

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 work piece.

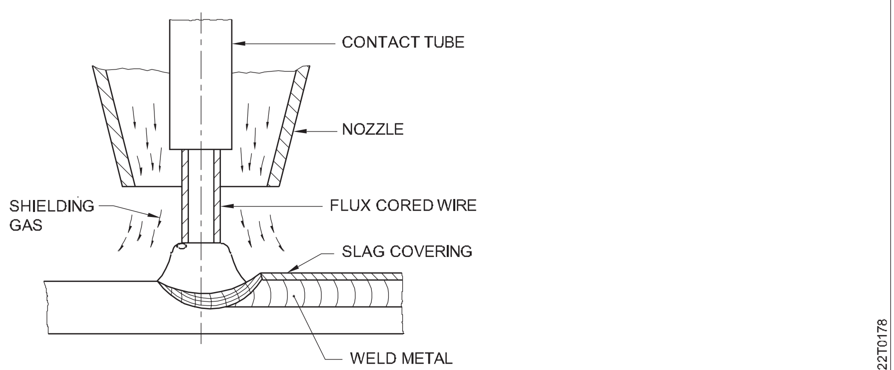
There are two major versions of the process, namely self shielded type (in which the flux performs all the functions of shielding) and the 'gas shielded type', which requires additional gas shielding.

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.

Fig 1



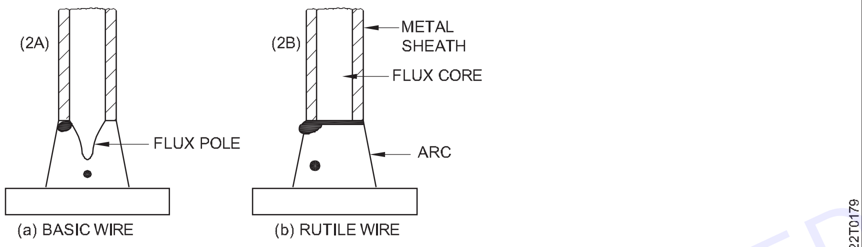
FLUX CORED ARC WELDING

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 deoxygenates into the weld pool and providing stability to the arc, besides producing the required shielding medium to protect the arc and weld pool.

Flux cored wires are now available for welding of plain carbon steel, low alloy steel and stainless steel and also for hard facing applications. These wires based on the nature of flux, may be classified as rutile gas shielded, basic gas shielded, metal cored and self shielded.

Rutile gas shielded wires have extremely good arc running characteristics, excellent positional welding capabilities and good slag removal and mechanical properties.

Basic gas shielded wires give reasonable arc characteristics, excellent tolerance to operating parameters and very good mechanical properties.

Metal cored wires contain very little mineral flux, the major constituent being iron powder and ferro alloys. These wires give smooth spray transfer in Argon/CO_2 gas mixtures. They generate minimum slag and are suitable for mechanised welding applications. Self shielded wires are avail-able 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 de-fined 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 deter-mined 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.

Introduction to GTAW (TIG welding), Equipment , Advantage over SMAW and oxy - acetylene welding

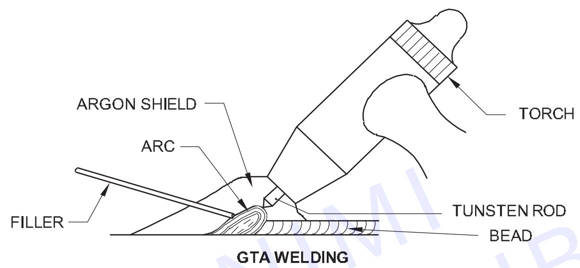
Objectives: At the end of this lesson you shall be able to

- describe the GTAW welding
- explain the GTAW equipments
- explain the GTAW advantage.

Gas Tungsten Arc Welding (GTAW), also known as tungsten inert gas (TIG) welding is a process that produces an electric arc maintained between a non consumable tungsten electrode and the part to be welded. The heat-affected zone, the molten metal, and the tungsten electrode are all shielded from atmospheric contamination by a blanket of inert gas fed through the GTAW torch. Inert gas (usually Argon) is inactive or deficient in active chemical properties. The shielding gas serves to blanket the

weld and exclude the active properties in the surrounding air. Inert gases, such as Argon and Helium, do not chemically react or combine with other gases. They pose no odour and are transparent, permitting the welder maximum visibility of the arc. In some instances Hydrogen gas may be added to enhance travel speeds

Fig 1



The GTAW process can produce temperatures of up to 3000° F. The torch contributes heat only to the work piece. If filler metal is required to make the weld, it may be added manually in the same manner as it is added in the oxyacetylene welding process, or in other situations may be added using a cold wire feeder. GTAW is used to weld steel, stainless steel, nickel alloys, titanium, aluminum, magnesium, copper, brass, bronze, and even gold. GTAW can also weld dissimilar metals to one another such as copper to brass and stainless steel to mild steel.

Advantages of GTA welding

- Concentrated Arc - Permits pinpoint control of heat input to the work piece resulting in a narrow heat-affected zone.

  No Slag - No requirement for flux with this process; therefore no slag to obscure the welder's vision of the molten weld pool.

- **No Sparks or Spatter -** No transfer of metal across the arc. No molten globules of spatter to contend with and no sparks produced if material being welded is free of contaminants.
- Little Smoke or Fumes - Compared to other arc-welding processes like stick or flux cored welding, few fumes are produced. However, the base metals being welded may contain coatings or elements such as lead, zinc, copper, and nickel that may produce hazardous fumes. Keep your head and helmet out of any fumes rising off the work piece. Be sure that proper ventilation is supplied, especially in a confined space.
- Welds more metals and metal alloys than any other arc welding process.
- Good for welding thin material.
- Good for welding dissimilar metals together.

Disadvantages of GTA welding

- Slower travel speeds than other processes.
- Lower filler metal deposition rates.
- Hand-eye coordination is a required skill.
- Brighter UV rays than other processes.

- Equipment costs can be higher than with other processes.
- Concentrations of shielding gas may build up and displace oxygen when welding in confined areas – ventilate the area and/or use local forced ventilation at the arc to remove welding fumes and gases. If ventilation is poor, wear an approved air-supplied respirator.

TIG welding equipment (Fig 2)

a An AC or DC arc welding machine.

b Shielding gas cylinders or facilities to handle liquid gases

c A shielding gas regulator

d A gas flowmeter

e Shielding gas hoses and fittings

f A welding torch (electrode holder)

g Tungsten electrodes

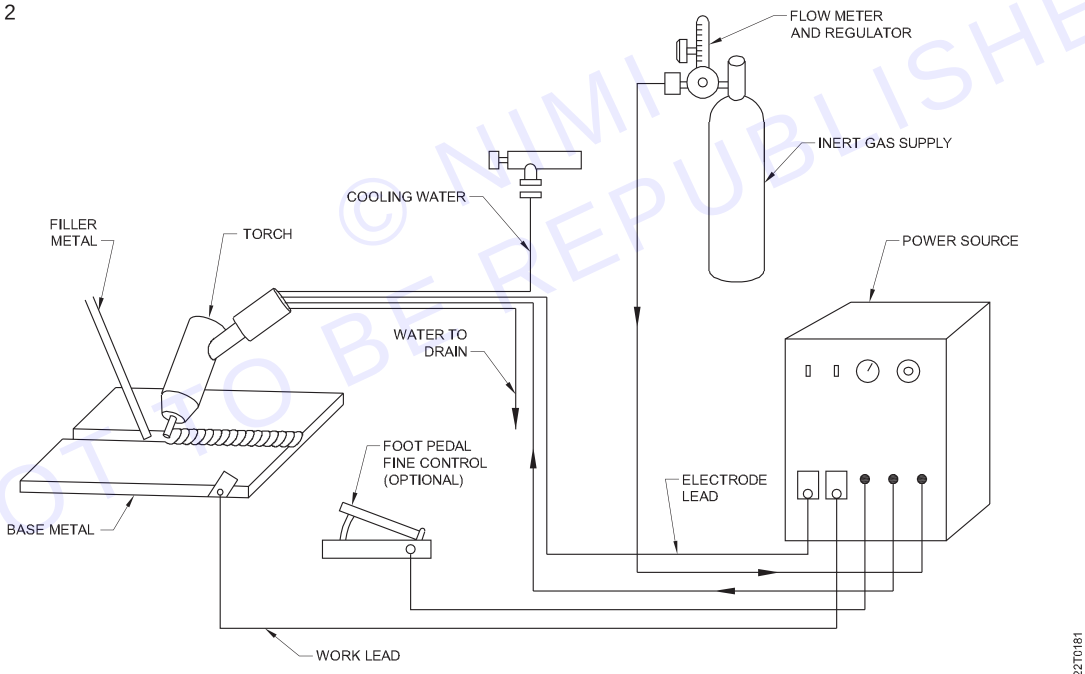
h Welding filler rods

i Optional accessories

j A water cooling system with hoses for heavy duty welding operations

k Foot rheostat (switch)

Fig 2

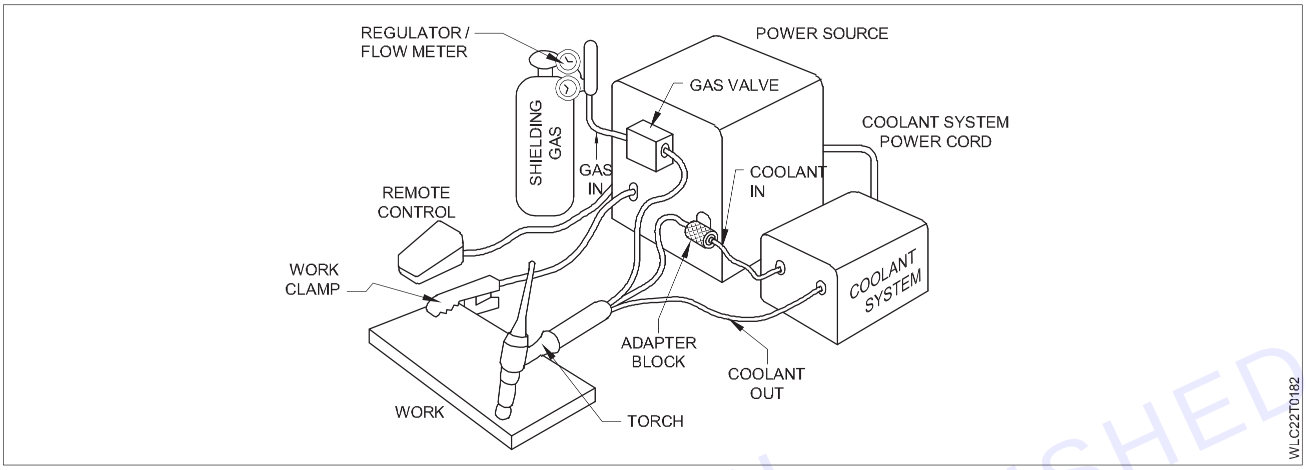


A DIAGRAMMATIC DRAWING OF A COMPLETE GAS TUNGSTEN ARC WELDING

TOPIC - POWER SOURCE- high frequency unit, D.C suppressor unit and uses

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

- describe the TIG welding power source
- explain the high frequency unit of TIG power source
- explain the working principal of TIG power source.



Selecting a Power Source

With the many types of welding machines available, certain considerations must be made in order to fit the right machine to the job. Rated output of the welding machine is an important consideration. The ranges of voltage and amperage needed for a particular process must be determined. Then, a welding machine can be selected to meet these output needs. Remember, the output must be within a proper duty cycle range. Light welding, (low output requirements of about 200 amps or less) can often be done with single-phase welding machines. Duty cycles are often in the 60% or less range. These types of welding machines are especially suited for shops and garages where only single-phase power is available. Some of these smaller single-phase machines may be capable of using 115 volt AC primary power. Other machines may use 230 volt or higher primary power. Larger DC TIG welding machines used for heavy plate, structural fabrication and high production welding generally need three phase AC input power. Most industrial locations are supplied with three-phase power since it provides the most efficient use of the electrical distribution system and it is required by many electric motors and other industrial electrical equipment. These welding machines often have capacities of over 200 amps, and often have 100% duty cycles.

Gas tungsten arc welding uses a constant current power source, meaning that the current (and thus the heat) remains relatively constant, even if the arc distance and voltage change. This is important because most applications of GTAW are manual or semiautomatic, requiring that an operator hold the torch. Maintaining a suitably steady arc distance is difficult if a constant voltage power source is used instead, since it can cause dramatic heat variations and make welding more difficult.

The preferred polarity of the GTAW system depends largely on the type of metal being welded. Direct current with a negatively charged electrode (DCEN) is often employed when welding steels, nickel, titanium, and other metals. It can also be used in automatic GTA welding of aluminum or magnesium when helium is used as a shielding gas. The negatively charged electrode generates heat by emitting electrons which travel across the arc, causing thermal ionization of the shielding gas and increasing the temperature of the base material. The ionized shielding gas flows toward the electrode, not the base material. Direct current with a positively charged electrode (DCEP) is less common, and is used primarily for shallow welds since less heat is generated in the base material. Instead of flowing from the electrode to the base material, as in DCEN, electrons go the other direction, causing the electrode to reach very high temperatures. To help it maintain its shape and prevent softening, a larger electrode is often used. As the electrons flow toward the electrode, ionized shielding gas flows back toward the base material, cleaning the weld by removing oxides and other impurities and thereby improving its quality and appearance.

Alternating current, commonly used when welding aluminum and magnesium manually or semi-automatically, combines the two direct currents by making the electrode and base material alternate between positive and negative charge. This causes the electron flow to switch directions constantly, preventing the tungsten electrode from overheating while maintaining the heat in the base material. Surface oxides are still removed during the electrode-positive portion of the cycle and the base metal is heated more deeply during the electrode-negative portion of the cycle. Some power supplies enable operators to use an unbalanced alternating current wave by modifying the exact percentage of time that the current spends in each state of polarity, giving them more control over the amount of heat and cleaning action supplied by the power source. In addition, operators must be wary of rectification, in which the arc fails to reignite as it passes from straight polarity (negative electrode) to reverse polarity (positive electrode). To remedy the problem, a square wave power supply can be used, as can high-frequency voltage to encourage ignition.

Effect of polarity in DC TIG Welding and application of straight and reversed polarity and Square wave concept and Wave balancing, and Pulsed TIG welding and application

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

- describe the effect of polarity in DC TIG welding
- explain the direct current straight polarity
- explain the direct current reverse polarity.

Power sources

TIG welding power sources have come a long way from the basic transformer types of power sources which were used with add-on units to enable the power source to be used as a TIG unit, eg high frequency unit and/or DC rectifying units.The basics of TIG welding has almost remained the same, but the advent of technology TIG welding power sources have made the TIG processes more controllable and more portable. The one thing that all TIGs have in common is that they are CC (Constant Current) type power sources. This means only output adjustment will control the power source amps. The voltage will be up or down depending on the resistance of the welding arc.

Characteristics of power source : The output slope or volt-ampere curve A, a change from 20 volts to 25 volts will result in a decrease in amperage from 135 amps to 126 amps. With a change of 25 percent in voltage, only a 6.7 percent change occurs in the welding current in curve A. Thus if the welder varies the length of the arc, causing a change in voltage, there will be very little change in the current and the weld quality will be maintained. The current in this machine, even though it varies slightly is considered constant. This is called drooping characteristic power source. Also called Constant Current (CC) power source. This type of power source is used in GTAW process.

Effect of polarity in DC TIG Welding and application of straight and reversed polarity

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.

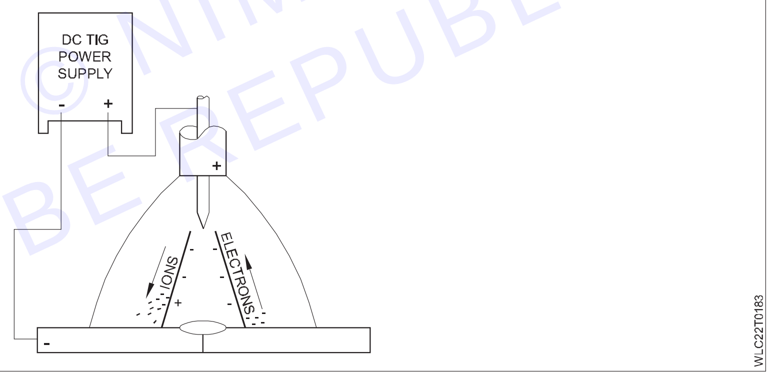
a **DCSP - Direct Current Straight Polarity:** (The tungsten electrode is connected to the negative terminal). This type of connection is the most widely used in the DC type welding current connections. With the tungsten being connected to the negative terminal it will only receive 30% of the welding energy (heat). This means the tungsten will run a lot cooler than DCRP. The resulting weld will have good penetration and a narrow profile.

Current type	DCSP
Electrode Polarity	Electrode Negative
Oxide Cleaning Action	No
Heat Balance in the Arc	70% at work end 30% at electrode end
Penetration Profile	Deep, narrow
Electrode Capacity	Excellent

b **DCRP - Direct Current Reverse Polarity- (Fig 1):** (the tungsten electrode is connected to the positive terminal). This type of connection is used very rarely because most heat is on the tungsten, thus the tungsten can easily overheat and burn away. DCRP produces a shallow, wide profile and is mainly used on very light material at low amps.

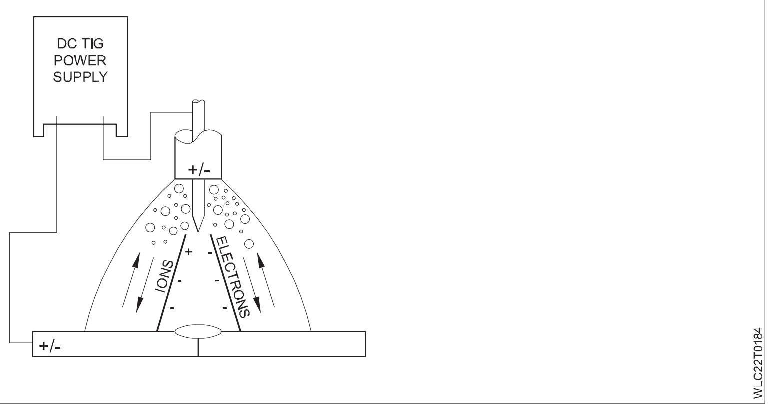
Current type	DCSP
Electrode Polarity	Electrode Positive
Oxide Cleaning Action	Yes
Heat Balance in the Arc	30% at work end 70% at electrode end
Penetration Profile	Shallow, wide
Electrode Capacity	Poor

Fig 1



AC - Alternating Current- (Fig 2) is the preferred welding current for most white metals, eg aluminium and magnesium. The heat input to the tungsten is averaged out as the AC wave passes from one side of the wave to the other.

Fig 2



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.

Current type	DCSP
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

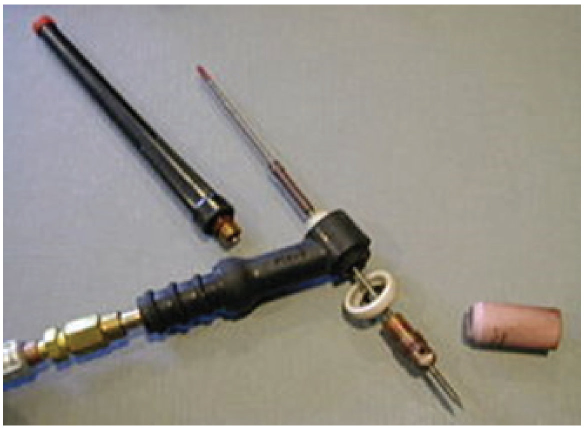
GTAW Torches, Types, parts and function

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

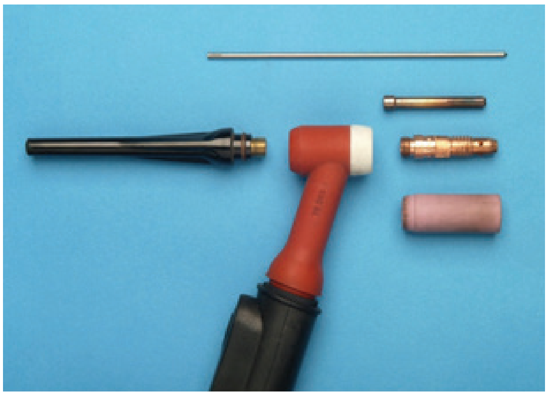
- describe the GTAW torch
- explain the GTAW types
- explain the GTAW parts and function.

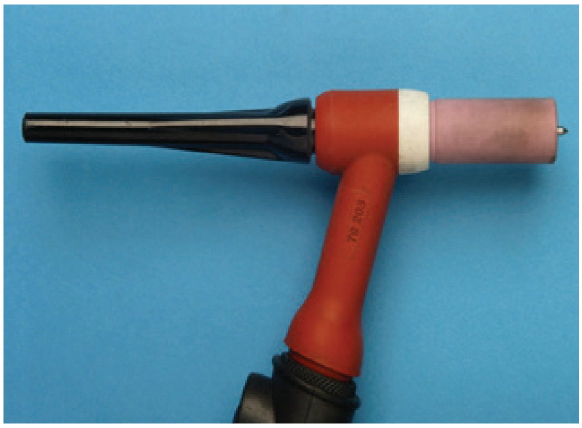
WELDING TORCH

GTAW torch with various electrodes, cups, collets and gas diffusers



GTAW torch, disassembled





GTAW welding torches are designed for either automatic or manual operation and are equipped with cooling systems using air or water. The automatic and manual torches are similar in construction, but the manual torch has a handle while the automatic torch normally comes with a mounting rack. The angle between the centerline of the handle and the centerline of the tungsten electrode, known as the head angle, can be varied on some manual torches according to the preference of the operator. Air cooling systems are most often used for low-current operations (up to about 200 A), while water cooling is required for high-current welding (up to about 600 A). The torches are connected with cables to the power supply and with hoses to the shielding gas source and where used, the water supply.

The internal metal parts of a torch are made of hard alloys of copper or brass in order to transmit current and heat effectively. The tungsten electrode must be held firmly in the center of the torch with appropriately sized collets, and ports around the electrode provide a constant flow of shielding gas. Collets are sized according to the diameter of the tungsten electrode they hold. The body of the torch is made of heat-resistant, insulating plastics covering the metal components, providing insulation from heat and electricity to protect the welder.

The size of the welding torch nozzle depends on the amount of shielded area desired. The size of the gas nozzle will depend upon the diameter of the electrode, the joint configuration, and the availability of access to the joint by the welder. The inside diameter of the nozzle is preferably at least three times the diameter of the electrode, but there are no hard rules. The welder will judge the effectiveness of the shielding and increase the nozzle size to increase the area protected by the external gas shield as needed. The nozzle must be heat resistant and thus is normally made of alumina or a ceramic material, but fused quartz, a glass-like substance, offers great visibility. Devices can be inserted into the nozzle for special applications, such as gas lenses or valves to improve the control shielding gas flow to reduce turbulence and introduction of contaminated atmosphere into the shielded area. Hand switches to control welding current can be added to the manual GTAW torches.

a Collet Body

The collet body screws into the torch body. It is replaceable and is changed to accommodate various size tungsten and their respective collets.

b Collets

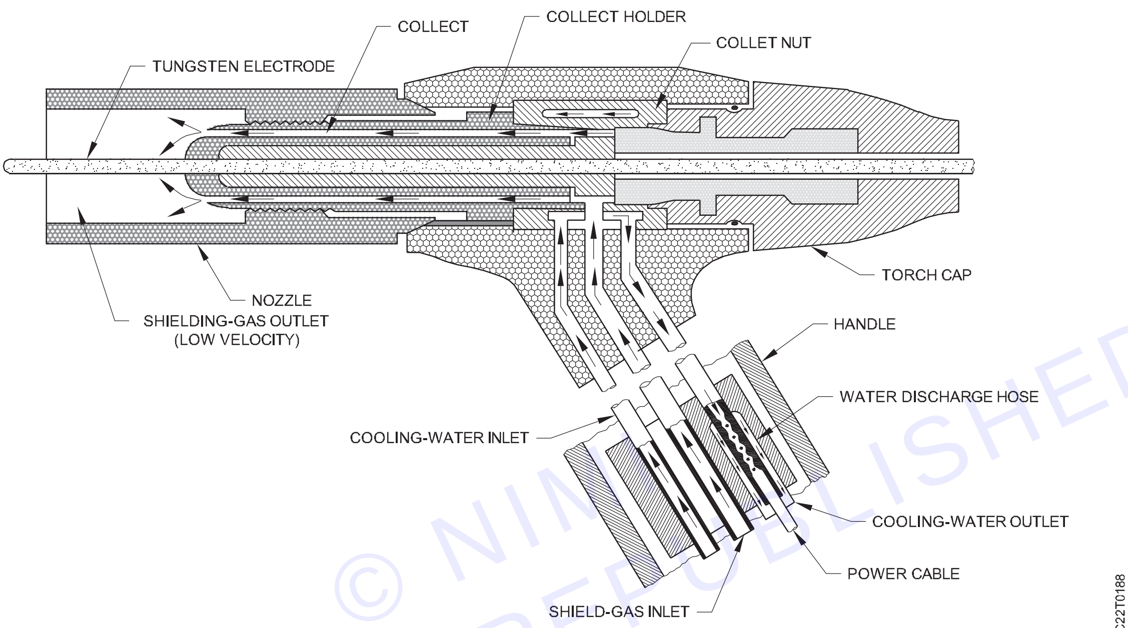
The welding electrode is held in the torch by the collet. The collet is usually made of copper or a copper alloy. The collet's grip on the electrode is secured when the torch cap is tightened in place. Good electrical contact between the collet and tungsten electrode is essential for good current transfer.

c Gas Lenses

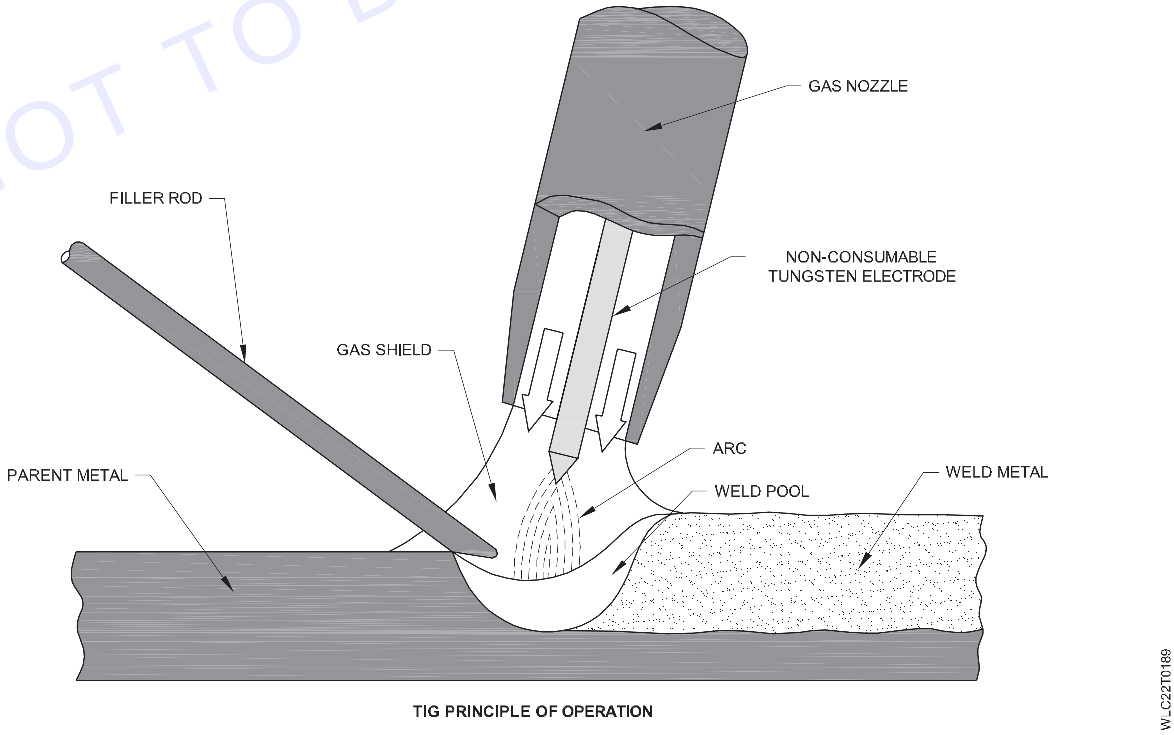
A gas lens is a device that replaces the normal collet body. It attaches to the torch body and is used to reduce turbulence and produce a longer undisturbed flow of shielding gas. A gas lens will allow the welder to move the nozzle further away from the joint allowing increased visibility of the arc. A much larger diameter nozzle can be used, which will produce a large blanket of shielding gas. This can be very useful in welding material like titanium. The gas lens will also enable the welder to reach joints with limited access such as inside corners.

d Nozzles

Gas nozzles or cups as they are better known, are made of various types of heat resistant materials in different shapes, diameters and lengths. The nozzles are either screwed into the torch head or pushed in place. Nozzles can be made of ceramic, metal, metal-jacketed ceramic, glass, or other materials. Ceramic is the most popular, but are easily broken and must be replaced often. Nozzles used for automatic applications and high amperage situations often use a water-cooled metal design. Gas nozzles or cups must be large enough to provide adequate shielding gas coverage to the weld pool and surrounding area. A nozzle of a given size will allow only a given amount of gas to flow before the flow becomes turbulent. When this occurs the effectiveness of the shielding is reduced, and nozzle size must then be increased to restore an effective non-turbulent flow of gas.



TIG WELDING TORCH



TIG PRINCIPLE OF OPERATION

Edge preparation and fit up for TIG welding sheet, plates, and pipes

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

- describe the TIG welding low alloy steel
- explain the TIG welding aluminium sheets and pipe.

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 jointing's 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 is well shown in practical Exercise book.

Low alloy steel (DCSP)

Metal	Joint	Tungsten	Filler Rod	Cup	Shield Gas Flow			Welding	Travel
Gauge	Type	size	Size	Size	Type	CFH (L/Min}	PSI	Amperes	Speed
1.6mm	Butt	1.6mm	1.6mm	4,5,6	Argon	15 (7)	20	95-135	400mm
	Fillet								
3.2mm	Butt	1.6mm	2.4mm	4,5,6	Argon	15 (7)	20	145-205	300mm
	Fillet	2.4mm							
4.8 mm	Butt	2.4 mm	3.2 mm	7, 8	Argon	16 (6.5)	20	210-260	250 mm
	Fillet								
6.4mm	Butt	3.2mm	4.0mm	8,10	Argon	18(8,5)	20	240-300	250mm
	Fillet								

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 900 to 2000C preheat temperature will slow the cooling rate and prevent the martensitic structure.

Typical manual GTA (TIG) welding parameters

Aluminium (ACHF)

Metal	Joint	Tungsten	Filler Rod	Cup	Shield Gas Flow			Welding	Travel
Thickness	Type	size	Size	Size	Type	CFH (L/Min}	PSI	Amperes	Speed MM/min
1.6mm	Butt	1.6mm	1.6mm	4,5,6	Argon	15 (7)	20	60-80	400mm
	Fillet							70-90	
3.2mm	Butt	1.6mm	2.4mm	4,5,6	Argon	15 (7)	20	125-145	300mm
	Fillet	2.4mm						140-160	
4.8 mm	Butt	2.4 mm	3.2 mm	7, 8	Argon	16 (6.5)	20	190-220	250 mm
	Fillet							210-240	
6.4mm	Butt	3.2mm	4.0mm	8,10	Argon/ Helium	18(8,5)	20	260-300	250mm
	Fillet							280-320	

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

Metal	Joint	Tungsten	Filler Rod	Cup	Shield Gas Flow			Welding	Travel
Gauge	Type	size	Size	Size	Type	CFH (L/Min}	PSI	Amperes	Speed MM/min
1.6mm	Butt	1.6mm	2.4mm	5,6	Argon	1/3 (5)	15	60	500
	Fillet		3.2mm					60	
3.2mm	Butt	2.4mm	3.2mm	7,8	Argon	1/9 (9)	15	115	450
	Fillet	2.4mm	4.0mm					115	
6.4 mm	Butt	4.8 mm	4.0 mm	8	Argon	2/5 (12)	20	100-130	550
	Butt (2)							110-135	500
6.4mm	Butt	3.2mm	4.0mm	8,10	Argon/ Helium	18(8,5)	20	260-300	250mm
	Fillet							280-320	

Welding magnesium

Magnesium alloys are in three groups, they are (1) aluminium-zinc-magnesium, (2) aluminium-magnesium, and(3) manganese-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.

MODULE 7 : GTAW

Lesson 61 - 76 : Welding parameters and Tables & data relating to TIG Welding.Tungsten electrode, Types, sizes, and uses. coding as per AWS

Objectives

At the end of this lesson you shall be able to

- describe the TIG welding parameter
- explain the TIG welding tungsten electrode
- explain the TIG welding tungsten electrode colour code.

Welding Parameters And Tables & Data Relating To Tig Welding

The Typical type of current, Tungsten Electrodes and Shielding Gases for Welding Different Metal are show in the Following table.

Sl No	Types Of Metal	Thickness	Types Of Current	Electrode	Shielding Gas
01	Aluminium	All	AC	PURE/ Zirconium	Argon
02	Magnesium	All	AC	PURE/ Zirconium	Argon
03	Copper	All	DCEN	Theoriated	Helium
04	Stainless steel	All	DCEN	Theoriated	Argon
05	Titanium	All	DCEN	Theoriated	Argon
06	Nickel	All	DCEN	Theoriated	Argon
07	Mild steel	All	DCEN	PURE/ Zirconium	Argon

Tig Welding Tungsten Electrode

In TIG Welding the electrode should by definition to non-fusible tungsten whose weigh point is extremely high in the metal 500 The electrode may be of pure tungsten tut is more generally of tungsten alloyed with thorium cride (thorium ThO) of Zirconium side (Zacerium-ZO) or Cerium Oxide (CO_2) or Lanthanum Oxide (La,O, The electrodes are obtained in ground finish form se chemically cleaned and etched

Tungsten has a melting point of 3380° C and a boiling point of 5950° C. So that there is only little Vaporization in the arc and it retains it's hardness when red hot. Thus these electrodes are virtually classified as non consumable

Classification of electrodes

The following titles gives the electrodes available as per American Welding Society Classification AWS A 5 12-92

Aws Classification	Percentage Of Alloying Element	Colour Code	Electrode Diameter
EWP	0% (Pure Tungsten)	Green	0.25mm, 0.50mm, 1.01mm, 1.52mm, 2.36mm, 3.17mm, 3.96mm, 4.74mm, 6.35mm,
EW Th-1	08-12% (Thoriated)	Yellow	
EW Th-2	1.7 2.2% (Thoriated)	Red	
EW ZR-1	0.15-0.40 (Zircoriated)	Brown	
EW Ce-2	1.8-2.2 (Ceriated)	Orange	
EW La-2	09-1.2 (Lanthanated)	Black	
EWG	Not specified	Gray	

In the AWS classification system. E stands for an electrode which is used as one terminal of the arc welding circuit. The W stands for the chemical symbol for tungsten (also called Woll- fram) .The final letters indicate the alloying element or oxide additions. P designator a pure tungsten electrode without internal alloying element, while all other designations are for certain oxide additions. The is for thoriated, Zr is for Zirconiated, La is Lanthanated and G stands for unspecified oxide additions. Finally the numbers specify the nominal alloying composition (in weight percent). For instance EWTh-1 is a thoriated tungsten electrode that contains nominally 1 Wt% thorium. Individual electrodes are marked usually with a band (or dot) of the appropriate colour, on one end of the electrode.

The addition of alloying element lower the voltage necessary to stick the arc because they gives of electron. The current carrying capacity of an electrode is increased depending on the percentage of alloying element, and the alloying elements help to stabilize the arc and increases the lfe of the electrode.

1 Pure Tungsten Electrode(EWP)

Pure Tungsten Electrode (EWP) contain a minimum of 99.5 wt% tungsten, with no intentional alloying elements. These electrodes are identified with a green colour code. The current carrying capacity of pure tungsten electrodes is lower than that of the alloyed tungsten electrodes. Pure tungsten electrodes are used mainly with alternating current (AC) for welding of aluminium and magnesium alloys. With this type of current, the tip of the EWP electrode forms a clean balled end, it provides good arc stability. The pure tungsten electrode also may be used with direct current, but they do not provide the arc initiation and arc stability characteristics of thoriated, ceriated, or lanthanated electrodes. Direct current electrode positive (DCEP) or reverse polarity welding also causes splitting and melting of pure tungsten electrodes.

The pure tungsten electrodes are the least expensive, but are more prove to contamination of the weld than the other types of tungsten electrodes. THEY ARE GENERALLY ONLY USED AC WELDING, because DC welding with pure tungsten electrodes typically produces small amounts of tungsten inclusions (discontinuities) in the weld.

2 Zirconiated Tungsten Electrodes (Ewzr-1)

Zirconiated tungsten electrodes (EWZr-1) contain a small amount (0.15 to 0.40 Wt-%) of Zirconium Oxide (ZrO2), as listed in Table. These electrodes are identified by a brown colour code. Zirconiated tungsten electrodes have welding characteristics that generally fall between those of pure tungsten and thoriated tungsten electrodes. THEY ARE NORMALLY THE ELECTRODE OF CHOICE FOR AC WELDING OF ALUMINIUM AND MAGNESIUM ALLOYS because they combine the desirable arc stability characteristics and balled end typical of pure tungsten along with the higher current carrying capacity and better arc starting characteristics of thoriated tungsten electrodes. They are more resistant to tungsten contamination of the weld pool then pure tungsten and are preferred for radiographic-quality welding applications as tungsten contamination of the weld must be minimized

3 Thoriated Tungsten Electrodes (Ew Ts-1 And Ew Th-2)

Thorium Oxide (Th O2), which is called throne is another oxide used to alloy tungsten electrodes Two types of thoriated tungsten electrodes are readily available .The EW Th -1 electrodes contain a nominal Wt% thoria and the EW Th 2 electrodes contain a normal

2 Wt-% thoria evenly disposed throughout their entire length . The 1 Wt% thorated tungsten electrodes have a yellow colour, while the 2 W% thoriated tungsten electrodes have a red colour identification

4 Ceriated Tungsten Electrodes (Ew Co-2)

The EW Ce2, electrodes are tungsten alloy electrodes that contain a nominal 2 Wt-% Cerium Oxide (CeO2, referred to as ceria) These electrodes have an orange colour code.

The ceriated tungsten electrodes were developed as possible replacements for thoriated tungsten electrodes, because ceria, unlike thoria is not radio-active material. Compared with pure tungsten, the ceriated tungsten electrodes provide similar current level, and the improved arc starting band arc stability characteristics of thoriated tungsten electrodes. They also tent to have longer life than thoriated tungsten electrodes. EW Ce-2 ELECTRODES WILL OPERATE SUCCESSFULLY WITH AC OR DC

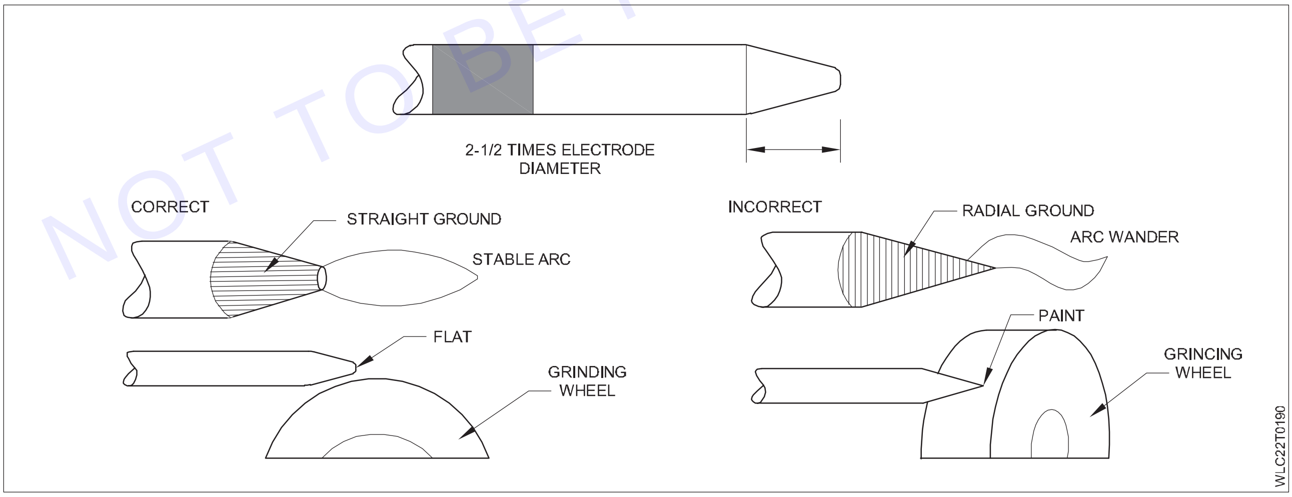
5 Lanthanated Tungsten Electrodes (Ew La-1)

The lanthanated (EW La-1) tungsten electrodes were developed around the same time as the ceriated tungsten electrodes and for the same reason, that is Lanthana is not radio active These electrodes contain a nominal 1 W% lanthanium oxide (La_2O_2), referred to a Lanthana The current levels, advantages and operating characteristics of these electrodes are very similar to the ceriated tungsten electrodes. THESE MAY HAVE OPERATING CHARACTERISTICS SIMILAR TO THE EW C-2 AND EW Th-2

Prepare Tungsten

Grind your tungsten to a point. When welding on aluminum, the tungsten will begin to form a ball. If the ball grows to the same diameter as your tungsten, re-point the tungsten. Grind in the long direction and make the point roughly 2½ times as long as the diameter.

Use a 200 grit or finer grinding wheel. Do not use the wheel for other jobs or tungsten can become contaminated causing lower weld quality



Filler metals for GTAW Types & Specifications as per BIS & AWS and Argon / Helium gas properties and application

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

- describe the filler metals types for TIG welding
- explain the filler metal specification for GTAW
- explain the TIG welding helium gas.

In the welding process (GTAW or gas tungsten) is an arc welding process operates the filler rods.

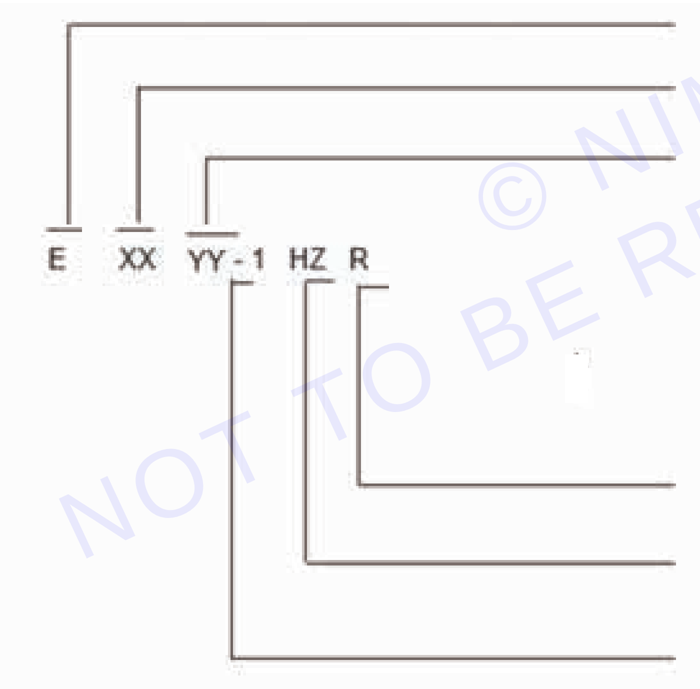
The TIG torch may be cooled by air or water and the process uses a filler metal in road form. The tungsten Elec trod selection and parameters for welds are guided them.

Gas tungsten arc welding also know as tungsten inert gas (TIG) welding, is an arc development within the GTAW process.

Now always the filler rods is withdraw from the weld pool each time the electrode can be changed.

welding filler metal designators

1 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

Designates that the electrode meets the requirements of absorbed moisture

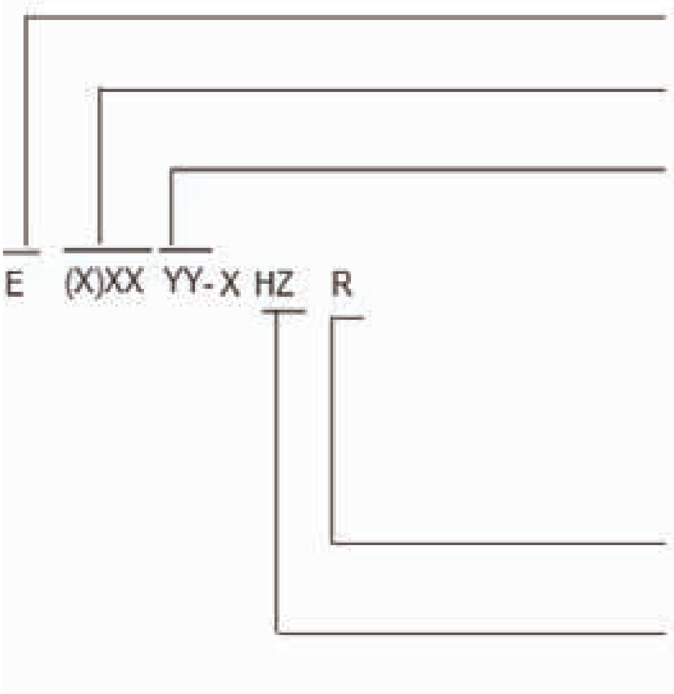
Designates that the electrode meets the requirements of the diffusible hydrogen test with an average value no exceeding "Z" mL of H2 per 100gms of deposited metal.

Designates that the electrode meet the requirements for improved toughness and ductility.

Optional supplemental designators			
AWS Classification	**Type of covering**	**Welding position**	**Type of current [b]**
E6010	High cellulose, sodium	F,V,OH, H	dcep
E 6011	High cellulose, potassium	F,V,OH,H	as or dcep
E 7018	Low hydrogen, Potassium, Powder	F,V,OH,H	ac or dcep
E7024	Iron Powder, Titanium	H-Fillets, F	ac, dcep or dcen

2 Alloy steel electrodes

Mandatory classification designators



Designates and electrode

Designates minimum tensile strength, in Ksi, of the as- deposited weld metal

Designates the welding position, the type of covering and the type of welding current for which the electrodes are suitable.

Designates the chemical composition of the undiluted weld metal produced by the electrode using SMAW process.

Optional supplemental designators

Designates that the electrode meets the requirements of absorbed moisture.

Designates that the electrode meets the requirements of the diffusible hydrogen test - with an average value not exceeding "Z" mL of H2 per 100gms of deposited metal, where "Z" is 4,8 or 16.

Refer to AWS A 5.5 for complete listing of mechanical properties, chemical composition of as deposited weld metal and testing procedures for SMAW process.

3 Stainless steel filler metal

Usability classification

Types of welding current and position of welding		
AWS classification	**Welding current**	**Welding position**
EXXX (X) - 15	dcep	All
EXXX (X) - 16	dcep or ac	All
EXXX (X) - 17	dcep or ac	All
EXXX(X) - 25	dcep	H,F
EXXX (X) - 26	dcep or ac	H,F

For more details on the usability classifications, refer to AWS A 5.4

Types of welding current and position of welding						
Base material	**Carbon steel**	**Carbon-molybdenum steel**	**1 and 1 1/4 Cr-1/2 Mo steel**	**2 1/4 Cr-1 Mo steel**	**5 Cr-1/2 Mo Steel**	**9 Cr - 1 Mo steel**
Carbon steel	AB	AC	AD	AE	AF	AG
Carbon-Molybdenum steel		C	CD	CE	CF	CH
1 and 1 1/4 Cr-1/2 Mo steel			D	DE	DF	DH
2 1/4 Cr-1 Mo steel				E	EF	EH
5 Cr - 1/2 Mo steel					F	FH
9 Cr-1 Mo steel						H

Legend

A AWS A 5.1 classification E 70XX low hydrogen (E7018 preferred)

B AWS A 5.1 classification E 70XX low hydrogen (E7018 preferred)

C AWS A 5.5 classification E70XX - A1, low hydrogen

D AWS A 5.5 classification E70XX - B2L or E80XX B2, low hydrogen

E AWS A 5.5 classification E80XX-B3L or E80XX B6L, low hydrogen

F AWS A 5.5 classification E80XX-B6 or E80XX-B6L, low hydrogen

G AWS A 5.5 classification E80XX-B7 or E80XX-B7L, low hydrogen

H AWS A 5.5 classification E90XX-B8 or E80XX-B8L, low hydrogen

1 Table 1 refers to coated electrodes (SMAW process) only. For bare wire welding (SAW, GMAW, GTAW and FCAW), use equivalent electrode classifications (AWS A 5.14, A 5.17, A5.18, A 5.20, A 5.23, At 28)

2 Higher allow electrode specified in the table should normally be used to meet the required tensile and toughness after post weld heat treatment (PWHT). If no PWHT is required, the lower alloy electrode specified may be required to meet the hardness requirements.

Table 2: Austenitic, super-austenitic and duplex stainless steel alloys

Types of welding current and position of welding										
Base Material	**304L SS**	**304H SS**	**316L SS**	**317L SS**	**904L SS**	**6% Mo SS**	**7% Mo SS**	**Alloy 20Cb-3**	**2304 Duplex SS**	**2205 Duplex SS**
Carbon and low alloy steel	ABC	ABC	ABC	ABC	ABC	ABC	ABC	ABC	N	N
Type 304L stainless steel	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 in one 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 (Has alloy C-276)

K - AWS A 5.11 classification ENiCrMo-11 (Has alloy 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

Recommended Filler Metal For Tig Welding

Sl No	Base Material		Filler Metal Classification	Aws Electrode Specification
	Type(Base Metal)	Classification(Base Metal)		
1	Aluminium and Aluminium Alloys (ASTM Standards Volume 2.02)	1100 3003, 3004, 5052, 5454, 5083, 5086, 5456, 6061, 6063	ER 4043, ER 5356, ER 5554, ER 5556, or ER 5183, ER 5556, ER 5356, ER 4043 or ER 5356	A 5-10
2	Magnesium alloys (ASTM standards Volume 2.02)	AZ 10A, AZ 318, AZ 61A, AZ 80A, ZE 10A, ZK 21A AZ 63A, AZ81A, AZ 91C AZ92A, AM100A, HK31A,HM 21A, HM 31A, LA141A	ERAZB1A, ERAZ92A ERAZ61A, ERAZ92A ERAZG1A, ERAZ92A, ERAZ92A, EREZ33A, EREZ33A, EREZ33A, EREZ33A	A 5-19
3	Copper and Copper alloys (ASTM Standards Volume 2.01)	Commercially Pure Brass Cu-Ni alloys Manganese bronze, Aluminium bronze, Bronze	ERCu ERCUSI-A, ERCuSn-A, ERCuNi, ERCUAI-A2 ERCUAI-A2 ERCuSn-A	A 5-7
4	Nickel and Nickel alloys (ASTM Standards Volume 2.04)	Commercially Pure NiCu alloys Ni-Cu-Fe alloys	ERNI ERNICu-7 ERNiCrFe-5	A 5-14

5	Titanium and Titanium alloys) (ASTM Standards Volume 2.04	Commercially Pure Ti-6 Al-4V Ti-0.15 Pd Ti-5 Al-2 5Sn Ti-13V-11Cr-3A1	ERTI-1, -2, -3, -4 ERTI -6 Al-4V ERTI -0.2 Pd ERTI-5 Al-2.5Sn ERTi-13V-11Cr-3Al	A 5-16
6	Austenitic Stainless Steels (ASTM Standards Volume 1.04)	Type 201 Types 301, 302, 304 and 308 Type 304L Type 310 Type 316 Type 321 Type 347	ER308 ER308 ER308L ER310 ER316 ER321 ER347	A5-9
7	Carbon Steels	Hot and Cold rolled Plain Carbon Steels	E70S-3, or E70S-1 E70S-2, E70S-4. E70S-5, E70S-6	A 5-18

Argon / Helium gas properties and application

Necessity

The Shielding gas provides the suitable ionising atmosphere for the arc and protects the weld pool from atmosphere contamination. Inert gases Argon and Helium are used for TIG Welding Nitrogen is tried along with argon for joining copper and copper alloys.

Argon gas

Argon is generally considered better shielding gas for the TIG welding because it provides better control of the weld puddle and the arc and prevents atmosphere contamination. It is possible to see the arc as there is less clouding. Argon provides a more perfect shield as it is heavier than air and it blankets weld better than air. It provides a better cleaning action on Aluminium and Magnesium. Argon being a chemically inert gas and it forms no compound with other chemicals

Argon is a heavy inert monatomic gas with an atomic weight of 40. It is obtained from the atmosphere by liquefaction of air, refined and transported as a liquid. Argon can be obtained at 99.995% purity

Helium gas

Helium is a light, inert, monatomic gas with an atomic weight of 4. All commercial helium is extracted from natural gas. It is shipped as a gas in cylinders. Because helium is lighter than air, higher flow rate is required than Argon.

COMPARISON BETWEEN ARGON AND HELIUM SHIELDING		
ARGON		HELIUM
1	Smoother arc.	Smaller heat affected zone
2	Easy starting.	Best for thicker metal welding due to higher arc voltage.
3	Best for thinner metal welding due to lower arc voltage	Better for welding at higher speed.
4	Good cleaning action while welding Al	Gives better coverage in vertical and overhead positions
5	Heavier than air Lower flow rates.	When used in back shielding flattens the root face
6	Lower cost, more availability	
7	Better for welding dissimilar metals	
8	Better control of puddle on positional	

Following table gives gas and gas mixtures recommended for the welding applications.

Sl No	Metals	Recommended Shielded Gas	Advantages
1	Aluminium	Argon Helium Argon-Helium	Easier ignition, better cleaning Improved weld Quality. Possibility of higher welding speed. Compared to pure helium, better weld quality.
2	Magnesium 0-1.5 mm > 1.5 mm	Helium Argon	Penetration easier to obtain. Excellent cleaning, pool easier to control.
3	Mild Steel 0-3 mm > 3 mm According to preparation TIG spot	Argon Argon-Helium Argon	Increasing operating flexibility. (possibility of overheating). Helium addition improves penetration of thick work pieces. Argon generally preferred. Lower electrode wear, easier ignition, lower gas flow. Control of weld pool easier, especially for positional welding.
4	Stainless Steel	Argon Argon-helium	Welding of thin work pieces, good (easier) control of penetration. Higher arc power, higher welding speed on thick sheets.
5	Copper –Ni Cupro –Ni Inconel Copper alloys	Argon Argon-Helium Helium	Easier to control pool, penetration and bead shape on thinner sections Higher arc energy is useful for thick materials having high thermal conductivity. High thermal power, useful for welding thick materials.

Pulsed TIG welding and application. Square wave concept and wave balancing

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

- describe the pulse TIG welding
- explain the pulse TIG application.

Pulsed TIG welding

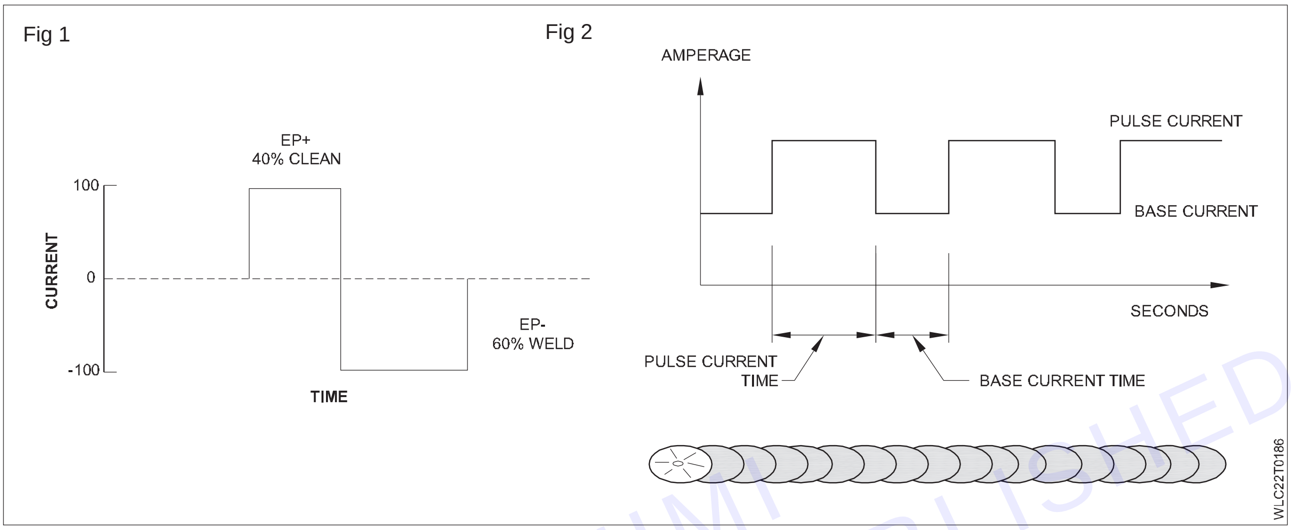
In the pulsed-current mode, the welding current rapidly alternates between two levels. The higher current state is known as the pulse current, while the lower current level is called the background current. During the period of pulse current, the weld area is heated and fusion occurs. Upon dropping to the background current, the weld area is allowed to cool and solidify. Pulsed-current GTAW has a number of advantages, including lower heat input and consequently a reduction in distortion and war page in thin work pieces. In addition, it allows for greater control of the weld pool, and can increase weld penetration, welding speed, and quality. A similar method, manual programmed GTAW, allows the operator to program a specific rate and magnitude of current variations, making it useful for specialized applications.

Advantages of pulsation are:

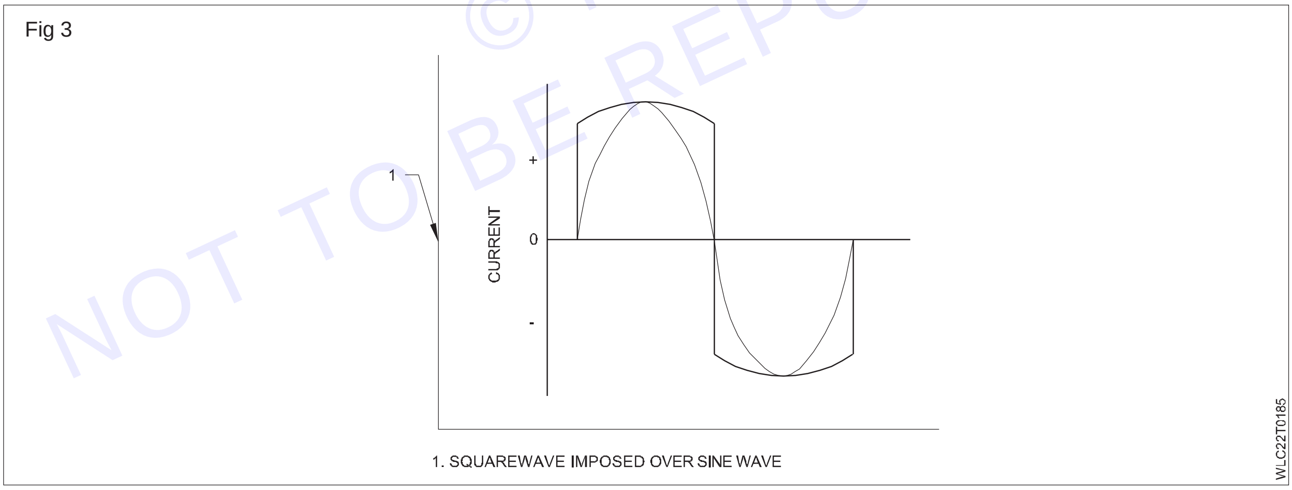
- Low heat input
- Low porosity formation
- Resistance hot cracking
- Added life to electrode
- Low distortion

- Small HAZ width
- Low power consumption
- better penetration
- better control when welding out of position
- easy to use on thin materials

In this type of power source, the supply current is not constant and it is being fluctuated from low level to high level. This causes low heat input to the metal and hence distortion effect will be less. (Fig 1,2)



AC - Alternating Current - Square Wave (Fig 3)



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

AC balance control allows the operator to adjust the balance between the penetration (EN) and cleaning action

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 cur-rent 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 percent-age of the total time, which controls how long the peak current is on for before dropping to the background cur-rent.

The pulse and base current periods are also controllable.

When welding is done with pulsing welding mode the weld is in principle a row of spot welds overlapping to a larger or smaller extent depending on the welding speed.

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 the positive and the negative semi-periods

Application of pulse welding

Pulse TIG welding is most commonly used to weld thin sections of stainless steel, non-ferrous metals such as aluminium, magnesium and copper alloys.

Different types of weld joint, plates & pipe. Advantage of root pass welding of pipe by TIG welding

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

- describe the filler metals types for TIG welding
- explain the filler metal specification for GTAW
- explain the TIG welding helium gas.

Types of welding joints by TIG welding

There are five basic joint designs mentioned below.

1 Butt joint

2 Lap joint

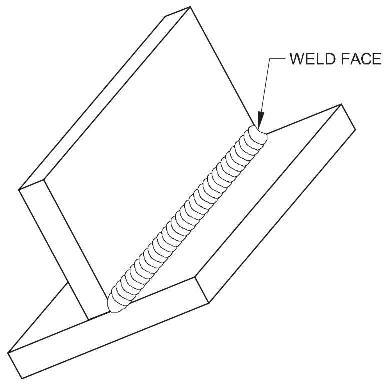
3 corner joint

4 T joint (Fillet joint)

5 Edge joint

The Fig 1 below shows, filler T joint welded in flat position, When the weld axis and weld face are horizontal.

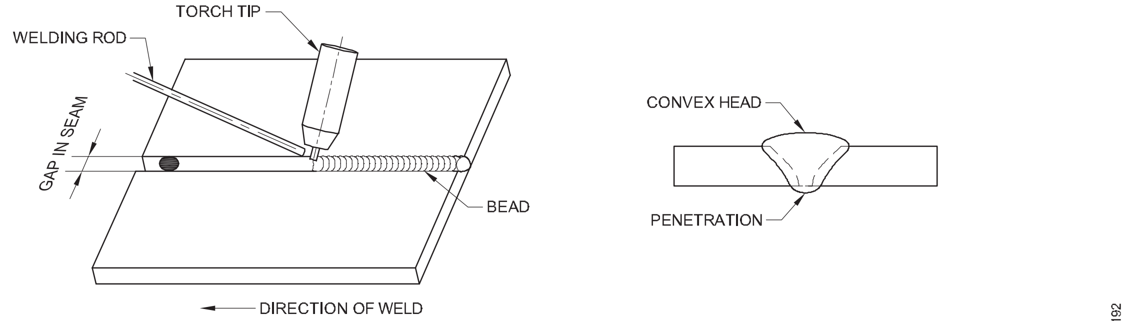
Fig 1



T - JOINT WELDED IN FLAT POSITION

Square butt joint on aluminium: The Fig 2 shows the recommended torch and welding filler rod positions for welding a butt joint in flat position.

Fig 2

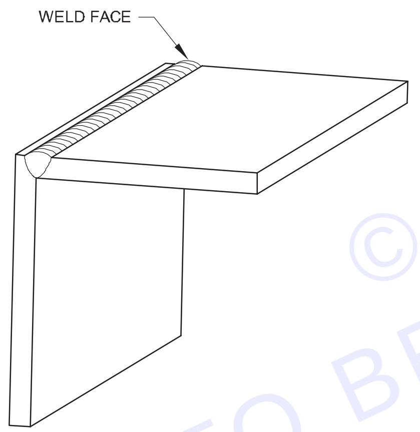


RECOMMENDED TORCH AND WELDING POSITIONS FOR WELDING A BUTT JOINT IN THE FLAT POSITION

Outside corner joint on aluminium: Fig 3 on the next page shows a typical corner joint welded from outside.

Fig 4 shows the setup for fillet tee joint on stainless steel sheets, welded by (TIG) GTAW process. Satisfactory weld, should be free from undercut at the toes and of equal leg lengths

Fig 3



OUTSIDE CORNER JOINT

Fig 4

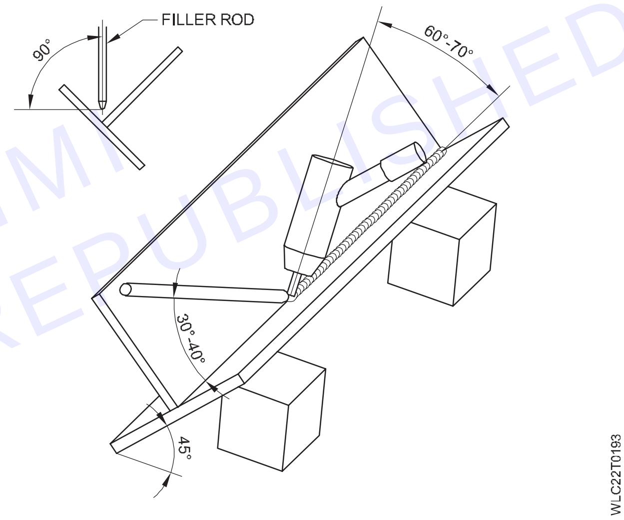
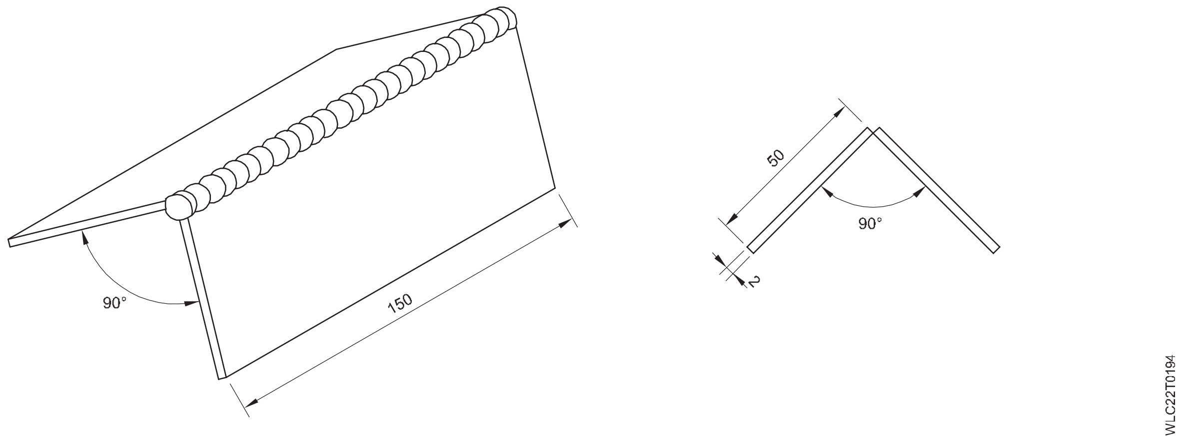


Fig 5 shows the corner joint welded by TIG process. It also gives the set up for making the outside corner joint in flate position.

Fig 5



Stainless steel (DCSP) Welding parameters

Metal Gauge	Joint Type	Tungsten size	Filler Rod Size	Cup Size	Shield Gas Flow		Welding Amperes	Travel Speed mm/min
					Type	CFH PSI (L/Min)		
1.6 mm	Butt	1.6 mm	1.6 mm	4,5,6	Argon	11 (5.5) 20	80-100	300
	Fillet						90-100	250
3.2 mm	Butt	1.6 mm	2.4 mm	4,5,6	Argon	11 (5.5) 20	120-140	300
	Fillet						130-150	250
4.8 mm	Butt	2.4 mm 2.4 mm 3.2 mm	3.2 mm	5,6,7	Argon	13 (6) 20	200-250	300
	Fillet						225-275	250
6.4 mm	Butt	3.2 mm	4.8 mm	8, 10	Argon	13 (6) 20	275-350	250
	Fillet						300-375	200

Pulsed TIG welding and description of pulse parameters

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

better penetration with less heat

less distortion

better control when welding out of position

Easy to use on thin materials

The down side is - more set-up cost and more operator training.

Pulsed TIG consists of

Peak current - This is set up higher than for non-pulsed TIG.

Background current - This is set lower than peak current and is the bottom current the pulse will drop to, but must be enough to keep the arc alive.

Pulses per second - This is the number of times per second that weld current reaches peak current.

%on time - This is the pulse peak duration as a percentage of the total time, which controls how long the peak current is on for before dropping to the background current. The pulse and base current periods are also controllable When welding is done with pulsing welding mode the weld is in principle a row of spot welds overlapping to a larger or smaller extent depending on the welding speed. Many double-current machines are equipped with a control function which makes it possible to modify the curve the alternating current in balance between thew positive and the negative semi-periods.

Types of weld defects, causes, remedy in GTAW

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

- describe the weld defect in GTAW
- explain the weld defect causes in GTAW
- explain the weld defect remedy in GTAW.

The following table relates to the cause and prevention of the more common defects encountered in welds made by the TIG welding process.

Sl.No	Defect	Appearance	Cause	Remedy
1	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.
2	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.
3	Lack on fusion	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.
4	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.
5	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 on surface of filler rod. Inadequate protection of underside of a weld. Loss of gas shield.	Clean all metal surfaces. Ensure a satisfactory supply of shielding gas. Exclude draughts.
6	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.	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.

Submerged Arc welding- principles, application - Types of flux, welding head, power source and parameter setting

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

- describe the submerge arc welding principal
- explain the submerged arc welding flux
- explain the submerged welding power source.

1 **Introduction**: The optimum performance of welded vessels and structures in service have led to the full exploitation of automatic welding processes. Submerged Arc Welding has been playing a prominent role in this endeavour and it finds application in a variety of components from pressure vessels, structures machine building etc., to hard facing of components exposed to wear. In submerged arc welding processes, the heat for welding is supplied by an arc, developed between a consumable electrode and the work piece under a blanket of granulated flux.

2 **Principle of Operation**: In submerged arc welding, the arc is submerged in the flux and hence there is no visible sign of the arc. Welding current flows through the arc and the heat of the arc melts the electrode, flux and some base material to form a weld puddle that fills the joint. Sufficient depth of flux present in this process completely shields the arc column and protects the weld pool from atmospheric contamination. As a result of this protection, the weld beads are exceptionally smooth. The flux adjacent to the arc columin, melts undergoes reaction and floats at the surface as slag.

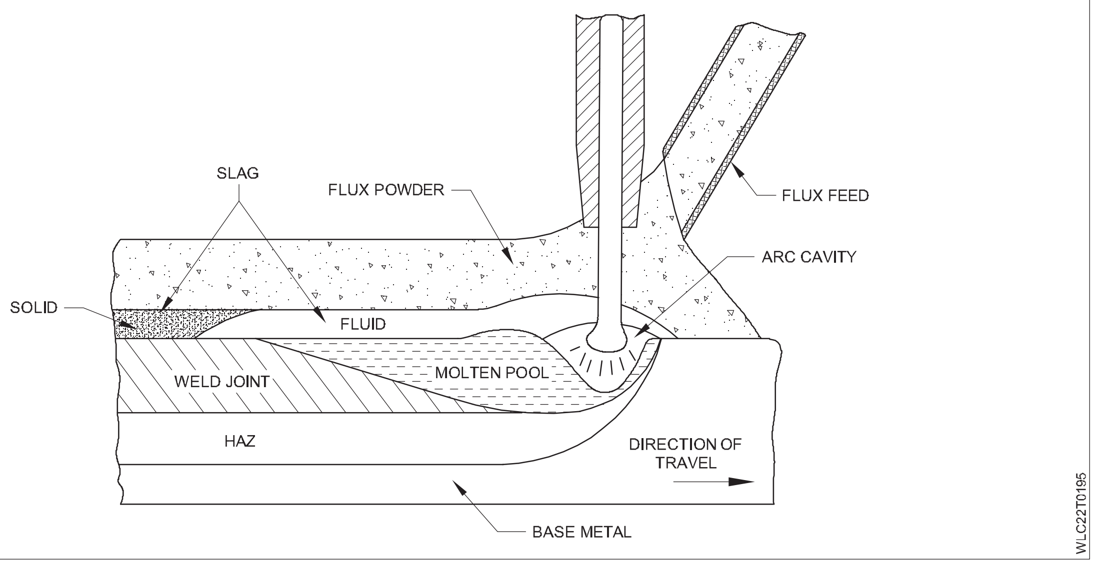
3 **Characteristics:** The hidden or submerged arc process has several distinguishing characteristics which are responsible for its numerous advantages.

a **High Current Densities:** Because the current is applied to the electrode so that it has a short distance to travel, relatively high amperages can be used on small diameter wires. This results in extremely high current densities on relatively small cross-sessional areas of electrode. Current as high as 600 amps can be carried on electrodes as small as 5/64" (2.0 mm). This creates a density on the order of 1,00,000 amperes per square inch, six to ten times that carried on manual electrodes.

b **Melt-off rates**: The melt-off rate of the electrode is affected by the electrode material,the flux, type of current, polarity and the length of wire beyond the where current is introduced Because of the high current density of the wire, the melt-off rate is very much higher for a given diameter electrode than it would be with hand welding.

c **Speed**: High current densities, high melt off rates and mechanical operation produce speeds of welding, ranging from 15" a minute on heavy fillet weld in 1" plate to 150" per minute on 12 gauge to 1/4" material. The operation of the process is such that it solves the problem of fast follow, as well as providing the optimum condition of fast fill.

Fig 1



d **Penetration:** The high speeds and current densities of submerged arc welding produce deep penetration. Full butt welds can be made in one pass from each side without edge preparation in material up to 5/8" thick. Full penetration fillet welds can be made in materials upto 3/4" thick without edge preparation. Because of the large amount of penetration into the base metal, even where a groove is used, the joint is largely base metal. Approximately two volumes of base metal are melted to one volume of filler metal. The large amount of base metal fused in the joint permits welding many different types of steel electrode. The chemistry of the joint can be controlled through procedure variables and by putting alloys in the flux, through which they are transferred to weld metal.

4 **Advantages**: The process has many advantages and equipment, for the application of the process is so versatile that the advantages can be realised on many types of jobs.

a **Cost:** The most obvious advantage of submerged arc welding is cost reduction. Not only arc welding speed increased to 2 to 10 times that of hand welding, but also, frequently, other factors that contribute to cost are significantly affected. The high penetration of the submerged arc can eliminate or reduce the cost of edge preparation. The uniform heat input and high speeds reduce the amount of distortion in the work. The automatic, continuous operation of the process greatly increases the operating factor for the job. Contributing also to this are improved working condition, absence of the visible arc and therefore need to wear a shield. The elimination of spatter by the flux shielding and the usually easy removal of the fuesd flux reduce cleaning time.

b **Quality**: The mechanical operation of the process, machine control of procedures, and the efficient shielding provided by the granular flux produce uniformly excellent weld metal. Welds are smooth with minimum reinforcement, strong, dense and ductile. Since the flux is inorganic, the welds are also low in hydrogen and therefore, low in crack sensitivity welds can be enameled without stress relieving and meet the rigid requirement of the ASME pressure vessel code.

5 **Welding Set Up (Fig 2)**

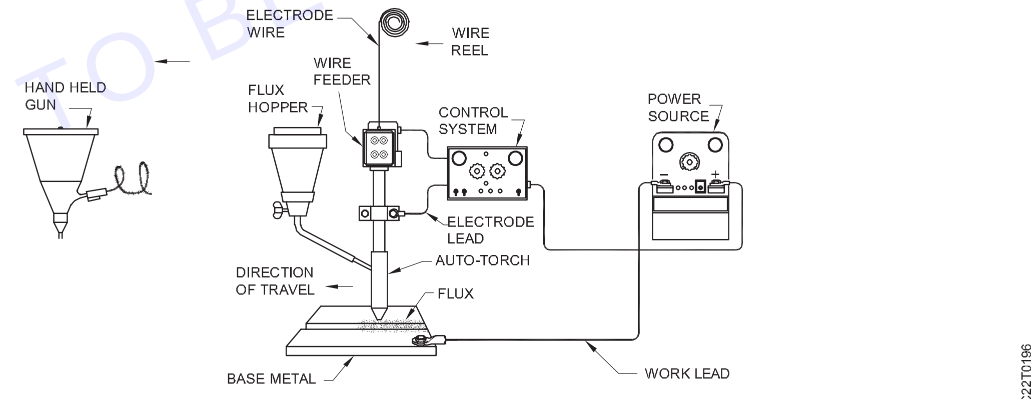
The basic requirement of the submerged arc welding set up are:

1 Power Source.

2 Welding head.

3 Flux feeding and recovery units.

Fig 2



SUBMERGED ARC WELDING

Welding Head: The submerged arc welding head consists of the wire spool, wire feed system, flux hopper and conveyor and electrical contact nozzle. The electrode wire is un-wound from the spool by the power driven rolls, straightened by a set of staggered pressure rolls and fed through the contact nozzle into the weld pool. The drive for feed is from a motor with speed control provided either by means of a gear box or by means of thyristor controls.

Wire Feed System

The wire feed control may be of the following types:

1 Voltage Sensitive System.

2 Constant Speed System.

The voltage sensitive system operates on the principle of feed back control. The wire is driven by a variable speed D.C. motor. The arc voltage is monitored by a sensing element, amplified and fed to the armature of the wire feed motor. Thus, the wire feed rate increases when the arc voltage rises up and vice versa. The arc voltage remains constant during the process. The system is used for high current density arcs.

The constant wire feed system operates through a constant speed motor, usually an induction motor. No feed back control is used in this system. This system is used in conjunction with a constant voltage or constant potential characteristic power source. The arc voltage is constant in this system due to the self adjusting nature of the constant voltage power source. This system is suitable for wire diameter not exceeding 4mm.

Mounting of The Welding Head : The welding head may be fixed by any of the following three methods:

1 Fixed Type

2 Carriage Mounted Type

3 Boom Mounted Type.

1 **Fixed Type**: In this set up, the welding head is kept fixed and movement is provided in the jobs to be welded. A typical application of this arrangement is in the welding of circumferential joints in cylindrical vessels. The job is mounted on powered roller positioners and the welding speed is maintained by controlling the speed of rotation of the job.

2 **Carriage Mounted Type :** In this set up, the welding head is mounted on a movable carriage. The carriage is mounted on rails and powered by a variable speed electric motor. The main controls such as carriage speed, current, voltage, etc., are provided on the carriage itself for facilitating ease of operation. Carriage mounted welding heads are most suitable for butt and fillet welding of plates.

3 **Boom Mounted Type :** These are the most versatile type of welding heads. Normally the boom is supported by means of a column. The welding head along with carriage is mounted on to the boom and longitudinal movement is provided on the carriage. The boom itself is provided with a drive, to move in the transverse direction. Because of the X and Y movements available to this set up, they find extensive applications in longitudinal welding of internal and external surfaces of cylinders and in the manufacture of platformed tubes and shells.

Power Sources: Submerged arc welding can be carried out with both Direct Current and Alternating Current power sources. Hence, a D.C. generator, a Transformer-Rectifier or a Transformer can be used as the power supply unit. The main requirement of the submerged arc welding power source is that it should be capable of supplying heavy current at high duty cycle.

Direct current powers source, with flat characteristics, provides more versatile control over the bead shape, penetration and speeds; difficult contours can be welded at high speeds. Control of bead shape is found to be best with direct current reverse polarity (electrode positive), while high deposition rates are obtained with DC straight polarity (electrode negative) with less penetration. However, Direct Current welding at higher currents create the phenomenon of arc blow.

Alternating current is usually preferred for high current arcs or when the diameter of the wire is 4 mm or above. Multiple are welding is possible using AC power source. The bead shape and penetrations with AC arc are intermediate between DCRP and DCSP.

Flux feeding & recovery system: The flux feeding is from a hopper mounted on the welding head through a tube into the welding zone. The food is normally through gravity in the automatic machines while pneumatic system sare used for semi-automatic machines. The conveyor tube is also provided with stop valve to control the flow of the flux. The conveyer tube is always kept ahead of the contact tube to ensure adequate supply of flux ahead of the arc.

A pressurised system is used for the recovery of the flux. This system sucks the un melted flux from the weld puddle for reuse. It is important that the flux recovery be carried out after the weld pool has completely solidified.

Welding variables: The major process variables in the approximate order of importance are:

1 Welding current

2 Welding voltage

3 Welding speed

4 Electrode stick-out

5 Width and depth of the flux

6 Materials

7 Joint design

8 Joint edges and edge preparation

9 Fit up

10 Tack welds.

1 **Welding Current:** Welding Current is the most influential process variable. It controls the rate at which the electrode is melted, the depth of fusion and the amount of base metal melted. Excessively high current produces a digging arc and the weld may melt through the backing, causing Burn- through, Other side effects are undercuts, highly narrow weld seam and large heat affected zone. Too low a current produces an unstable arc.

The optimum ranges of current for different wire diameters are given below:

Wire dia (mm)	Current range (amps)
1.6	150-350
2.0	200-400
2.4	250-500
3.15	300-650
4.0	450-800
5.0	600-1000
6.3	700-1300

Welding Voltage: The welding voltage is a function of the arc gap. This primarily determines the shape of the fusion zone and reinforcement. High welding voltage produces a wider, flatter, less deeply penetrated weld. The wider bead increases the flux consumption and decreases the resistance to porosity caused by rust or scale. However, a wide bead can accommodate a poor joint fit up. Excessively high voltage produces a hat shaped bead which is prone to cracking.

Low are voltage produces a stiffer arc and improves the penetration in a deep groove joint. However, slag removal is poor in such cases. Excessively low voltages produce a high, narrow bead with very difficult slag removal.

Welding Speed: The welding head travel speed has main influence on the weld size and penetration. Very high travel speeds decrease the wetting action and increases the possibility of undercuts, arc blow, porosity and uneven bead shapes. Since travel speed determines the amount of weld metal deposited per unit length of the weld, the bead shape is essentially controlled by the welding speed. Too low a travel speed increases the heat input into the weld, produces a heavy reinforcement and causes slag inclusions. However porosity is decreased since sufficient time is permitted for the gases to escape to the atmosphere.

Electrode stick-out: This plays an important role for current densities higher than 80,000 amps/in^2. The electrode stick-out is the length of the wire extending beyond the tip of the contact tube above the work piece. Higher stick out imparts resistance heating to the wire before it enters the arc, hence deposition rate is increased. Too high a stick out would soften the wire and stiffness of the wire would be lost.

Width and Depth of Flux: The depth of the flux layer affects the shape and penetration of the weld. If the flux layer is too shallow, the arc is exposed resulting in a porous weld. If the layer is too deep, the weld is rough and uneven. Porosity may result as the gases generated during welding cannot escape to the atmosphere.

Materials: Plain carbon steels which can be readily welded using standard procedures and speeds depends some extent on rigidity of the joint.

Fillet welds for example are somewhat more critical in regard to weld cracking than are butt welds because of inherent rigidity of the joint. Due to this reason the fillet weld and lap welds are restricted to 45,000 to 60,000

Lb// in minimum tensile strength steel with the specific composition range. Whereas butt welds can be made with steels having tensile strength of 45 to 70,000 lb// in2 with specific and preferred composition range. When steels with outside the preferred range of composition it is necessary to reduce welding speed and current to avoid cracking.

Joint design: Because of its high penetration the submerged arc process requires less deposited metal and therefore a change in joint design. Frequently multi pass welds will be changed to a single pass automatic welds.

The Vee groove should be made within 10% of the expected bead width and it should be only as deep as required to eliminate unnecessary built up.

The groove is primarily used to prevent built up of weld rather than secure penetration. In general, for automatic use, Vee groove should be wider than deep otherwise the following may result:

(i) Internal bead cracking is likely to result from internal shrinkage.

(ii) If the arc voltage happens to be high with this narrow groove, there will be a possibility of slag inclusion and incomplete fusion at the bottom of the Vee.

(iii) With a low voltage, an undercut is apt to appear at the edges of the bead.

(iv) There is a tendency of arc to wander to one side resulting in weld being off the seam.

A good rule to follow is to have weld 1.5 times as wide as it is deep. In designing joints, consideration must also be given to the possibility of burn through caused by the penetrating arc.

Joint edges and Edge preparation: Joint edges must be clean of all foreign matters such as moisture, rust, dirt, oil grease and paint primer if satisfactory welds are to be obtained. It is important that the abutting edges are dry and free from foreign matter. It is very important that flux also to be free from contamination by foreign matter, such as grease, water, mill scale and iron oxide.

Fit up: For uniform results the fit up must be accurately controlled and should be as indicated in the procedure tables. For sheet metal, seams should be tight where no gap is specified and the minimum offset of the edges must not be over 10% of the thickness and never be more than 2.4 mm. Drive fits are to be avoided, as they increase tendency for cracking and porosity on heavy plates. A slight gap of 0.4 to 0.8 mm is helpful to minimise rigidity of the joint and reduce the tendency for cracking.

Gaps over 0.8 mm should be sealed for satisfactory automatic welding. For square butt joints up through 9.6 mm (3/8") thickness, the sealing bead should be on the side of the first automatic pass. For plates over 9.6 mm seal on the second pass side.

On butt welds with beveled edges, make the sealing bead on the automatic first pass side. As a general rule E 6010-11 or E 6015-16 should be used for sealing square butt welds and beveled butts. Never use electrode for sealing that will given an oxidised bead, such as, AWS E-6012 or E- 6013. Tack welds should be made with E 6010 or E 6015.

If work is held firmly against a platen, gap can be allowed since the granular flux fills up the gap and supports the molten metal. As long as the flux is held absolutely stationary, the molten metal will be supported. If the molten flux runs out of the joint the molten metal easily follows.

Whenever plate edges, Vee or Square butt, are open over 0.8 mm allowing flux to fall into the seam, precautions must be observed in order to eliminate trapped slag porosity. This type of porosity consists of short large diameter hole compared to long small holes found in the presence of moisture or rust.

The joint must be prepared that the automatic weld completely remelts and eliminates all the flux in the groove or Vee. This may require an increased cross section manual seal bead or a change of design to a 'U' groove or wider Vee (90°) so that the arc reaches the bottom of Vee.

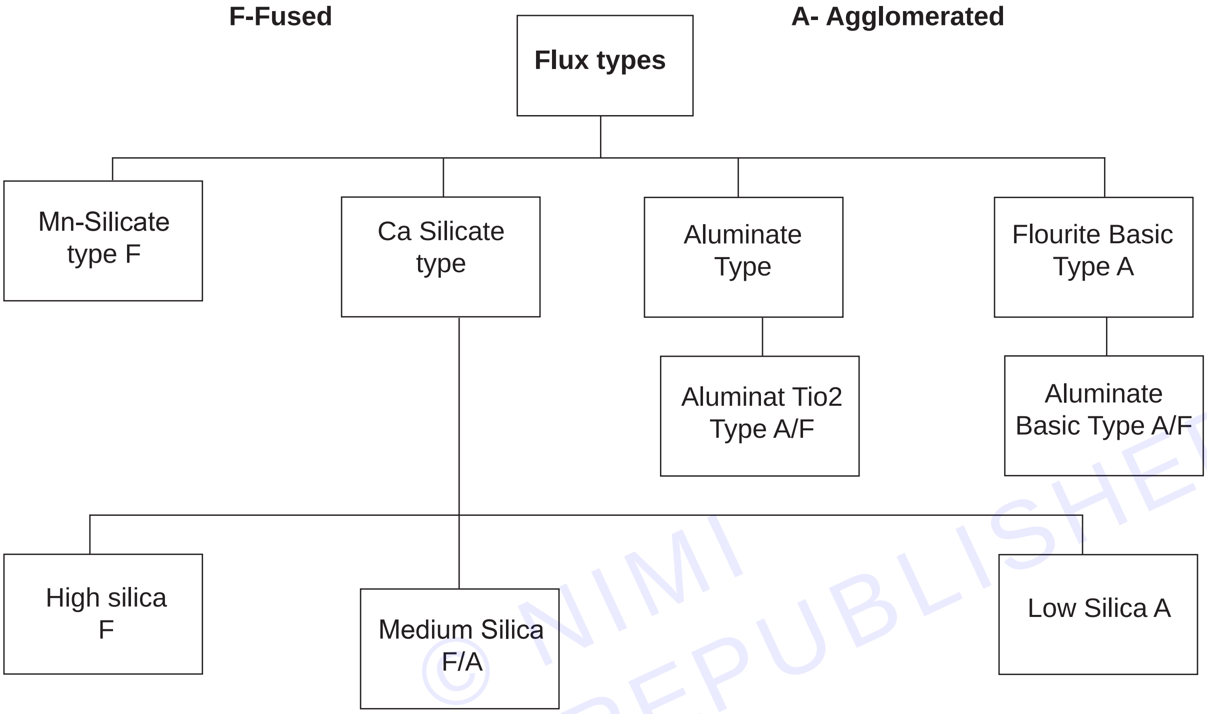
Tack welds: When tack welds are used for holding the edges together, they should be as small in cross section as practical. Avoid the use of short heavy build up tacks. Small fast bead with minimum penetration are the most desirable. E 6010 is most satisfactory. Do not use E 6012, E 6013 or E 4510 as these may result in some porosity. This is especially true at the higher automatic speeds.

Submerged Arc Welding Consumables: Continuous bare wires in the form of coils and dry granular fluxes are used in combination as consumables for the saw of mild steel, low-alloy steels, stainless steels, non-ferrous alloys and for surfacing applications. The bare wires are usually solid wires, but in recent times flux cored wires (i.e. tubular wires carrying flux in the core) have been introduces, which also have to be used in combination with fluxes.

Fluxes: Today two main types of fluxes are available depending on the method of manufacture fused and agglomerated.

1 **Classification**: Like electrode coatings, SA fluxes can be divided into four main classes and five sub classes as shown below. Through A and F the method by which each type of flux is manufactured is Indicated. The table which follows gives composition ranges of various flux types along with their chemical character and basicity index range.

Flux classification



1 **Fused Fluxes:** Fused fluxes are usually complex silicate with a high percentage of SiO2 which makes them acidic in character. The fused flux is usually produced in an electric furnace using graphite electrode fed from a transformer and a graphite or refractory lined crucible to hold the melt. Heat is generated by passing large current through the molten bath. Typical melting and pouring temperature ranges between 1500-1700° C. The melt is solidified by quenching into water. It is then dried, crushed, sieved and packed in bags or drums.

Fused fluxes have excellent chemical homogenety and are unaffected by moisture. Their main disadvantage is the ability to take up deoxidisers or ferro alloy addition due to high temperature involved in their processing which result in their segregation and high losses.

The fused flux can withstand very high current from 1500-2000 Amps. There are two grades of fluxed flux produced. The Mn Silicate type for general purpose applications and the Ca - Silicate type for special application. The sized particles have lower and upper limit (minus 12 mesh to plus 200 mesh).

2 **Agglomerated Flux**: For producing agglomerated flux, finely powdered ingredients are mixed and ground dry in a mixer. The mix is steadily moistured by spraying with a solution of alkaline silicate and the mixing is continued. The mixer blades are suitably designed to assist agglomeration. Like low-hydrogen electrodes, agglomerated fluxes have to be backed at around 500° C to remove the last trace of water clinging in the silicate binder. After backing the flux is graded to a specified granule size by sewing and packed in water-proof containers.

The basicity of the flux has been a criteria for selection of flux. The ratio of these oxides along with other basic oxides to acidic oxides like SiO_2 and Al_2O_3 is termed as Basicity.

Basicity of a molten flux = Basic Oxides /Acidic Oxides = Cao + MgO+CaFa + Na_2O + K_2O + 1/2 (MnO + FeO)/SiO2+1/2 (Al_2O_3+TIO_2+ZrO_2)

Basicity index range for each flux is shown in the earlier table. The higher the basicity, lower are the oxygen and sulphur contents of the weld metal and higher its notch toughness value. Agglomerated basic fluxes of good performance characteristics have maximum basicity between 2.6 to 3.2. An inverse of basicity results in decrease of Arc stability, a reduction in weld appearance and more difficult slag removed. In general the flux of highest basicity consists with stable arc, good weld appearance and easy slag removal should be chosen.

Metallic deoxidizers and ferro-alloys can be incorporated into agglomerated basic fluxes since low temperature are involved in their manufacture. Use of alloyed flux (also termed active flux) demands a closer control of the welding parameters, especially the arc voltage to ensure consistent weld metal chemistry. An increase in arc voltage increases the flux-wire consumption ratio and thereby results in increased alloy transfer to the weld metal. Like low hydrogen type of electrodes the agglomerated flux to be backed to remove moisture when stored in humid atmosphere due to the hygroscopic properties.

Agglomerated fluxes have lower bulk density than fused fluxes. This has the advantage that under identical condition of current and voltage, less flux is melted and forms a slag as compared to fused fluxes.

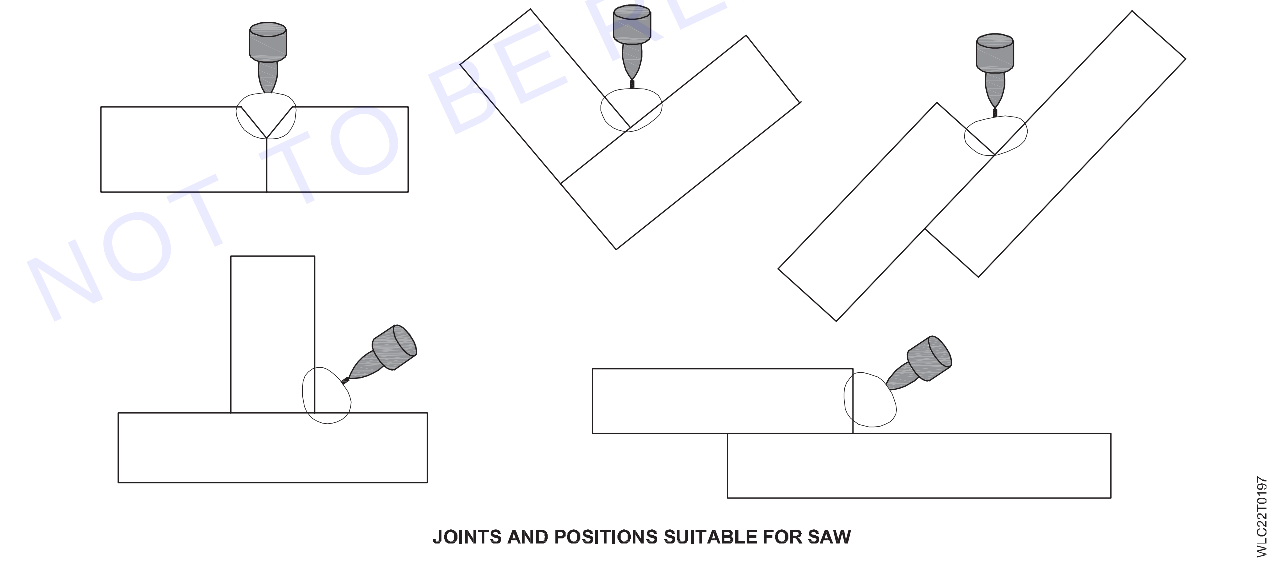
The use of agglomerated fluxes offers the greatest advantage for hard facing applications. Sinc ferro alloys can be very easily incorporated into agglomerated fluxes and significant alloying affect obtained, deposits of varying hardness and wear resistant properties can be obtained by using simple mild steel wire in combination with variously alloyed agglomerated fluxes. But with fused fluxes, alloy wires invariably have to be used, which are expensive and not readily obtainable.

3 **Aluminate Fluxes:** Fluxes high in Al_2O_2 (40-50%) produced a microstructure of good notch toughness in as deposited weld metal as opposed to other flux composition. The level of non-metallic inclusions in the welds generated from aluminate fluxes is lower than in the case of acidic fluxes, but higher than those produced by highly basic fluxes,

4 **Particle size**: Particle size is an important property of a SA flux. For current higher than 800 Amps or for muid wire applications a finer grain size are suitable. For lower current applications cause grain sizes are to be used.

Saw procedures: SAW, semi-automatic and fully-automatic, is used for making butt joints in the downhand position and for making fillet welds in T and lap joints in the downhand and horizontal-vertical positions as shown in Fig 3. Normally this process cannot be used in vertical and overhead positions, because of the difficulty of replacing the flux.

Fig 3



JOINTS AND POSITIONS SUITABLE FOR SAW

(a) AWS A 5-17-1980 specification for carbon steel electrode and fluxes for submerged-arc welding. This standard gives eight classification based on wire chemistry and divided into three groups according to the Mn levels, as shown in ANNEXURE - 1. In this classification system, the prefix E designates an electrode. The letter L. M and H Indicate low, medium and high Mn content respectively. The letter K which appears in some classes indicate that the electrode is made from the heat of Silicon - killed steel (as is obvious from the Si levels). The digits 8, 12 etc., indicate in points, the nominal carbon content of the electrode (for example 8m). Standard electrode diameters in mm are 1.6.1 2.0, 2.4, 3.2, 4.0, 5.6 and 6.4) This standard also gives the classification system for fluxes based on the mechanical properties of the weld metal they deposit in combination with certain classifications of electrodes. The mechanical tests, in effect, evaluate the quality of a flux-wire combination.

b) AWS A 5-23-1980 "Specification of low-alloy steel electrodes and fluxes for submerged arc welding". This standard covers a fairly wide range of low alloy wires divided into five groups as carbon steel, carbon-molybdenum steel, chromium-molybdenum steel, Nickel Steel and other low alloy steel. The ANNEXURE-2 describes the classification system. I For composition requirement for the electrode wire, the reader may go through the latest specification. It must be pointed out that this standard deals with solid electrodes as well as flux cored electrodes, the latter being referred to as composite electrodes. In the classification system letter C is to be used after E to indicate a composite electrode.

c) IS 7280-1974 is the Indian standard specification for base wire electrode for submerged arc welding of structural steels.

d) IS 3613-1974 is the Indian standard for acceptance tests for wire-flux combination for submerged arc welding of structural steels.

Extension of table 3 to thicker plates

Plate Thickness T,Mm	Root Opening G,Mm	Electrode Dia Mm	Current Amps Electrode +Ve	Voltages V	Speed Mm/Sec
4.8	1.6	5	850	32	15
6.4	3.2	5	900	33	11
9.5	3.2	5.6	950	33	10
12.7	4.8	5.6	1000	34	8

Data For To-Pass Square Butt Weld One From Each Side

Plate Thickness T,Mm	Backing Pass				Second Pass			
	Electrode Dia Mm	Current Amps	Voltage V	Speed Mm Sec	Electrode Dia	Current Amps Mm	Voltage V	Speed Mm Sec.
6.4	4.0	475	29	20	4.0	575	32	20
9.5	4.0	500	33	14	4.0	850	35	14
12.7	5.0	700	35	11	5.0	950	36	11
15.9	5.0	900	36	9	5.0	950	36	9

Data For 19 Mm And 25.4 Mm T Butt Welds

	19 Mm T	25.4 Mm T
First Pass		
Electrode Dia,. Mm	5	5
Current(DC+),Amp	700	850
Voltage,V	35	35
Speed,mm/Sec.	12	5.5
Second pass		
Electrode dia,mm	5	5
Current(DC+),amp	950	1000
Voltage,V	36	36
Speed,mm/sec	6	7

Plate Thickness T,mm	First Pass				Second Pass				Third Pass			
	Electrode Dia	Current Amps.	Voltage V	Speed mm/sec	Electrode Dia	Current Amps mm	Voltage V	Speed mm/sec	Electrode Dia Mm	Current amps .	Voltage V	Speed mm/sec
32	5	850	35	5.5	5	1000	36	5	5	850	35	4
38	5	1000	36	4	5	1000	36	4	5	1000	34	3

Micro plasma welding principles, Equipment, power source, parameter settings, Advantages

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

- describe the micro plasma welding
- explain the micro plasma equipments
- explain the micro plasma advantage.

Introduction

Micro plasma arc welding is welding process in which plasma producing gas (Argon, Nitrogen, Helium, and Hydrogen) is ionized by the heat of an electric arc and passed through a small welding torch orifice. A shielding gas protects the plasma arc from atmospheric contamination in welding or cutting. A non-consumable Tungsten electrode is used in Plasma Arc Welding and additional metal is added to the weld with a filler rod.

Plasma Arc welding uses the keyhole method to obtain a full penetration and can be done manually or automatically. The works of temperature obtained in this process is about 20000ºC to 30,000ºC.

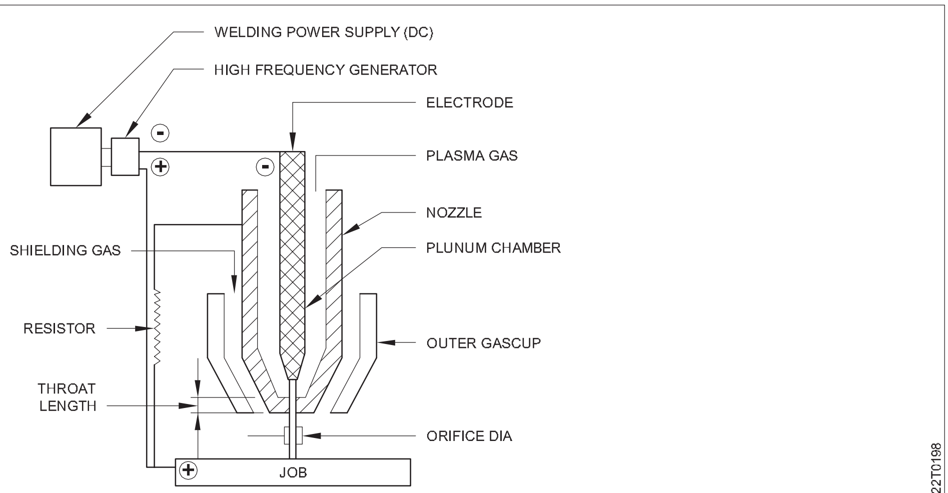
It is divided in to two basic types. They are:

1 Transferred arc

2 Non-transferred arc

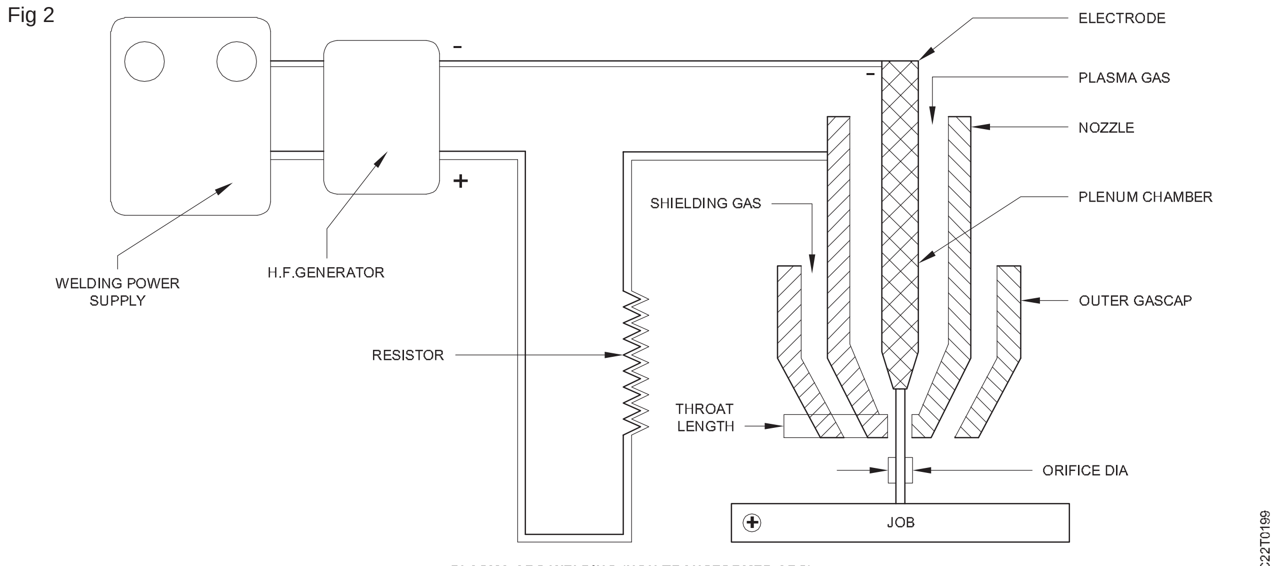
Transferred arc process (Fig 1): The arc is formed be- tween the electrode(-) and the work piece (+). In other words, arc is transferred from the electrode to the work piece. A transferred arc possesses high energy density and plasma jet velocity. For this reason it is employed to cut and melt metals. Besides carbon steels this process can cut stainless steel and nonferrous metals also where oxyacetylene torch does not succeed. Transferred arc can also be used for welding at high arc travel speeds.

Fig 1



PLASMA ARC WELDING (TRANSFORMED ARC)

Fig 2



PLASMA ARC WELDING (NON-TRANSFORMED ARC)

The arc is formed between the electrode (-) and the water cooled constricting nozzle(+). Arc plasma 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).

Equipment's

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

- Argon for carbon steel, titanium, zirconium, etc
- Hydrogen increase heat Argon + (5-15%) Hydro gen for stainless steel, Nickel alloys, Copper alloys

Plasma process techniques

1 Micro plasma

- very low welding currents (0,1-15 Amps)
- very stable needle-like stiff arc & minimizes 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.

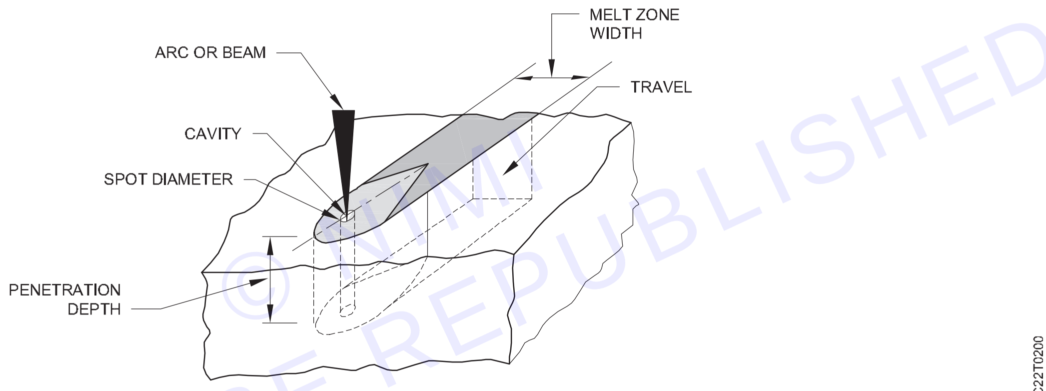
Micro plasma and medium current plasma advantages

- energy concentration is greater & higher welding speed
- energy concentration is greater & lower current is needed 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 contamination, less time for repointing, greater tolerance to surface contamination (including coatings).

Micro plasma 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

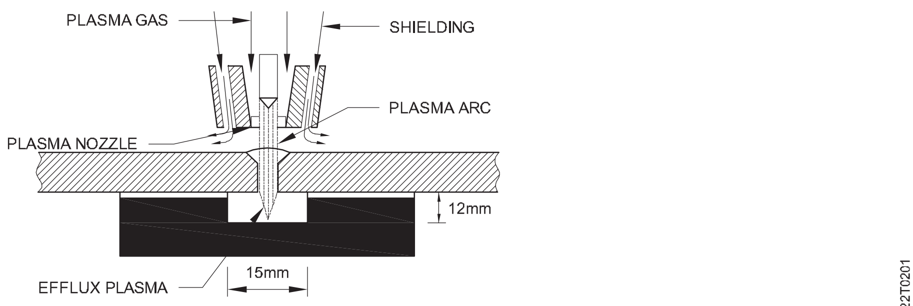
Fig 3



PLASMA PROCESS TECHNIQUE

1 Keyhole plasma welding (Fig 4)

Fig 4



KEYHOLE PLASMA WELDING

- welding currents over 100 Amps
- for welding thick materials (up to 10 mm)

Keyhole plasma welding advantage

- Plasma stream helps remove gases and impurity .
- 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 aluminum alloys, keyhole welding is restricted to down hand 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

- **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 mechanized due to bulkiness of torch.
- **Keyhole plasma**: over 100 amps – By increasing cur- rent and plasma gas flow a very powerful beam is possible which can achieve full penetration in 10 mm stain- less 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.

Plasma cutting principles and advantages

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

- describe the plasma cutting process
- explain the plasma cutting principal
- explain the plasma cutting advantage.

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, aluminum 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.

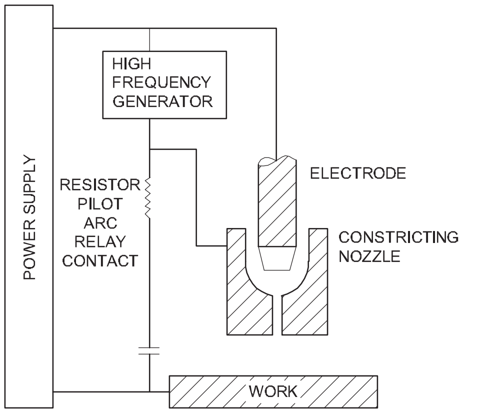
Principle of operation

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 work piece, and ions in the plasma recombine into gas atoms and liberate a great amount of latent heat. This heat melts the work piece, vaporizes part of the material and the balance is blasted away in the form of molten metal through the heat (Fig 1).

Plasma cutting system (Fig 2,3,4)

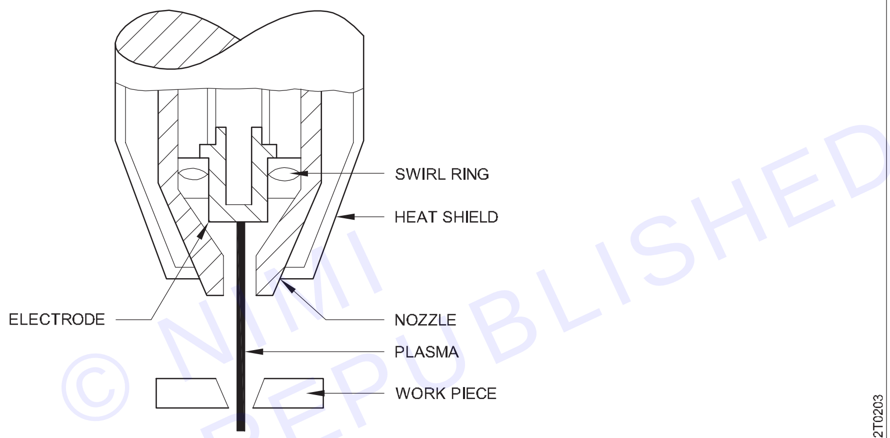
Plasma cutting requires a cutting torch, a control unit, a power supply, one or more cutting gases and a supply of clean cooling water (in case water-cooled torch is used).

Fig 1



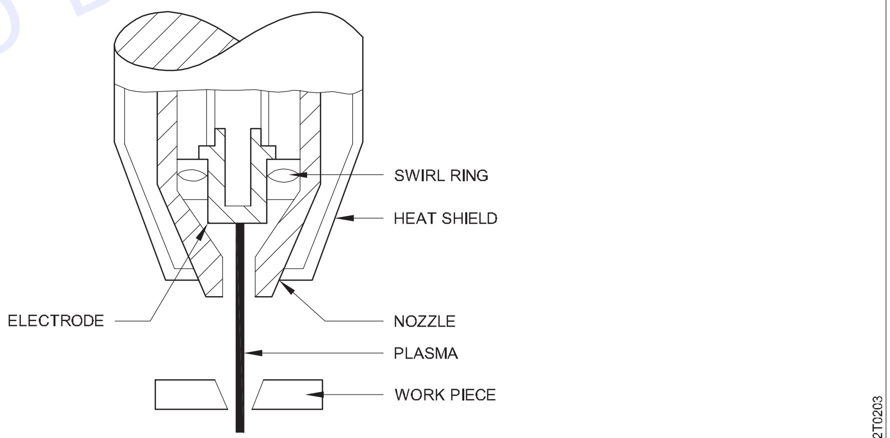
BASIC PLASMA ARC CUTTING CIRCUITRY

Fig 2



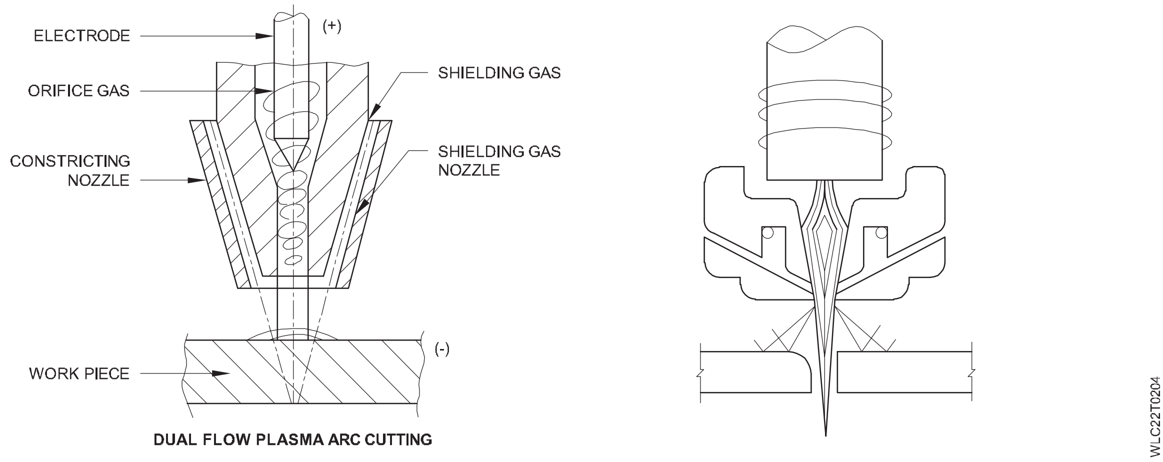
COMPONENTS OF AN AIR-PAC TORCH

Fig 3



COMPONENTS OF AN AIR-PAC TORCH

Fig 4



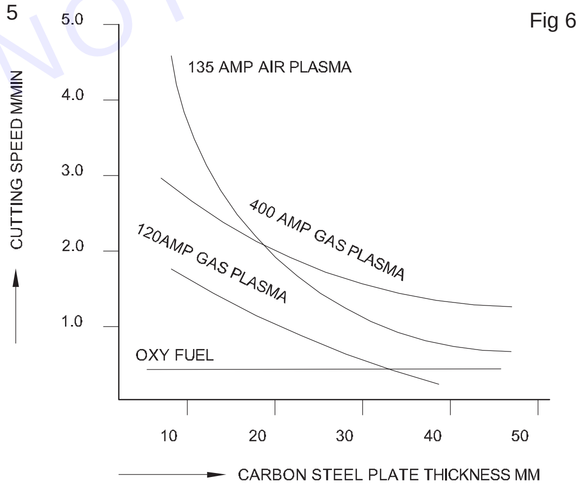
DUAL FLOW PLASMA ARC CUTTING

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 work piece (positive) through a current limiting resistor 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 work piece 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.

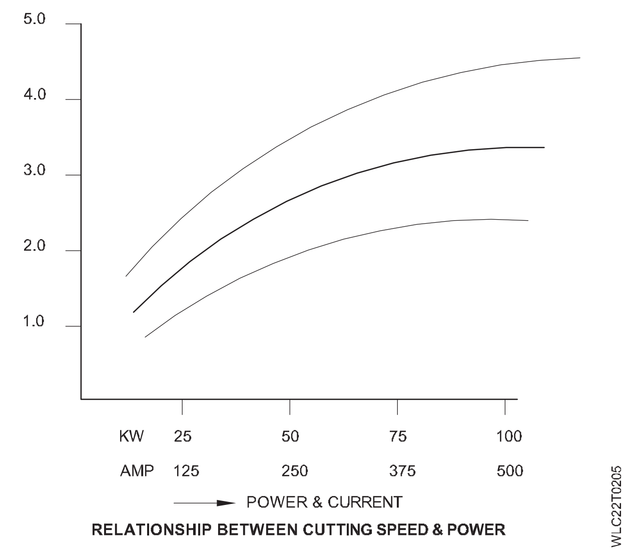
In conventional gas plasma cutting, discussed above, the cutting gas can be argon, nitrogen, (argon + hydrogen), or compressed air. For all the cutting gases other than compressed air, the non-consumable electrode material is 2% throated tungsten. In air plasma cutting (Fig 2) where dry, clean compressed 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 con strict the plasma flame and to increase the nozzle life. Good quality cut with sharp and clear edges with little or no dross is possible in water injection plasma cutting. Process variables (Fig 5 & 6)

Fig 5



COMPARISON OF OXY FUEL AND PLASMA CUTTING PROCESSES

Fig 6



RELATIONSHIP BETWEEN CUTTING SPEED & POWER

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.

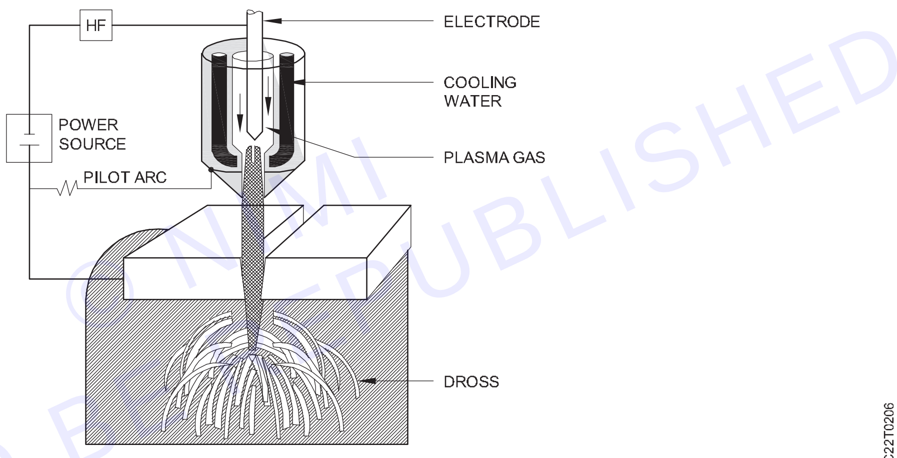
v Cutting cost is quite low as compared to other processes, especially for stainless steels.

vi Cutting speed is high.

vii Cutting is possible in all positions and locations (underwater also).

Gases for plasma cutting (Fig 7)

Fig 7



GASES FOR PLASMA CUTTING

- no need to promote oxidation & no preheat
- works by melting and blowing and/or vaporization
- “gases : air, Ar, N2, O2, mix of Ar + H2, N2 + H2
- air plasma promotes oxidation and increased speed but special electrodes need
- shielding gas - optional
- applications : stainless steels, aluminum and thin sheet carbon steel.

Friction welding process: principles, application, advantages

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

- describe the friction welding process
- explain the friction welding application
- explain the friction welding advantage.

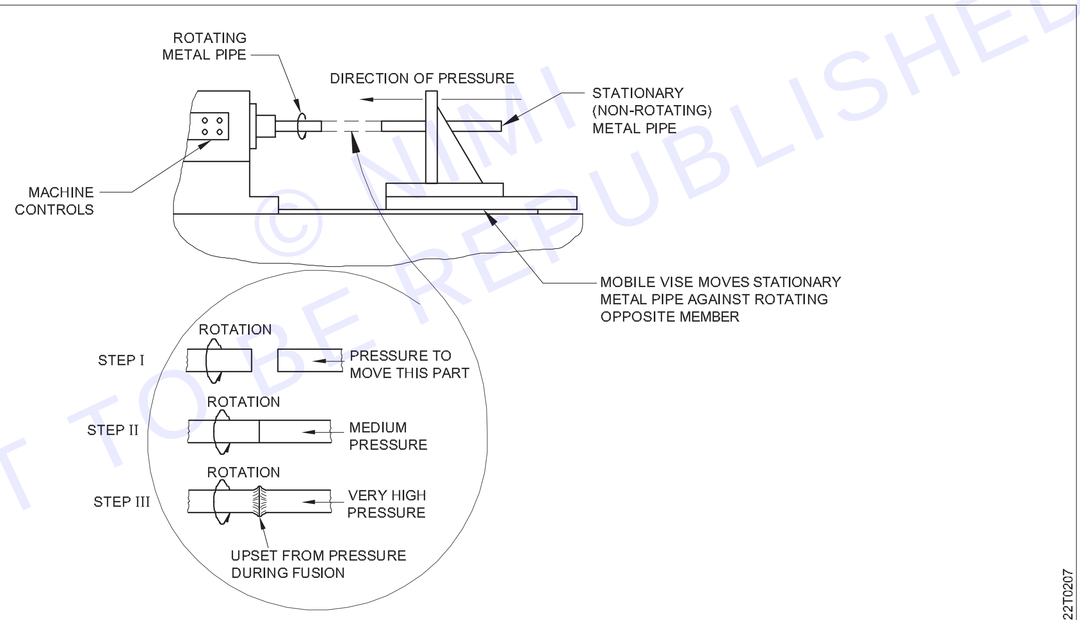
Friction welding

Principle: Friction welding uses friction to create heat to fuse two pieces of metals together. This process is used mainly in butt welding of large sections round rods, very heavy tubes and pipes.

Method of welding: No external heat is supplied. One of the pieces is made to rotate. The ends of the parts to be joined are then brought together under a light pressure. The resulting friction between the stationary and rotating parts develops the heat required to form the weld. As the metal surfaces reach the plastic stage, they are forced together under a much higher pressure. The process produces a clean metal-to-metal welding surface. (Fig 1)

A 1/2" diameter low carbon steel rod with welding temperature of 1650ºF can be joined with a contact pressure in the range of 5000 to 10000 pounds/inch while rotating at approximately 3000 rounds per minute for about 5 second. Medium and high alloy steels require heating pressure (Contact Pressure) ranging from 10000 to 30000 pounds/inch and forging pressure between 15000 to 60000 pounds/inch.

Fig 1



SCHEMATIC OF FRICTION WELDING

Applications

Metals that can be welded by the friction welding process include Carbon Steel, Steel Alloys. Stainless Steel, Copper, Aluminum and Titanium.

Advantages over metallic arc welding

Itis more suitable process for joining dissimilar metals.

- The process produces a clean metal-to-metal welding surface.
- A highly skilled welder is not required.
- A weld with less defects can be obtained.
- No filler rod or electrode is required.
- Power consumption is less. Limitations
- The machine is costly.

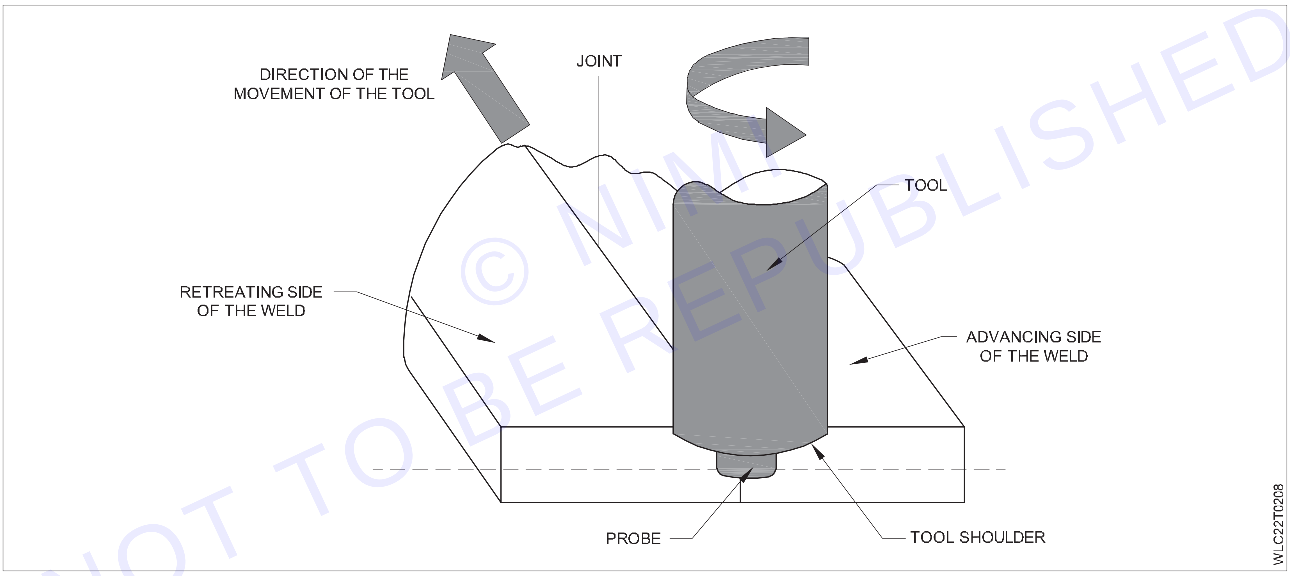
- Plates/sections of less thickness/size cannot be welded.
- Welding can be done only inside a factory/shop and not at sites.
- Soft metals and metals with low compressive strength cannot be welded.
- Only butt joint can be done.
- There is a burr surrounding the weld area.

Friction stir welding

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

- describe the principal of friction stir welding
- explain the application of friction stir welding
- explain the parameter of friction stir welding.

Principle of operation: Friction stir welding (FSW) is an innovative solid-state joining process which was invented and patented by “The Welding Institute”, in 1991. During FSW, a welding tool, which consists of a shoulder and a specially designed pin, is plunged into the plates to be welded, while rotating and advancing at a welding speed along the joint line until the plates have been butted together.



The parts are clamped rigidly onto a backing bar in a manner that prevents the plates from being forced apart. ϖ The length of the pin is slightly less than the weld depth required and the tool shoulder is in full contact with the work surface

Process parameters ¬ Welding speed (mm/min) ¬ Rotational speed (RPM) ¬ Axial force (kN) ¬ Geometry and design of the welding tool ¬ Tool tilt angle ¬ Location of each material (AS, RS) when welding of dissimilar alloys is applied,

FSW machines:

I-STIR BR Performance Characteristics

Axis	Travel Range	Max Speed (Uploaded)	Load Capacity
X (standard)	2540 mm (100 in)	106 mm/s (250 ipm)	22 kN (5 kip)
Option	3810 mm (150 in)		
Y (standard)	1270 mm (50 in)	106 mm/s (250 ipm)	22 kN (5 kip)
Option	2032 mm (80 in)		
Z/Forge	0-713 mm (0-28 in)	72 mm/s (179 ipm)	22 kN (5 kip)
Spindle	NA	4000 RPM	24/15 HP, 35/25 HP
Option		8000 RPM	

◆MODULE 8 : Advance Welding & Cutting◆

Lesson 77- 82 : Principles and applications of Laser welding, Electron beam welding

Objectives

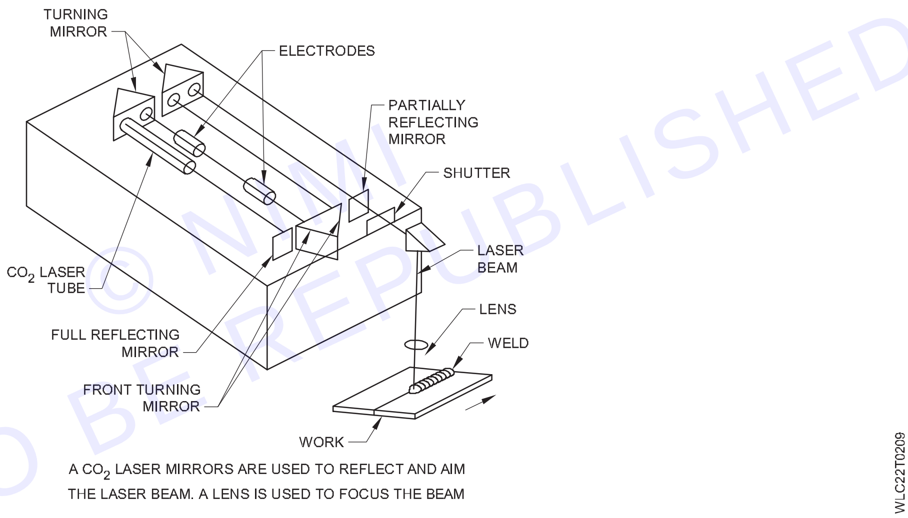
At the end of this lesson you shall be able to

- describe the principal of laser welding
- explain the equipment of laser welding
- explain the electron beam welding.

1 Laser welding

Laser is the acronym for Light Amplification by Stimulated Emission of Radiation. Laser Welding is a method in which work piece is melted and joined by narrow beam of intense Monochromatic Light. (Laser Beam) When the beam strikes the job, the heat produced melts and fuses even the hardest materials. (Fig 1)

Fig 1



Process:

Electrical energy stored in a capacitor bank is discharged into a flash lamp. The stimulating light source usually in a linear arc discharge lamp such as Zeon, Argon, or Krypton gas flash lamp. When the flash lamp fires, and then is a powerful burst of light that pumps electrons with the light emitted (Ruby Rod) to higher than normal energy levels. The light emitted by ruby rod is in pulse and is of single wave length travelling parallel to ruby rod. The mirrors are provided to reflect the light coming to the ends of ruby rod. So that light may pass back through the ruby rod increasing the energy level of electrons further to emit Laser Beam.

It goes through a focusing device where it is pin pointed on the work piece. Fusion takes place and the weld is accomplished. There are three basic types of Lasers.

a The solid laser

b The gas laser and,

c The semi-conductor.

The type of Laser depends upon the lasing source. The Solid Laser some type of crystal such as the Ruby or the Sapphire used for its lasing ability

The gas laser consists of a gas (Carbon Di-oxide, Xenon) or a mixture of gases (90% Helium, 10% Neon) contained in a glass tube with highly polished mirrors at each end. One of the most widely used Gas Laser is CO2 Laser. The radiant energy density of the CO2 Laser is greater than that of the sun.

Equipment and setup

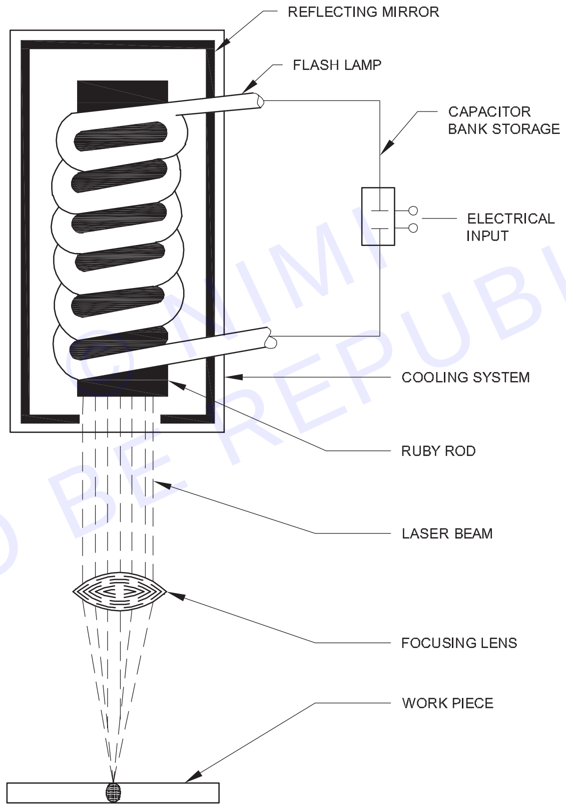
Fig 2 shows a line diagram of a laser beam welding equipment/setup. The light or heat energy is put into a single molecule of a substance (ruby or carbon-di-oxide) to create the beam. This single frequency energy of the single molecule substance in the form of a beam, when travelling between the rear and front mirrors, increases in intensity until it passes through the partially reflecting mirrors. The release of the laser beam is controlled by the operator/ welder.

The heat of the laser beam which is of high intensity is conveniently directed towards the joint to be welded by different combination of mirrors. This is possible because the laser beam can be reflected like light rays. The laser beam produced can be either a continuous heat source or a pulsed beam. When the beam contacts the base metal to be welded through a lens the heat is instantaneously released. The amount of heat applied on the base metal can be controlled by controlling the input to the laser beam source depending on the melting of the base metal being welded.

Applications

Laser Welding is used in the Space, Aircraft, Electronics industries for thinner section metals and dis-similar metals.

Fig 2



LASER WELDING

WLC22T0210

Electron beam welding.

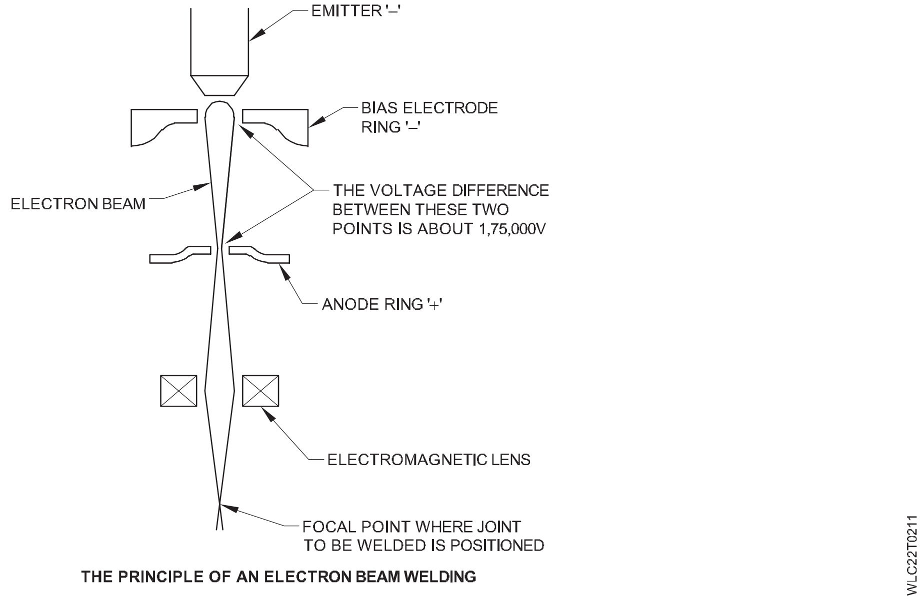
Introduction

The use of the Electron Beam in industry is relatively new. The need for Electron Beam Welding developed for welding costly metals such as Titanium, Molybdenum and Tungsten as structural components.

Process

Electron Beam Welding is an automatic welding process performed in a vacuum without a shielding gas. Neither an electrode nor a filler rod is used. In the electron beam process, electrons are emitted from the heated filament called the ‘Cathode’ and then focused in to a beam which is directed at the welding point. When the beam strikes the welding point, the kinetic energy of the high speed electrons is converted in to heat. The heat is great enough to melt and fuse the metal. The speed of electrons in electron beam welding ranges from 48000 kms /second to 192000 kms /second, depending upon the voltage of the unit (Fig 3).

Fig 3



THE PRINCIPLE OF AN ELECTRON BEAM WELDING

Electron beam welding equipment's

An Electron Beam Welding machine consists basically of the following components:

1 Electron Beam Gun

(a. Tungsten Filament b. Anode c. Cathode and d. Focusing Coil)

2 A vacuum chamber

3 A transport system

Electron beam gun

Most electron beam guns used are the triode type. It consists of a) Tungsten Filament b) Anode c) Cathode and d) Focusing Coil. The Tungsten Filament units' electrons when it is heated in vacuum chamber to 2000°C. Electrons carry a negative charge and are repelled by the cathode electrode and are made to pass through the central hole of the anode (+). The electrons are greatly accelerated by the potential differences between anode and cathode. Then, the beam is focused by a lens. (Electromagnetic Focusing Coil) The purpose of the electron into a narrow beam.

Vacuum chamber

The vacuum chamber is operated in conjunction with pumps and a pumping system to control the vacuum environment. The size and design of the vacuum chamber used in electron beam welding will depend on the dimensions of the weldment.

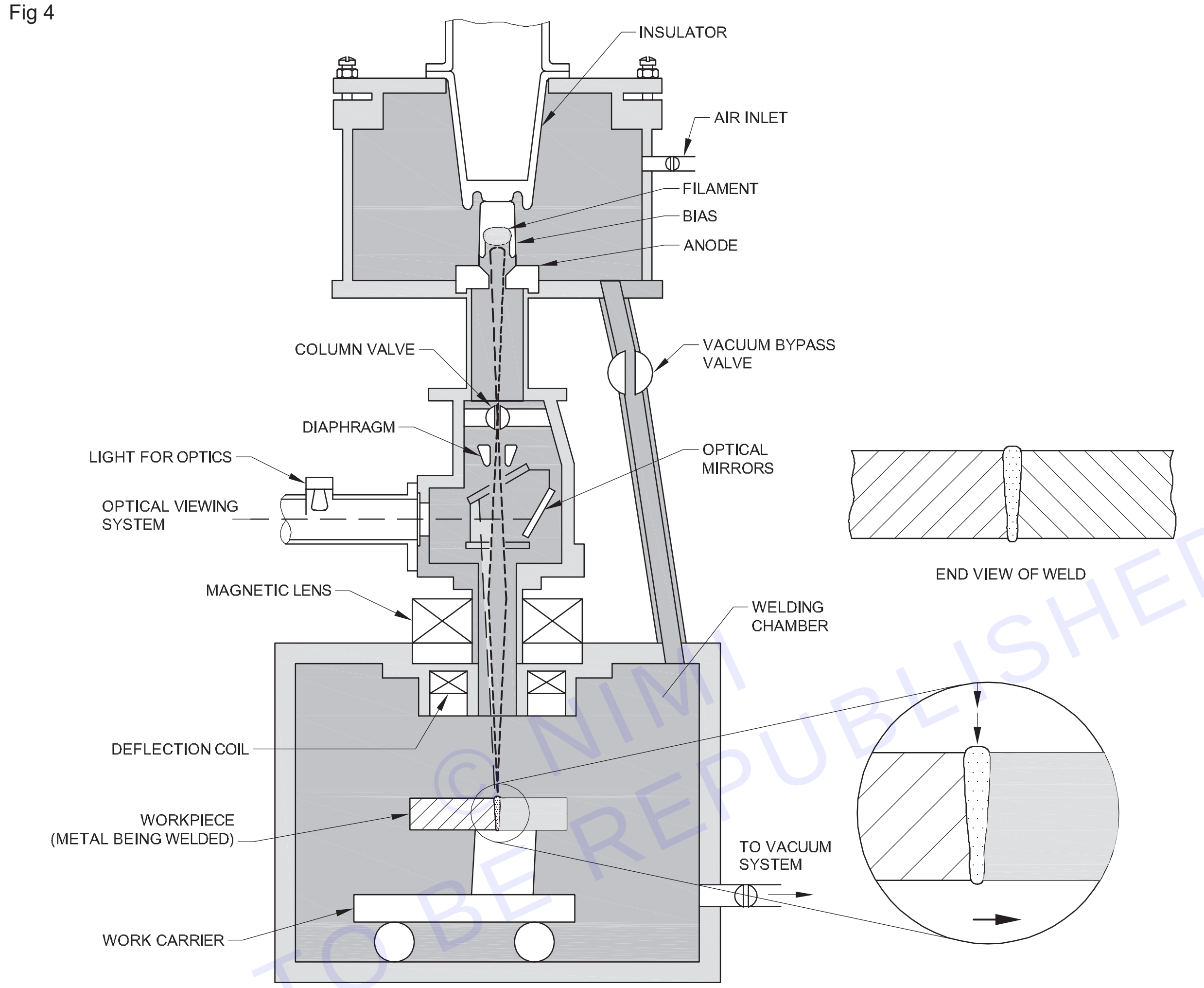
Transport system

Each machine is equipped with some form of transfer sys- tem to provide movement for the gun and work. These systems are usually driven by DC motors, which control position, Location and Velocities of both the gun and the work.

Description of equipment and welding procedure Fig 4 shows an electron beam welding equipment/setup. The machine has a chamber in which a filament is used.

This filament emits (gives off) a stream of electrons. These electrons from the emitter passes through an anode, column valve, diaphragm and then passes through an electromagnet called magnetic lens. This magnetic lens is used to focus the high energetic electron beam which also possesses a high heat intensity. The work piece to be welded is kept in a vacuum chamber below the magnetic lens. The electron beam can be directed either downwards or deflected in any other direction within the vacuum chamber by using deflection coils. The welding is done in a vacuum chamber because the air if present will interfere with the electron beam and affect the welding action. Also the vacuum acts as a shield against radiation hazards. The heat energy required to melt the base metal is controlled by the current in the electron gun filament. The operator/ welder can watch the welding area on the joint through a safe optical viewing system containing optical mirrors. The surfaces to be joined should be properly cleaned before welding. The parts to be joined are to be held together very tightly and moved within the vacuum chamber using suitable trolleys

Fig 4



WELDING ENERGY IS CREATED BY HITTING THE BASE METAL WITH A BEAM OF ELECTRONS. THE HEAT ENERGY IS VERY INTENSE. WELD FORMED ARE VERY NARROW.

ELECTRON BEAM WELDING (EBW)

Advantages

1 The weld zone and heat affected zone are relatively small in electron beam welding.

2 Distortion affects only a very small area.

3 Extremely successful in achieving deep penetration.

4 On steel plate 100 mm. thick welds can be made in one pass at a speed of 170 mm/minute with penetration.

5 Usage of current only in the mile ampere range is required, while the other electrical welding system many amperes are required.

6 Speed of welding is high.

7 No porosity and contaminations.

8 Very useful to weld Titanium, Zirconium, Molybdenum with same control of purity as in the original material.

Disadvantages

1 The cost of the equipment is high.

2 Obstructed joints can't be welded because electron beam travels in straight line.

3 Job is limited in sized as per the work chamber dimensions.

Electro slag welding & Electro gas welding

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

- describe the principal of electro slag welding
- explain the equipments of electro slag welding
- explain the electro gas welding.

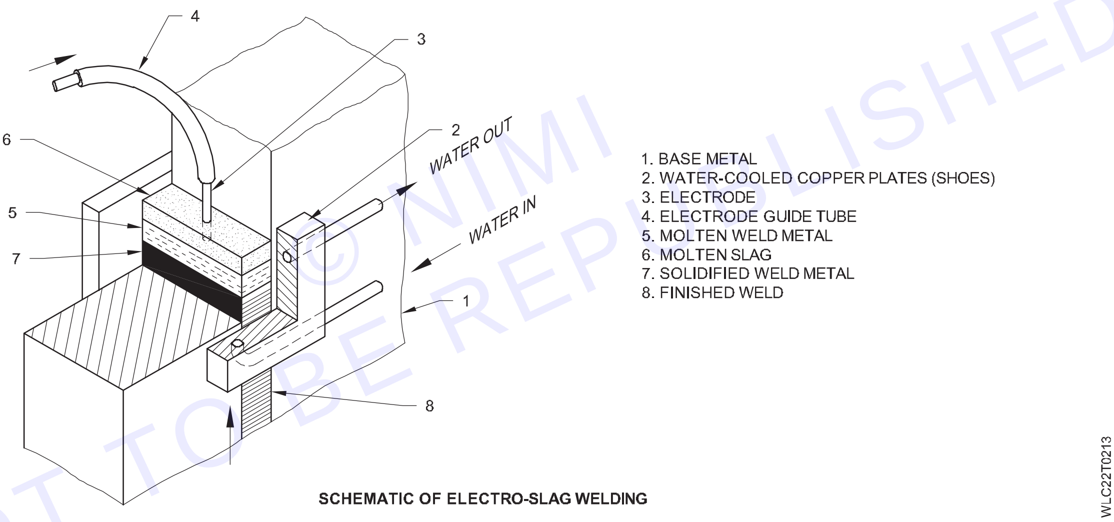
1 Electro slag welding

Introduction

Electro slag welding process is considered as a further development of submerged arc welding and developed for the welding of thick plates with a single pass. With this process, plates of 25mm or more can be joined without multiple passes and without edge preparations such as bevel joints, 'V' joints and 'J' joints and 'U' joints and reduced the twice in the fabrication.

Principle: The electro-slag process is fully automatic. The plates to be joined are kept in vertical position. (The axis of the weld joint is vertical) The flux is continuously fed into the area being welded where it forms a cover of molten slag over the weld metal. This covering of molten slag serves as a major source of heat for the electro-slag welding process. The welding takes place in the flat or down hand position with vertical upward travel of the weld pool. (Fig 1)

Fig 1



SCHEMATIC OF ELECTRO-SLAG WELDING

Operation: An electric arc is struck between the electrode and the joint bottom with the help of a piece of steel wool.

Welding flux is added which melts by the heat of the arc. When a thick layer of hot flux or molten slag is formed, the arc action stops and the electric current passes from the electrode to the work pieces through the conductive slag pool.

The conductive slag pool remains molten because of its resistance to the electric current passing between the electrode and the work through it. The temperature of this molten slag pool is 1650°C at the surface and 1930°C inside under the surface. The heat fuses the edges of the work piece and the welding electrode. Fig 2 shows an electro-slag welding process in progress.

The function of welding flux: The welding flux shields the molten metal and reduces oxidation. It cleans impurities from the molten metal. The flux is added in small quantities periodically.

Copper dams or shoes

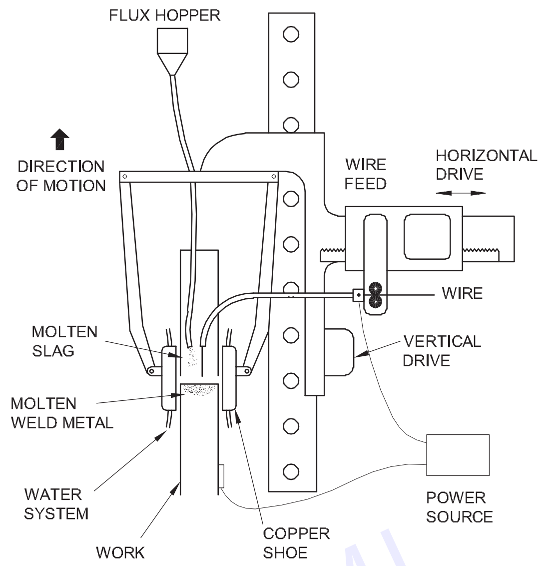
Water-cooled copper shoes contain and confine the molten slag and molten welding metal until it solidifies. The copper shoes accelerate solidification of the weld metal.

Advantages

- Less edge preparation.

- Thicker steels can be welded in a single pass.
- High deposition rate.
- Residual stresses and distortion low.
- Less flux consumption.
- No spatter.

Fig 2



ELECTRO-SLAG WELDING OPERATION

Application

- Forging and castings of heavy thickness can be welded.
- Some alloys such as low carbon and medium carbon steels can be welded.
- High strength structural steels can be welded.
- High strength alloy steel such as stainless steel and nickel alloy can be welded.

Limitations: This process can be used only for welding of very heavy plates.

Equipment's:-

1 AC Power Source
2 Wire Feeder
3 Electrode Guide Tube
4 Control Panel
5 Travel Carriage
6 Water cooled Copper Shoes

1 AC power source

Electro Slag Welding requires a Power Source, capable of delivering the AC welding current, recommended for the process. The Power Source is stationary.

2 Wire feeder

The function of the wire feeder is to deliver the electrode wire through the guide tube to the molten flux.

3 Electrode guide tube

The tube is insulated materials to avoid short circuiting. It is made of beryllium copper alloys because this alloy can withstand high temperature and retains its strength.

4 Control panel

It consists a mounting near the welding head which as the following components a Ammeter, Voltmeter and a remote control for each of the Power Source.

b A speed control for each wire drive motors.

c Alarm Systems for equipment mall functions.

5 Travel carriage

All functions of the machine are controlled from a Panel located at the vertical transport carriage assembly.

6 Water cooled copper shoes

The Copper Shoes accelerate solidification of the weld metal. The functions of the Copper Shoes are to maintain the molten metal and molten slag until it solidifies

Electro gas welding

Electro Gas Welding is an automatic welding Process that uses a Carbon Di-oxide (CO2) or a mixture of CO2 and Argon Shielding Gas to protect the Arc and molten weld metal from Atmospheric Contaminants. A Consumable Flux cored or Solid electrode wire is continuously and mechanically led into the arc and molten pool. Edge Preparation is not necessary. This process may be carried out by two methods

1 Solid Electrode Process

2 Flux Cored Electrode Process

Solid electrode process

In this Process, generally single electrode is fed into the joint. Two electrodes can be used for welding of thick plates. The Shield is done by the CO2 gas and no extra flux is required.

Flux cored electrode process

In this Process, electrode with flux is fed into the joint and a thin layer of Slag on the top of molten pool. The Shielding is done by Flux.

Electro gas welding equipment and supplies

The Equipment's of Electro Gas Welding are similar to Electro Slag Welding but the difference is Shielding Gas.

1 AC power source

2 Water cooled copper shoes

3 Welding gun

4 Wire feeder

5 Shielding gas and

6 Control panel

Applications

It is used for welding of thick plates in vertical position. It can be applied on Carbon Steel and Alloy Steels.

Advantages

1 Welder can see the welding pool easily.

2 Restarting the weld is easier.

Disadvantages

It is not suitable economical for welding metal lesser than 25 mm. thick.

Thermit welding

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

- describe the principal of thermit welding
- explain the equipments of thermit welding
- explain the thermit welding process.

Thermit welding

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

Principle of thermit welding

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

1 Plastic or Pressure Thermit Welding

2 Fusion of Non-pressure Thermit Welding

Plastic or Pressure thermit welding

This type is used mainly for butt welding of thick pipes of rails. In this weld, pressure is used to join the metal. The work pieces are clamped into C.I moulds and are forced together when the desired temperature is achieved. The thermit is heated in a crucible above the work. While heat- ing, the lighter aluminium oxide slag rises to the top. When pouring temperature is reached, the thermit solution is poured into the mould. When the thermit mixture has heated the work pieces sufficiently, the work pieces are forced together forming a pressure butt weld. The whole welding process takes 45 to 90 seconds for welding of thick walled pipe.

Fusion of non-pressure thermit welding

In this process, the work pieces are lined up, leaving a space between the ends the are to be welded. Wax is placed between the joint. The whole frame is suspended in a mould, and then the molten metal is poured. The first step in preparing a non-pressure thermit weld is the cleaning of the joint.

Equipments, materials and supplies

The thermit welding process requires an adequate sup- ply of

1 Thermit mixture

2 Thermit Ignition powder and a

3 Device (Flint Gun, Hot Iron Rod etc…)

Thermit mixture

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

1 Plain Thermit

2 MS Thermit or Forging Thermit

3 Cast Iron Thermit

4 Steel Mill Wobblers

5 Rail welding Thermit

6 Thermit for welding electric connections

Plain thermit

A mixture of finely divided Aluminium and Iron Oxide. This is the basic of most thermit mixtures and yields maximum temperature.

MS thermit

This is a plain thermit with the addition of manganese and mild steel punching, and is used in welding steel. Manganese is added to adjust the chemistry of thermit mixture (Carbon may also be added, the mild steel punching are used to augment the metal content)

Cast iron thermit

Cast iron Thermit consists of plain thermit with addition of Ferro-silicon and Mild Steel punching and is used for welding cast iron. The mild steel punching augments the total metal content. Unless the weld area is post heat treated, this weld metal is generally not Mechinical and, because of the different contraction between it and the cast iron parent metal. It is limited to use where the maximum weld dimension is less than 8 times its width.

Thermit for steel mill wobblers

This consists of plain thermit with additions of manganese and carbon to provide a hard, wear resistant, machinable steel especially adopted to the building up of worn wobbler ends of steel mill rolls.

Thermit for welding rail

These mixtures usually consist of plain thermit with additions of carbon and manganese to adjust hardness of the deposited metal to the hardness of the rail being welded. Alloys are also added for controlling resistance to abrasion and to act as grain refiners.

Thermit for welding electric connections

This consists of Copper Oxide and Aluminium.

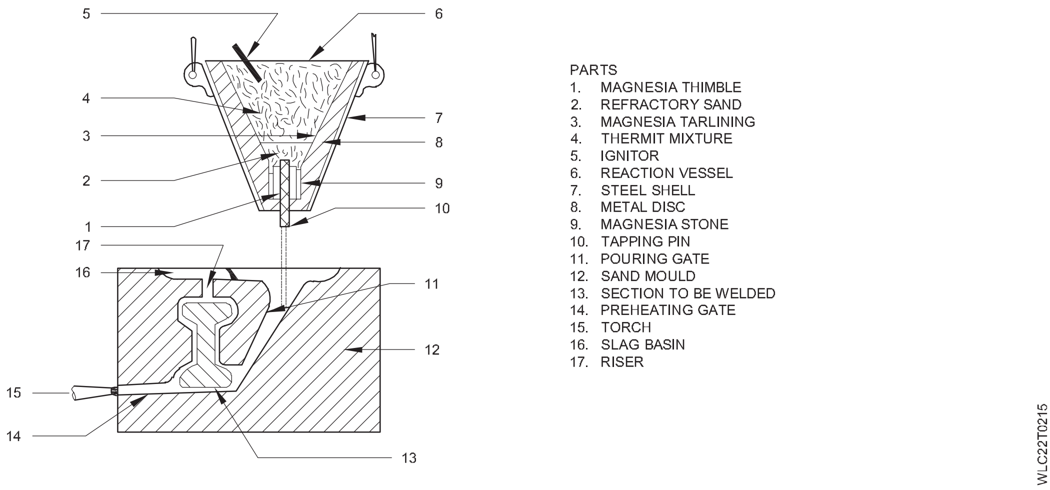
Thermit ignition powder

There are a number of different ignition powders available. Barium per oxide is frequently used. The thermit ignition powder is ignited directly with a match. This should be done by partly burying the match head in the mixture and igniting the match with a thin red hot rod. This avoids the danger of burns injuries to the finger or hand due to the sudden flare in igniting. The thermit ignition powder can also be ignited with a spark from a flint gun or by using a burning magnesium ribbon.

Thermit welding procedure

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

Fig 1



Application

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

1 Rail welding

Rails are welded to create long railways for electrified and other fast tracks. This increases the passenger comfort and keeps the maintenance cost down. Spill- age of goods (like coal) is minimized in mining industry.

2 Reinforcement steel rod welding

In big building projects, a massive number of joints are to be carried out for joining of reinforcement steel at a short time. Thermit welding is applied by using prefabricated moulds with reaction chambers.

Principal application Water jet cutting and Laser cutting

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

- describe the water jet technology
- explain the water jet cutting advantage and limitation
- explain the laser cutting

Introduction

Today, as the competition circumstances get tougher, manufacturing technology demands materials to be cut more precisely and faster. In the last years, water jet cutting has come at first for this purpose. High pressure water jet has been used for surface cleaning since 1968 Today, in industry, water jet cutting is used for cutting hard and soft materials except for a few hard-to-cut materials like diamond and since it is not a hot process, cut materials are not affected by heat and minimum cutting stresses are introduced compared to other cutting processes. There are no health-related hazardous outputs like fume, gas, dust etc. during cutting process, so it is healthier and more environment friendly compared with other cutting processes.

Water Jet Technology

In water jet process, water is pressurized to a very high level via hydraulic pump and intensifier and it forms a very high pressured steam (4000 ~6000 bar) [4] when focused through a sapphire, ruby or diamond orifice [4,5]. In pure waterjet cutting, the supersonic stream erodes the material with its kinetic energy. In abrasive waterjet cutting, the high velocity abrasive particles, usually garnet, are introduced in a chamber and water with abrasive particles passes through a nozzle, which is made of tungsten or boron carbide and then impact the kerf face and do the actual cutting. Kerf material is removed as microchips.

Pure Water jet Cutting

Original water cutting method is pure water jet cutting and it is usually used for cutting soft materials. Tissue

Fig 1

papers, disposable diapers and automobile interiors are the largest use for pure water jet cutting. It is interesting note that in the case of tissue paper and disposable diapers cutting, water jet process produces very low moisture on the materials. Pure water jet has a very fine stream of 0.1 mm to 0.25 mm in diameter and cut not only thick but also thin materials. It produces extremely low cutting forces and it does not introduce heat to material. This process is also able to cut soft and light materials, which may have detailed

Abrasive Water jet Cutting

In the abrasive waterjet, the waterjet stream accelerates abrasive particles and those particles, not the water, erode the material. Therefore, the abrasive water jet is hundreds of times more powerful than a pure waterjet and thus, it is able to cut harder materials, such as, ceramics, composites, metals, stone, marble etc.

Abrasive waterjet usually has a stream of 0.5 mm to 1.3 mm and it can also cut geometries with details and it produces no heat affected zone, mechanical stresses and little burr like pure waterjet cutting. In addition to this, abrasive water jet cutting process is able cut materials with 250 mm thickness.

Abrasives

The most common abrasive in waterjet cutting is almandine garnet 150-300 μm particle size is common for cutting most of the materials with a good finish. If particle size is lowered then a better quality is achieved. If coarser grade is used for cutting, finish quality gets worse while cutting speed increases [4]. When more abrasive is added to water jet, first, cutting speed increases and after a certain point it starts to decrease. This is also valid for cost in inverse proportion. When more abrasive is used, first, total cost per inch decreases, then again after a certain point, total cost starts to increase. Since fastest cutting speed means lowest cost per millimeter, one must try to achieve highest cutting speed while maintaining cutting quality Moreover, high abrasive flow rate does not mean that cutting quality would be high. In fact, there is an optimum level for each setting.

Effect of Parameters in Water jet Cutting Some researchers have studied the effects of water pressure, abrasive flow rate, standoff distance and traverse speed on surface roughness and depth of cut. They found out that when water pressure gets higher, the depth of cut increases; and when traverse speed gets higher, depth of cut decreases. High traverse speed also results in higher surface roughness. When abrasive flow rate gets higher, first, surface roughness decreases and then after a certain point it increases. Similarly, when standoff distance gets higher gradually, first, surface roughness decreases and after a certain point it increases

Advantages

a Short machine setup times

b Easy automation

c Environmental friendly materials are used (water and garnet). Reuse of the abrasive up to 80% is possible. No impurities like oil and emulsions.

d No dust or fume generated

e Loss material to be cut is too small

f Heat generated during the process is insignificant

g Almost no distortions

h One tool for cutting different types of materials and thicknesses

i Can cut very thick materials (over 300 mm)

Limitations

a High speed linear cutting gets a V profile

b Water jet deviates at high speed cutting of circles and arches

c Water jet may produce notches at high speed cutting of inner angles

d In cutting of thick materials striations may occur along the depth of the cut due to high

e Transverse speed or insufficient pressure

f Limitations in machining 3D shapes

g Machining very hard materials is difficult

h After cutting, corrosion prone materials need to be protected

INTRODUCTION

Laser Cutting

Mechanical Cutting Each method has its relative pluses and minuses and no one method fits every situation. The thickness of the stock to be cut, hardness of the stock, whether or not the stock is stacked or layered, your cost and timing requirements, and the desired condition of the material after it's been cut are among the key factors that determine which method is right for a particular job. There are also some application procedures where one process or another is most suitable. Before we compare the three methods, let's briefly overview how they work.

Laser

The cutting action is the result of light from a laser (typically a CO2 laser with an energy of up to 2600 watts) passing through a lens and being directed at the material to be cut.

Fig 2

Mechanical

The cutting action occurs when a power-driven, hardened cutting blade removes excess material to create a desired shape. Three of the most common mechanical cutting methods are as follows.

Die cutting: A die (a blade made in a particular shape, like a cookie cutter) shears webs of sheet metal or other relatively low-strength stock such as rubber or plastic.

Lathe: A machine spins the stock while a hardened cutting blade removes excess material into the desired shape.

Milling: The stock is mounted on a movable table that maneuvers around a fixed cutting blade.

Laser-Cutting

Key criteria for comparing these two methods include:

Thickness of Materials. Lasers perform better on materials three-eighths of an inch thick or less. While it's possible to cut thinner materials with a water jet by cutting multiple layers at once (i.e., stacking them), doing so reduces precision. Laser-cutting speed for these thinner materials is faster than that of a water jet. However, depending on the materials, once you get above acertain thickness lasers are no longer an option, while water jets are. Lasers can't cut through inch-thick steel, for example, but water jets can (although very slowly) Precision. The minimum size of the laser-cutting slit is 0.006 inches versus the water-jet-cutting slit of .02 inches - so lasers can cut finer details. The tolerance of laser cutting is also better, typically +/- 0.005", while a water jet is typically +/- 0.010". And, as just noted, when materials are stacked, a water jet's precision diminishes further.

Time. Laser jets cut thinner materials faster and more precisely than water jets can. Also, water-jet jobs generally take longer to prepare, meaning you have to allow more time in your production schedule for material cutting, and alert your vendor if you plan to use an outside vendor for cutting.

Surface Abrasion and Staining. Water jets with abrasive particles may stain your materials or delaminate (abrade) the surface, while lasers won't. Cost. It generally costs less to cut thinner materials with a laser and costs less to cut thicker materials with a water jet.

Resistance welding processes, principal, application, advantage, Elements, control parameter, various types, viz spot welding, seam welding, Projection welding, Flash butt welding

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

- describe the principal of resistance welding.
- explain the spot welding
- explain the seam welding.

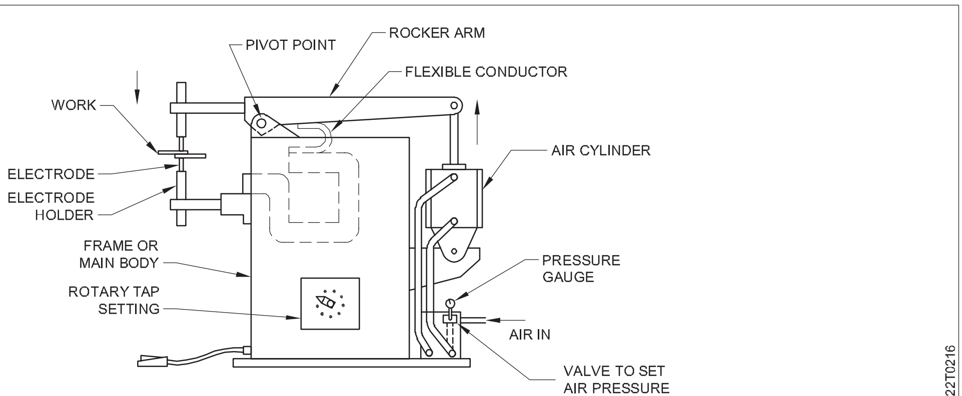
Principle of resistance welding: Resistance welding is a welding process wherein coalescence is provided by the heat obtained from the resistance offered by the work to the flow of electric current in a circuit and the joint is effected by the application of pressure.

The fundamental principle on which all resistance welding is based is as follows. The heat is generated due to the resistance offered by the parts to the passage of heavy electric current for a fraction of a second.

Heat produced at the junction is calculated by the formula $H = I_2Rt$

where H for Heat, I stands for the amount of current in amps. R for resistance offered in ohms t - time taken for duration of current flow in seconds. This heat at the junction of the two parts changes the metal to a plastic state,

Fig 1



ROCKER ARM TYPE RESISTANCE WELDING MACHINE and when combined with the correct amount of pressure, fusion takes place. The different types of resistance welding machines are spot welding, seam welding, projection welding, flash butt welding and upset welding machines. A standard rocker arm type resistance welding machine is shown in Fig 1.

The main parts are

1 **The frame:** It is the main body of the machine which differs in size and shape for the stationary and portable types.

2 **Force mechanism:** The compressed air cylinder and the pivoted rocker arm gives the necessary high pressure to the lever to which the upper electrode holder is attached.

3 **The electric circuit:** It consists of a step down trans-former which provides for the necessary current to flow at the point of weld.

4 **The electrodes:** The electrodes include the mechanism for making and holding contact at the weld area.

5 **The timing controls:** The switches which regulate the value of current, current flow time and contact period time as the timing controls.

6 **Water cooling system** to circulate cooling water to the electrodes.

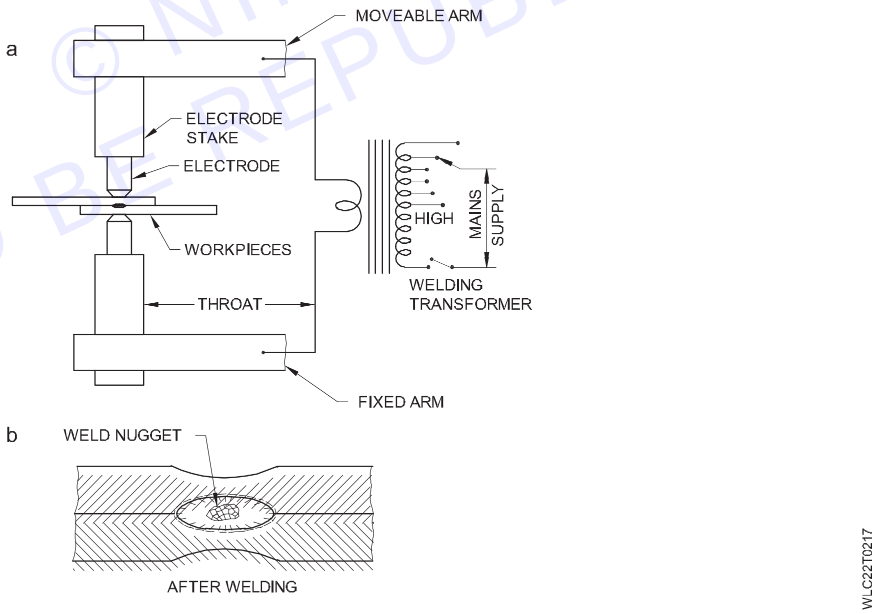
This is the additional part consisting of a water reservoir and flow system.

Spot welding: This type of resistance welding machine is most commonly used for resistance welding. The material to be joined is placed between two electrodes as shown in Fig 2a. Pressure is applied after a quick shot of electricity is sent from one electrode through the job to the other electrode.

Spot welding is made in three steps.

The first step is when the parts to be joined are clamped between the electrodes. In the second step, a high current is allowed to pass through the clamped members and is raised to the welding temperature. The third step sees the current being cut off and high pressure being applied to the joint and the joint completed. A nugget is formed as shown in Fig 2b.

Fig 2



A special copper alloy material has been developed for use as electrodes.

Cooling of the electrodes is accomplished by internally circulating water.

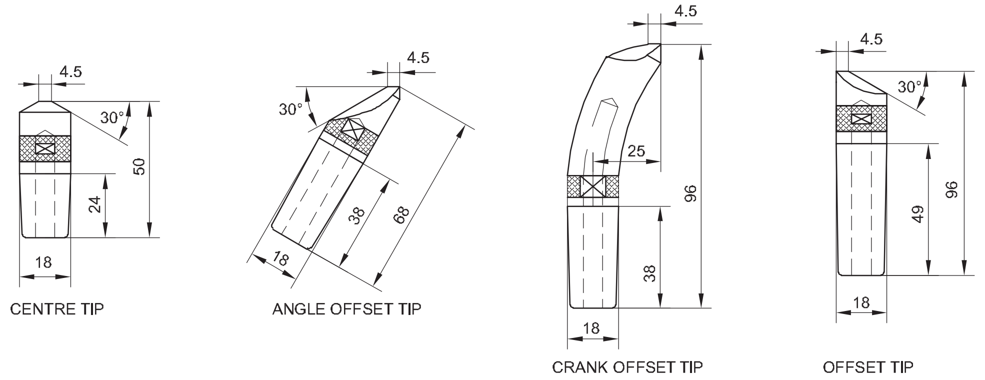
Electrodes are of many shapes and sizes, the most common being the centre tip and offset tip types. (Figs 3 and 4)

Regular spot welding leaves slight depressions on the metal. These depressions are minimized by the use of larger sized electrode tips and by inserting 1.6 mm copper sheets between the electrode and the job.

Spot welds may be made one at a time or several welds may be completed at one time.

Spot welding is utilized extensively for welding steel, and when equipped with an electronic timer, it can be used for other materials, such as aluminium, copper, stainless steel, galvanised metals etc.

Fig 3



FOUR STANDARD TYPES OF ELECTRODES

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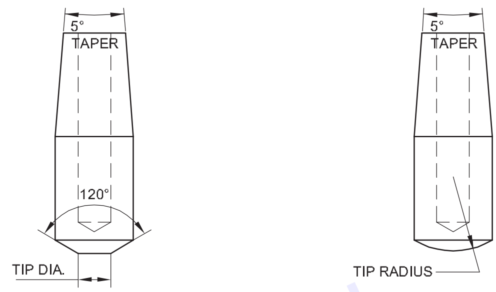
Fig 4



THE RADIUS OF THE DOMED TIP (RIGHT) VARIES FROM 25mm FOR WELDING 26 S.W.G. MATERIAL, UPTO 150mm FOR 3 S.W.G. THE DIAMETER OF FLAT PART OF THE OTHER ELECTRODE VARIES FROM 4mm TO 12mm FOR SIMILAR MATERIAL THICKNESS.

TWO STANDARD TYPES OF CENTER TIP ELECTRODE

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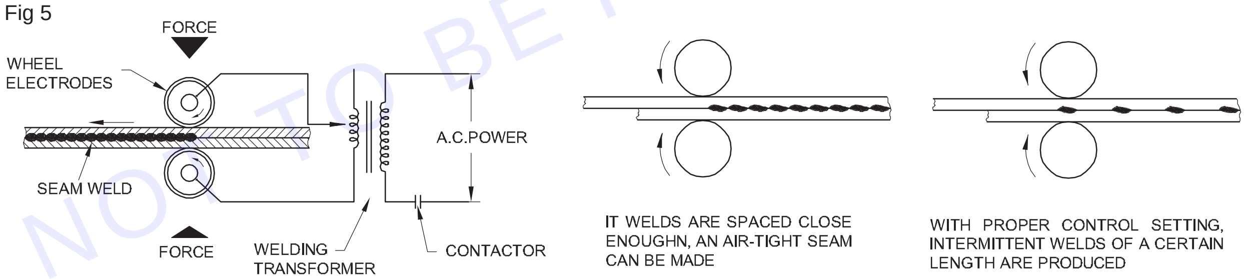
Seam welding: Seam welding is like spot welding except that the spots overlap one another, making a continuous weld seam. In this process the metal pieces pass between the roller type electrodes as shown in Fig 5.

Fig 5



RESISTANCE SEAM WELDING PROCESS

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As the electrodes revolve, the current is automatically turned ‘on’ and ‘off’ at intervals corresponding to the speed at which the parts are set to move. With proper control, it is possible to obtain airtight seams suitable for containers, water heaters, fuel tanks etc.

When spots are not overlapped long enough to produce a continuous weld, the process is sometimes referred to as roller spot welding.

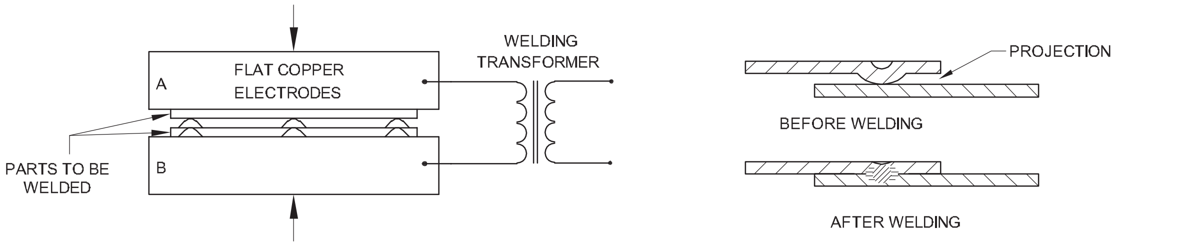
Cooling of the electrodes is accomplished either by circulating water internally or by an external spray of water over the electrode rollers.

Both lap and butt joints are welded by seam welds. In the case of butt joints, foils of filler metals are used on the joints.

Projection welding: Projection welding involves the joining of parts by a resistance welding process which closely resembles spot welding. This type of welding is widely used in attaching fasteners to structural members.

The point where welding is to be done has projections which have been formed by embossing, stamping or machining. The projections serve to concentrate the welding heat at these areas and facilitate fusion without the necessity of employing a large current. The welding process consists of placing the projections in contact with the mating part and aligning them between the electrodes (flat copper electrode) as illustrated in Fig 6.

Fig 6



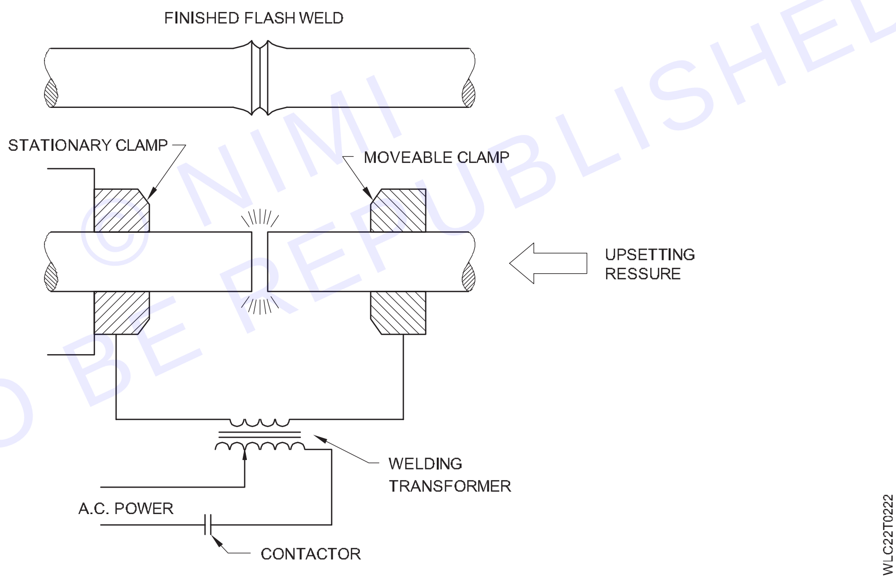
SCHEMATIC REPRESENTATION OF PROJECTION WELDING

Either single or a multitude of projections can be welded simultaneously.

Not all metals can be projection-welded. Brass and copper do not lend themselves to this method because the projections usually collapse under pressure. Galvanised iron and tin plates, as well as most other thin gauge steels, can be successfully projection-welded.

Flash butt welding: In the flash butt welding process the two pieces of metals to be joined are firmly held in clamps which conduct current to the work. (Fig 7)

Fig 7



The ends of two metal pieces are moved towards and away from each other until an arc is established. The flashing action across the gap melts the metal, and as the two molten ends are forced together, fusion takes place. The current is cut off just before the heavy pressure is applied through the movable clamp.

Flash butt welding is used to butt-weld plates, bars, rods, tubing and extruded sections. It is not generally recommended for welding cast iron, lead and zinc alloys.

The only problem encountered in flash butt welding is the resultant bulge at the point of the weld. It should be removed by grinding or machining if the part needs finishing.

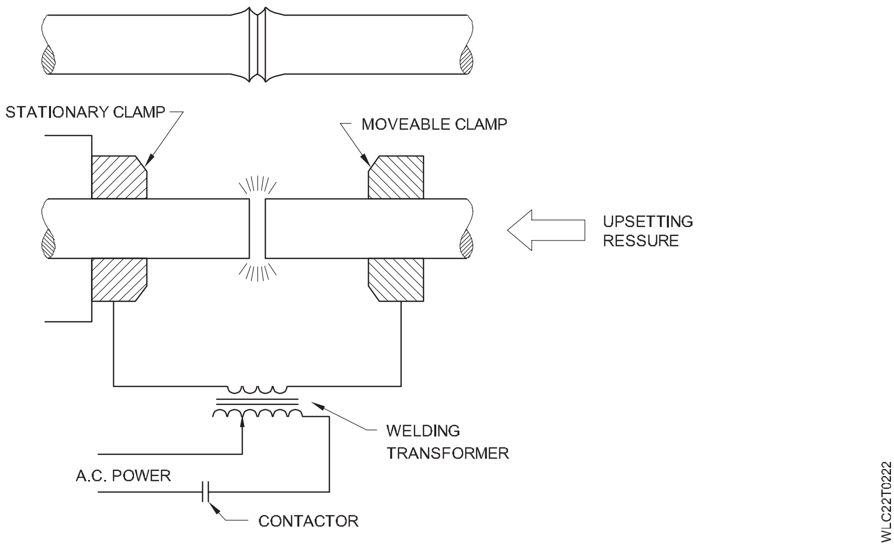
Butt or upset welding (Slow butt weld)

In butt welding the metals to be welded are in contact under pressure. An electric current is passed through them, and the edges are softened and fused together as illustrated in Fig 8.

This process differs from flash butt welding in that constant pressure is applied during the heat process which eliminates flashing. The heat generated at the point of contact results from resistance. The operation and control of the butt welding process is almost identical to that of flash butt welding.

Butt or upset welding is limited to parts with a cross-section area of not more than 200-250 mm2. Bars with cross-sectional area of 250mm2 and above are joined by flash butt welding.

Fig 8



Application: Spot, seam and projection welding is widely used in the production of cars, tractors, farm machines, rail coaches etc. where thin sheets are to be joined.

Large sections like square, rectangular, cylindrical rods with regular and irregular end faces are welded without any edge preparations by flash butt or butt welding processes.

Advantages of resistance welding

- Widely used for joining sheet metals.
- Speedy process.
- No distortion.
- Less skilled operators can do the job.
- No problem of edge preparation.

Robot welding. Principal, Application and advantage , Programming concept

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

- describe the robot welding principal
- explain the robot welding application
- explain the robot programming concept.

Introduction

Robotic welding techniques are being analysed to perform welding processes in industry. This welding technology can be used in many large and small industries, with the main application being analysed in the automotive industry. The various types of welding techniques practiced in the industry include electron beam welding, ultrasonic welding, high frequency induction welding, explosive welding, arc welding and friction welding. Industry makes the most of 6-arm robots to control all welding processes. This welding technology helps meet market demands for products very easily during the welding process. Products are in high demand when market demand is always at its highest, and this process helps in rapid production and launch.

Robotic welding principal

Robotic welding technology is the latest technology being developed and implemented in the industry using different programming codes and different electrical circuits. It automates the welding process and handles all tasks from the welder to forming new components. These robots are designed to perform complex welding tasks such as resistance welding and arc welding. Use previously developed programmable code to control all robot actions and movements to automate industrial processes in welding technology. This robotic technology is used to improve the productivity and accuracy of product development in industry.

Robots used in the welding process consist of multiple mechanically programmed tools that help automate the welding process in industry. This type of robot is used to automate welding techniques developed and used in industry to join two material components by increasing their melting point temperature. This technique is used for resistance spot welding and arc welding, which are most commonly used in the industry. The most commonly used type of robot in industry is the 6-axis industrial robot, which includes a 3-axis lower arm and a 3-axis wrist arm.

Robot welding application

1 Robotic Welding Technology is used in industry to automate the welding process. This automation is done using mechanically programmable codes, which are shaped to control the motion of the robotic arm and structure during the welding process. If the mechanism of the manufacturing process is continuous and the same, it can be easily replaced by the robot technology used and implemented in industry.

2 This robotic welding technology saves time in the welding process. If the welded manufacturing process is continuous and follows the same manufacturing process, the process also takes time to perform human skill in the industry. This robotic welding technology intervenes with the help of developed programs and codes, whose movements are fixed and performed by the robot in a short time.

3 Robotic welding technology is widely used in the automotive industry. Arc welding, spot welding and resistance welding are mainly used here. Spot welding and resistance welding use electrical current with resistance to perform the welding process. Here, electrical energy is used to heat the object, so the object begins to melt after the temperature reaches its melting point. A robotic arm is used to correctly place different equipment and material components in the right place to carry out the welding process, after which the welding process is also carried out. It controls all the activities of the welding process, from the initiation of the weld, to raising the required melting point, to the final welding of the body components and their final joining.

4 Robotic welding technology is also used in arc welding, which uses an arc to carry out the welding process. An inert gas such as argon is used here to prevent the final product from reacting with the external atmosphere. All these processes from setting up equipment and tools to finishing the final welding process are controlled using a robotic arm. The robot's actions are fully programmed and controlled, so there is little chance of error during the manufacturing process and it runs very quickly. 5) 6-axis industrial robots are used to perform arc welding processes in industry. This welding process includes a complete electrical circuit and power setup from the beginning. The welder's main task here is to control the work piece and the torch during operation. This will deliver the shielding gas to the right place. This process is very slow even with skilled workers, but very quickly with robots. The role of the robot arm here is to control the movement of the welding torch and work piece to the correct position during the welding process.

Advantages of the robotic welding

The advantages of the robotic welding process are:-

1 The high consistency of the welding process helps the industry to repeat the same welding process regularly to improve productivity. This consistency results in a greater amount of weld pooling, which also results in stronger weld joints. The welding quality is higher and better as it is done by a pre-programmed robot that performs the welding without the possibility of error during operation. This welding technique is used in the industry to increase productivity and deliver products on time.

2 Uses robotic technology to increase the efficiency of the welding process and reduce waste. If the welding process is performed robotically, the chances of error are minimized. The robot is fully pre-programmed for all welding phases and activities involved during the welding process (Epping et al. 2018). Pre-programmed activities help control all activities in advance, improving the finalization process during the crafting process. Effectiveness and pre-determination of welding work reduces waste when carrying out the welding process.

3 Reduced waste generation during welding reduces post-weld clean-up associated with scrap and waste generated during the welding process. The high efficiency of this welding technology means that no scrap is generated during the welding process and less energy is required to clean up the waste generated during the welding

Disadvantages of the robotic welding

Disadvantages of the robotic welding technique are:

1 Company's cost analysis is performed in every industry to remain competitive while increasing revenue. Weldable robots are so expensive that they are still not used by most companies to reduce product costs.

2 Robotic welding technology is not yet used in most industries due to its lack of flexibility. This flexibility comes with adapting to new techniques, as robots are pre-programmed, making it difficult to adapt to new welding techniques. Next, the robot must be pre-programmed with the process of using this technology to control all activities. This takes a lot of time during the welding process. This makes the welding process inflexible and creates time lags between welding processes.

3 There are risks when using robots in welding technology. This risk includes the condition that if the robot fails due to mechanical failure, the industry will have trouble doing further welding work. Therefore, the industry should not rely entirely on robots for welding tasks.

Function of a KUKA robot system

Robots part details

a Robot arm of a KUKA robot Manipulator

b KR C4 robot controller

c KUKA smartPAD/ Teach pendant

a Robot arm of a KUKA robot/ Manipulator

1 The manipulator is the actual robot arm. It consists of a number of moving links (Axes) that are linked together to form a "kinematic chain".

2 The individual axes are moved by means of targeted actuation of servomotors. These are linked to the individual components of the manipulator via reduction gears

- Base frame
- Rotating column
- Counterbalancing system
- Link arm
- Arm
- Wrist

(The components of a robot arm consist primarily of cast aluminium and steel. In isolated cases, carbon-fiber components are also used.)

b KR C4 robot controller

The manipulator is moved by means of servomotors controlled by the (V)KR C4 controller

Robot control (path planning): control of six robot axes plus up to six external axes.

Optional sequence control: integrated Soft PLC KUKA.PLC in accordance with

a Safety controller

b Motion control

c Communication options via bus systems

d Programmable logic controllers (PLC)

e Additional controllers

f Sensors and actuators

g Communication options via network:

h Host computer

i Additional controllers

Robot controller

c KUKA smartPAD

Touch screen (touch-sensitive user interface) for operation by hand or using the integrated stylus

Large display in portrait format

a KUKA menu key

b +/- keys that can be used flexibly (e.g. as jog keys)

c Keys for operator control of the technology packages

d Program execution keys (Stop/Backwards/Forwards)

e Key for displaying the keypad

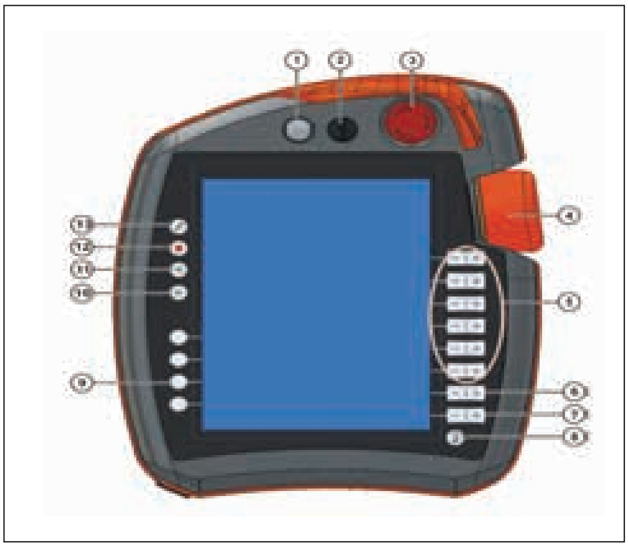
f Key switch for changing the operating mode

g Emergerncy stop button

h Space Mouse

i Detachable

j USB connection



Overview of smartPAD

Item Description

1 Button for disconnecting the smartPAD

2 Key switch for calling the connection manager. The switch can only be turned if the key is inserted. The operating mode can be changed by using the connection manager.

3 EMERGENCY STOP button. Stops the robot in hazardous situations. The EMERGENCY STOP button locks itself in place when it is pressed.

4 Space Mouse: For moving the robot manually.

5 Jog keys: For moving the robot manually.

6 Key for setting the program override

7 Key for setting the jog override

8 Main menu key: Shows the menu items on the smartHMI

9 Status keys. The status keys are used primarily for setting parameters in technology packages. Their exact function depends on the technology packages installed.

10 Start key: The Start key is used to start a program.

11 Start backwards key: The Start backwards key is used to start a program backwards. The program is executed step by step.

12 STOP key: The STOP key is used to stop a program that is running.

13 Keyboard key

Displays the keyboard. It is generally not necessary to press this key to display the keyboard, as the smartHMI detects when keyboard input is d: 15.01.2015 Version: P1KSS8 robot programming 1 (R2) V4 15 / 297 1

Robot programming

A robot is programmed so that motion sequences and processes can be executed

Automatically and repeatedly. For this, the controller requires a large amount of information:

a Current robot position = position of the current tool (Tool) in the current space (Base)

b Type of motion

c Velocity / acceleration

d Signal information for wait conditions, branches, dependencies, etc.

MODULE 9 : Inspection & Testing

Lesson 83 - 97 : Non Destructive testing of Metal - Visual inspection

Objectives

At the end of this lesson you shall be able to

- describe the non destructive testing
- explain the visual inspection
- explain the visual inspection after welding.

INTRODUCTION

Non destructive testing is a branch of the materials sciences that is concerned with all aspects of the uniformity, quality and serviceability of materials and structures. The science of nondestructive testing incorporates all the technology for detection and measurement of significant properties, including discontinuities, in items ranging from research specimens to finished hardware and products. By definition, nondestructive techniques are the means by which materials and structures may be inspected without disruption or impairment of serviceability.

Nondestructive testing (NDT) has been defined as comprising those test methods used to examine an object, material or system without impairing its future usefulness.

It is very difficult to weld or mold a solid object that has the risk of breaking in service, so testing at manufacture and during use is often essential. During the process of casting a metal object, for example, the metal may shrink as it cools, and crack or introduce voids inside the structure. Even the best welders (and welding machines) do not make 100% perfect welds. Some typical weld defects that need to be found and repaired are lack of fusion of the weld to the metal and porous bubbles inside the weld, both of which could cause a structure to break or a pipeline to rupture.

During their service lives, many industrial components need regular nondestructive tests to detect damage that may be difficult or expensive to find by everyday methods. For example:

- aircraft skins need regular checking to detect cracks;
- underground pipelines are subject to corrosion and stress corrosion cracking;
- pipes in industrial plants may be subject to erosion and corrosion from the products they carry;
- concrete structures may be weakened if the inner reinforcing steel is corroded;
- pressure vessels may develop cracks in welds;

the wire ropes in suspension bridges are subject to weather, vibration, and high loads, so testing for broken wires and other damage is important.

An industrial product is designed to perform a certain function. The user buys a product with expectation that it performs the assigned function well and gives trouble – free service for a stipulated period of time. Trouble free service given by any product may be termed as "reliability". Reliability comes through improving the quality level of the component. The quality of products, components or parts depends upon many factors. Quality is related to the presence of defects and imperfections in the finished product which impair the performance level. In the correct sense, a defect is a rejectable discontinuity or flaw of rejectable nature. Certain flaws acceptable in one type of product need not be of acceptable nature in another product. A defect is definitely a discontinuity but a discontinuity need not necessarily be a defect. Acceptance standards dictate the type of inspection and testing the weld is subjected to.

Nondestructive testing (NDT), also called nondestructive examination (NDE) and nondestructive inspection (NDI), is testing that does not destroy the test object. NDE is vital for constructing and maintaining all types of components and structures. To detect different defects such as cracking and corrosion, there are different methods of testing available, such as X-ray (where cracks show up on the film) and ultrasound (where cracks show up as an echo blip on the screen). This article is aimed mainly at industrial NDT, but many of the methods described here can be used to test the human body. In fact methods from the medical field have often been adapted for industrial use, as was the case with Phased array ultrasonic and Computed radiography.

While destructive testing usually provides a more reliable assessment of the state of the test object, destruction of the test object usually makes this type of test more costly to the test object's owner than nondestructive testing. Destructive testing is also inappropriate in many circumstances, such as forensic investigation. That there is a tradeoff between the cost of the test and its reliability favors a strategy in which most test objects are inspected nondestructively; destructive testing is performed on a sampling of test objects that is drawn randomly for the purpose of characterizing the testing reliability of the nondestructive test.

Non Destructive Testing (NDT) plays a significant part in maintaining the quality of the products at various stages of manufacture. Raw material stage i.e. before the start of manufacture, intermediate stages, and final stage after manufacture all utilizes Nondestructive testing techniques.

Since the 1920s, nondestructive testing has developed from a laboratory curiosity to an indispensable tool of production. No longer is visual examination the principal means of determining quality. Nondestructive tests in great variety are in worldwide use to detect variations in structure, minute changes in surface finish, the presence of cracks or other physical discontinuities, to measure the thickness of materials and coatings and to determine other characteristics of industrial products.

Modern nondestructive tests are used by manufacturers (1) to ensure product integrity, and in turn, reliability; (2) to avoid failures, prevent accidents and save human life; (3) to make a profit for the user; (4) to ensure customer satisfaction and maintain the manufacturer's reputation; (5) to aid in better product design; (6) to control manufacturing processes; (7) to lower manufacturing costs; (8) to maintain uniform quality level; and (9) to ensure operational readiness

Methods And Techniques

NDT is divided into various methods of nondestructive testing, each based on a particular scientific principle. These methods may be further subdivided into various techniques. The various methods and techniques, due to their particular natures, may lend themselves especially well to certain applications and be of little or no value at all in other applications. Therefore choosing the right method and technique is an important part of the performance of NDT. Below are many NDT methods and they are merely mention to grasp the fact that NDT is more vast and the method to be applied is specific for each and every application.

1 Visual Inspection

2 Dye penetrant test /Liquid penetrant testing D(PT or LPI)

3 Magnetic-particle inspection (MT or MPI)

4 Ultrasonic testing (UT)

5 Radiographic testing (RT)

6 Eddy-Current Testing (ECT)

Visual inspection - 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:

a Before welding

b During welding

c after welding

Visual inspection before welding

a The operator must be familiar with the type of work, electrode and welding machine.

b The following factors are to be ensured.

c The material to be welded is of weld able quality.

d The edges have been properly prepared for welding as per thickness of the plate.

e Proper cleaning of the base metal. Setting of proper root gap.

f Proper procedure to be followed to control distortion.

g Proper selection of blow pipe nozzle and filler rod, flux and flame.

h Polarity of the electrodes in the case of DC welding current. Whether the cable connections are tight.

i Current setting according to the size of the electrode and position of welding.

h Whether any jigs and fixtures are necessary to ensure proper alignment.

Visual inspection during welding

The following points are to be checked. Studying the sequence of weld deposit.

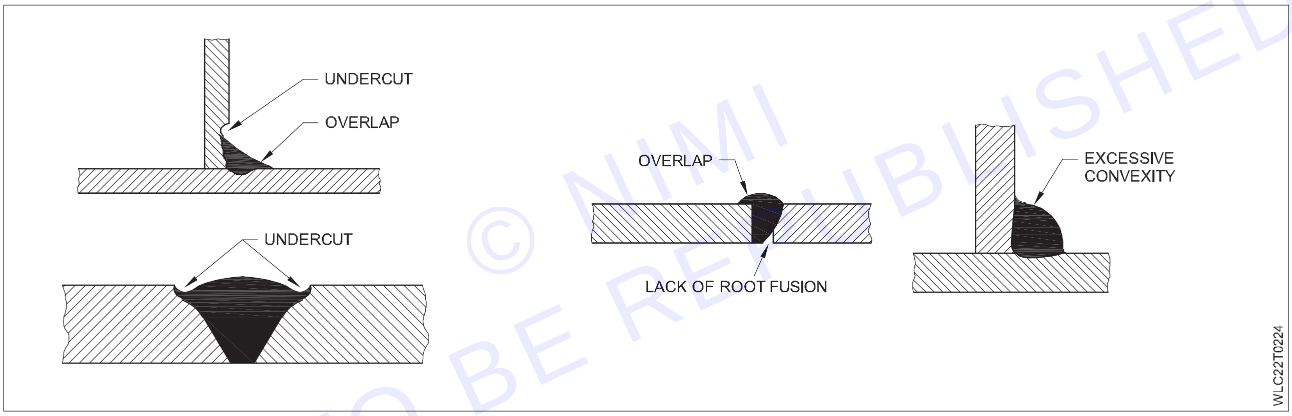
a Examining whether each weld is cleaned adequately before making the next run in multi-run welding.

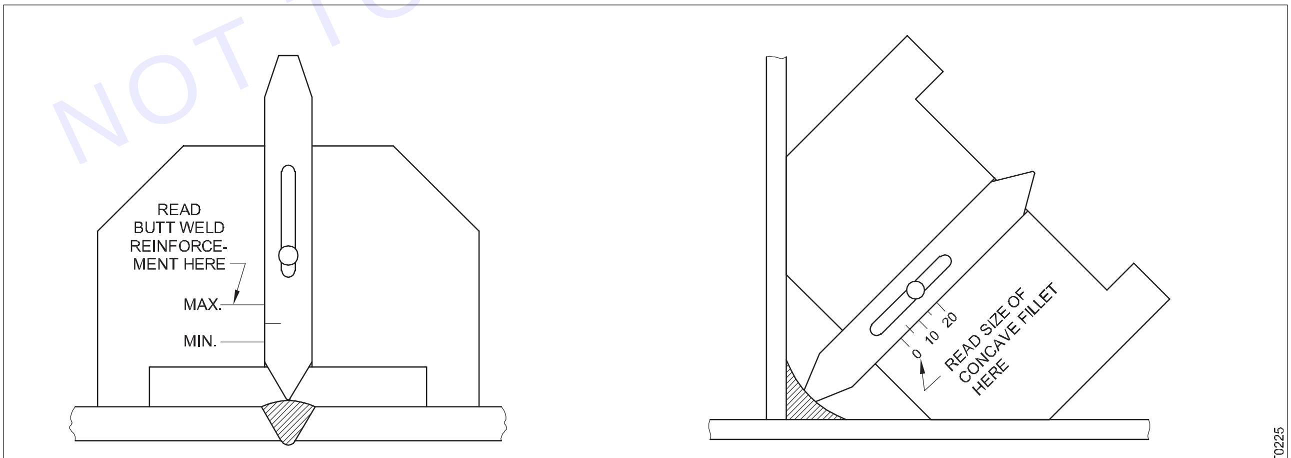
b Weld alignment proper need.

c Welding electrode should be dry need

Visual inspection after welding

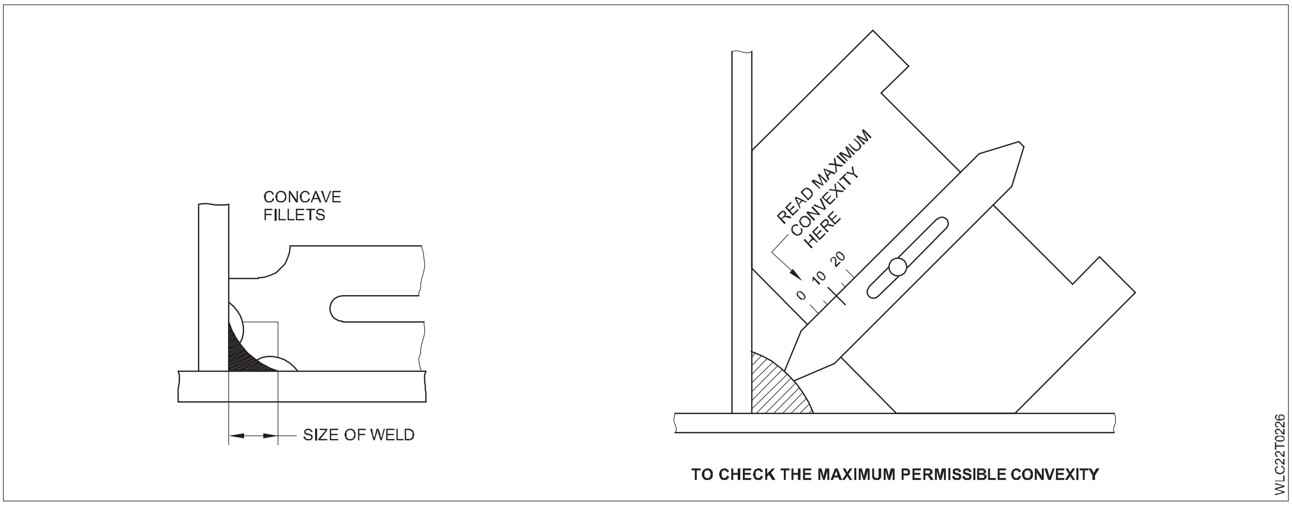
Surface defects in and around the welds, such as cracks, (longitudinal and transverse) undercut overlap excessive convexity of contour, the weld surface smoothness of the run and penetration, control of distortion, unfilled crater are to be inspected. Freedom from surface cavities and slag inclusions. Deposition of runs, single or multiple. Penetration bead in butt weld.Check the all weld bead and shape by weld measure gauge

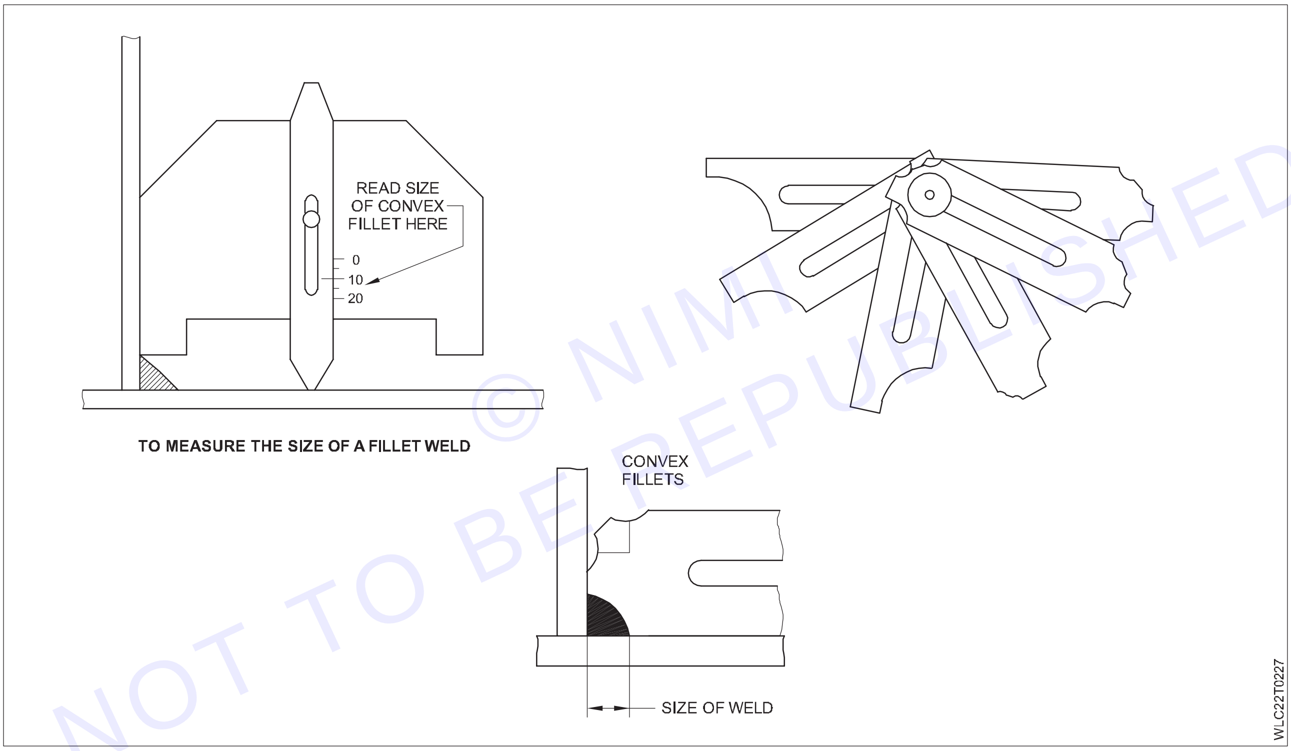




CHECKING BUTT WELD FOR MAXIMUM AND MINIMUM CONVEXITY

TO DETERMINE THE SIZE OF A CONCAVE FILLET





Dye Penetrant Test, Principal, Advantage, limitation, Type of penetrant, Cleaners Dwelling time

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

- describe the principal dye penetrant test
- explain the types of penetrant
- explain the procedure dye penetrant test.

Introduction

Dye penetrant inspection (DPI), also called liquid penetrant inspection (LPI), is a widely applied and low-cost inspection method used to locate surface-breaking defects in all non-porous materials (metals, plastics, or ceramics). Penetrant may be applied to all non-ferrous materials, but for inspection of ferrous components magnetic-particle inspection is preferred for its subsurface detection capability. LPI is used to detect casting and forging defects, cracks, and leaks in new products, and fatigue cracks on in-service components.

Location of surface flaws and sub-surface flaws is essential for many of the industrial components since the failure to do so may lead to catastrophic situations. For locating gross surface flaws, visual inspection with the aid such as magnifying glasses is adequate. However, location of minute cracks may not be possible even with the aid of magnifying devices. In such cases, Liquid Penetrant Inspection can come to the assistance in the location of defects. For locating only surface flaws, Liquid Penetrant Inspection is sufficient Penetrant examination is generally considered to be one of the easiest methods of surface inspection to locate discontinuities that are open to the surface. Consequently the need for an accurate application and competent personnel may be under-estimated. To obtain optimum results, the method should be applied with care and accuracy. PT can be used on any material except when it is extremely porous.

Principle

DPI is based upon capillary action, where low surface tension fluid penetrates into clean and dry surface-breaking discontinuities. Penetrant may be applied to the test component by dipping, spraying, or brushing. After adequate penetration time has been allowed, the excess penetrant is removed, and a developer is applied. The developer helps to draw penetrant out of the flaw where a visible indication becomes visible to the inspector. Inspection is performed under ultraviolet or white light, depending upon the type of dye used - fluorescent or non-fluorescent (visible).

Surface discontinuities, such as cracks or other separations, as well as porosity open to the surface can be detected by 'bleeding' after the surface has been treated with a penetrant. A developer is generally used to increase the evaluation efficiency.

Types of Penetrant

Since the main feature of penetrant testing is the visibility of the indications, the liquid penetrant contains a coloured dye (usually RED eye) easily seen in white light or a fluorescent dye visible under black or ultra violet light. Hence, the penetrant can be classified as visible dye penetrant or fluorescent dye penetrant

Penetration Time or Dwell Time

The period of time during which the penetrant is permitted to remain on the specimen is a vital part of the test. The minimum time required for the penetrant to enter into the discontinuity is determined by the following factors:

Manufacturer's recommendation.

Type of material tested.

Type of discontinuity expected.

Temperature of the specimen.

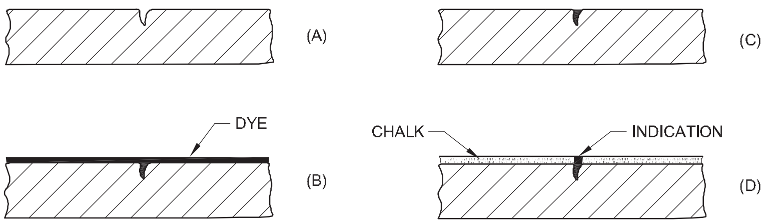
It may be pointed out here that tight crack like discontinuities may require as high as 30 minutes while gross discontinuity may require 3 to 5 minutes.

The temperature of the specimen is most important. Usually at 10 to 45°C the usual liquid penetrants work normally well and at elevated temperature more than 45 , the normal penetrants will become dry and hence will not penetrate into discontinuities. Similarly, at temperature below 10, the mobility of the particles will be very slow and hence, there will not be any penetrating action. For use at higher temperature special penetrants have been developed. However, in case of low temperature, the article has to be heated to a temperature of 10 to 45°C.

This test is based on the principle that colored 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 colored 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 1)

Fig 1



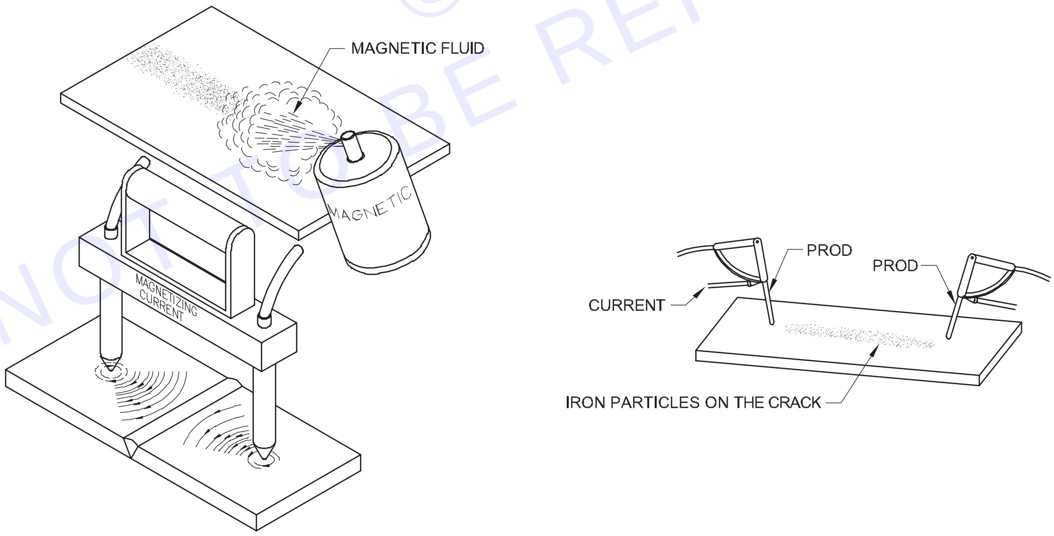
LIQUID PENETRANT TEST

Magnetic particle Test(MPT) Principal, advantage, Limitation., Types of Magnetation, Current requirement, Testing equipment, indication and interpretation.

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

- describe the principal MPI test.
- explain the MPI advantage and limitation.
- explain the equipments of MPI.

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.



MAGNETIC PARTICLE TEST

Eddy current testing, Principal, advantage

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

- state eddy current
- explain the applications of the eddy current
- explain the advanctages of the eddy current.

Eddy Current Testing is a versatile non-destructive testing method that is typically used to identify defects in materials without causing any harm to the object or reducing the shelf life of the component.

It permits examining the conductivity, thus the hardness, geometry, and chemistry of any material that is electrically conductive when it is brought into the vicinity of a coil.

Generally, Applications of Eddy Current Testing are used to detect porosity, voids, cracks, hardness, the density of the material, thickness, thread, and surface condition.

Applications of Eddy Current Testing

Eddy Current Testing includes various applications; here are some of the applications that are widely used.

1 Material Sorting

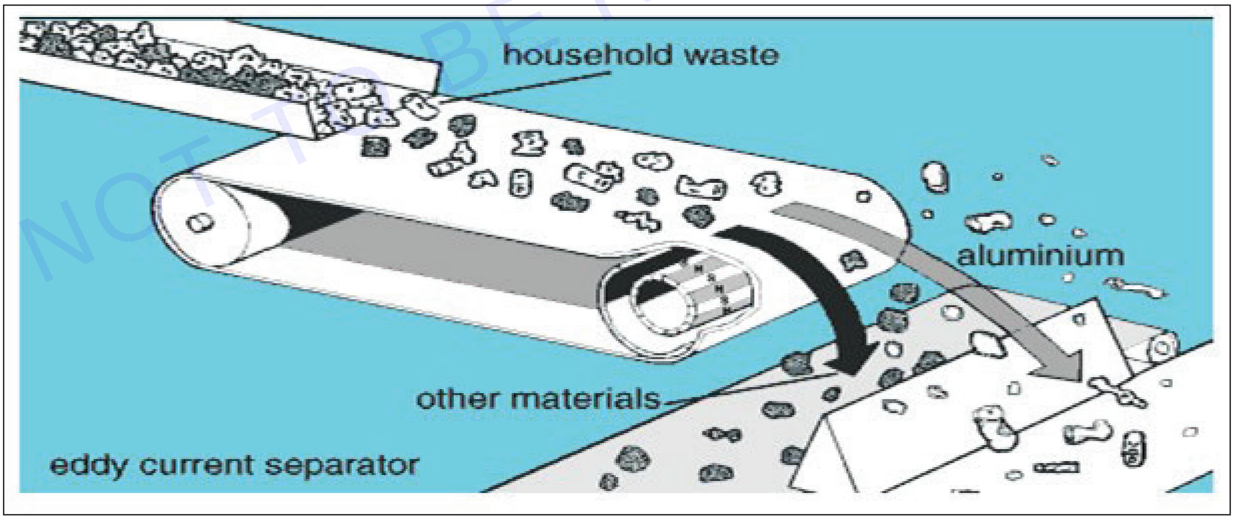
Electromagnetic sorting bridges and Ferrous segregation are some of the valuable tools for sorting steel that has been hardened.

Conductivity meters can be used in sorting copper and aluminum alloys in both cases, i.e., hardness variation and compositional variation.

A lot of concentration is required in order to ensure that the variation being inspected is the appropriate one.

For instance, the occurrence of a change in the conductivity of an aluminum alloy is due to a change in its composition or a change in its hardness.

This particular method delivers a better classification of the properties that material holds than any other method used for sorting materials because eddy current fields permeate below the surface of the components.



2 Weld Testing

Eddy current testers with high frequencies have been used for a long time to identify cracks in ferrous welds.

There is an advantage to executing this method, as it is capable of detecting cracks through paint layers.

One drawback of this method is the high noise levels that result from the permeability changes that occur in the weld. This is one of the major applications of ECT.

3 Crack Detection

Eddy Current Testing equipment for identifying cracks can be classified into two categories.

The first one is a high-frequency instrument for detecting surface-breaking cracks in non-ferrous and ferrous components.

The second one is a low-frequency instrument for inspecting subsurface cracks in non-ferrous components.

In ferrous materials, identifying the subsurface cracks is possible only when the materials are saturated magnetically to eliminate permeability impacts.

This is a complicated procedure that is achievable with automated tube testing systems. Applications of Eddy Current Testing are widely used in detection.

In the detection procedure of surface cracks, eddy currents are too sensitive. High frequencies of the order of 2 MHz provide high resolution, but the probes are too small, and covering a vast surface area consumes a lot of time.

Large probes are required for low-frequency crack detectors in order to enable favorable coil inductances.

The setting of the frequency is critical, and it is in the range of 10 Hz to 100 Hz, which depends on the depth of penetration needed.

Phase sensing circuits are necessary because phase changes, rather than amplitude changes, have a significant impact on the subsurface eddy current fields.

4 Measurement of The Coating Thickness

The outstanding surface resolution of Eddy current testing makes it highly useful.

Its application is seen in meticulously measuring the thickness of the coatings, whether metallic or paint, on the components.

5 Tube and Wire Testing

The automated eddy current test systems are developed for examining bars, tubes, and wires at a speed of 3 m/s.

After the operator calibrates the equipment by using a wire or tube with already known defects, the implemented test runs automatically, defenestrating defective pieces from the production line or marking them with the help of paint.

The actual eddy current test instrumentation can appear to be an insignificant part due to the mechanical handling equipment for the test pieces that becomes complicated.

There is an increase in costs because of the facilities required for magnetic saturation and the demagnetization of ferrous wires and tubes.

The continuous test speeds and differential coils enable the modulation of the test signals with speed, and then it filters to remove the noise.

But sadly, when it comes to using differential coils, it becomes possible for the tubes (which comprise consistent defects over their full length) to pass through the eddy current system without any detection.

Also, due to the edge effects, the tube ends cannot be identified. Moreover, the extrusion flaws along the Centre of the bars cannot be identified because the eddy current field from an encircling coil remains at zero intensity, which is at the center of a strong cylinder.

Purpose of Eddy Current Testing

Eddy Current Testing serves a critical role in the realms of material inspection and quality assurance.

This electromagnetic testing technique is specifically designed to detect flaws, defects, cracks, and other irregularities in conductive materials without causing any damage to the tested object.

The primary purpose of ECT is to ensure the structural integrity and reliability of components across various industries, including aerospace, automotive, manufacturing, and energy.

Advantages of Eddy Current Testing

In the world of Non-destructive Testing, Eddy Current Testing stands out as a versatile and powerful technique used to inspect a wide range of conductive materials. There are many ECT companies.

Here are a few advantages.

1 High Sensitivity and Precision

Eddy Current Testing offers an unparalleled level of sensitivity, making it capable of detecting even the minutest cracks or imperfections in conductive materials.

Its high precision ensures that potential issues are identified early, minimizing the risk of catastrophic failures.

2 Non-Destructive Nature

One of the most significant advantages of ECT is its non-destructive nature. Unlike some testing methods that may cause damage during the inspection process, ECT allows for a thorough examination without altering the material's properties.

3 Rapid Inspection

Eddy Current Testing is known for its efficiency in rapidly assessing large volumes of materials.

This speed makes it an ideal choice for industries where time-sensitive inspections are crucial, such as manufacturing or maintenance operations.

4 Versatility

From inspecting heat exchanger tubes for corrosion to detecting surface cracks in aircraft components, Eddy Current Testing proves its versatility across a multitude of applications.

It can be adapted to various geometries and materials, further expanding its utility.

5 Cost-Effectiveness

By enabling early detection of defects, ECT contributes to cost savings in the long run.

Timely identification of issues allows for targeted repairs or replacements, preventing expensive downtime or equipment failures.

Limitations of Eddy Current Testing

While ECT offers numerous benefits, it's essential to acknowledge its limitations to ensure appropriate utilization and interpretation of results.

Here are the major limitations of Eddy Current Testing.

1 Conductivity Dependency

ECT is most effective on materials with high electrical conductivity. Inspecting materials with low conductivity may yield less accurate results, requiring careful consideration of the material's properties.

2 Depth Limitations

The depth to which Eddy Current Testing can penetrate and effectively detect flaws is limited.

Deeper defects may go undetected, necessitating supplementary NDT Testing Methods for comprehensive evaluation.

3 Surface Condition Influence

Surface conditions, such as roughness or curvature, can impact the accuracy of ECT results.

Proper preparation and calibration are crucial to accounting for these variations.

4 Skilled Operator Requirements

Interpreting Eddy Current Testing results demands a certain level of expertise. Skilled operators are required to assess the data accurately, minimising the risk of misinterpretation.

5 Complex Data Analysis

The data generated by ECT can be complex, requiring specialised software and analysis techniques for meaningful interpretation. Adequate training and resources are necessary for efficient data processing.

Wrap-Up

Eddy Current Testing is a powerful tool that plays a vital role in ensuring the integrity and reliability of conductive materials.

High sensitivity and rapid inspection capabilities position ACT as a valuable asset across various industrial applications. However, it's crucial to be aware of its limitations, such as its dependency on material conductivity and depth constraints.

By harnessing the applications of ECT while mitigating its limitations through careful planning and expert execution.

Industries can benefit from enhanced quality control, improved safety, and increased cost-effectiveness.

Mechanical Testing of Metals. Principles, Applications of - Hardness testing (Rockwell and Brinell) - Impact testing (Izod and Charpy) - Tensile testing and Bend Test

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

- describe the mechanical testing of metal
- explain the hardness testing
- explain the impact testing.

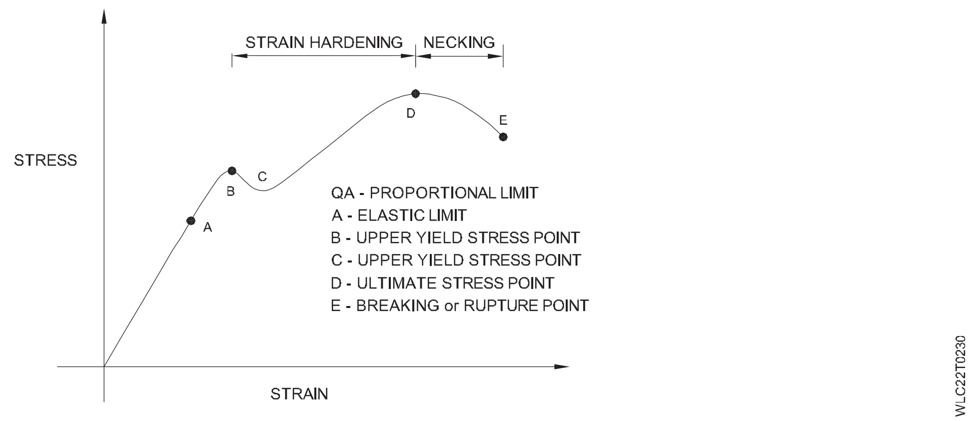
1 **Introduction:** The mechanical properties are those which affect the mechanical strength and ability of a material to be molded in suitable shape. Some of the typical mechanical properties show huge applications in space and automobile industries. These properties are associated with the capability of the materials to resist mechanical forces and load and they are measured in terms of the behavior of the material when subjected to a force. Mechanical properties may be determined to provide either design data for the engineer or as a check on the standard of raw materials

1 Mechanical properties may be changed by heat treatment process and the working temperature. Mostly, the strength, toughness and hardness of materials are to be measured after the metal forming process

2 The main objective of the paper is to give the overview of the importance of mechanical properties of the materials, testing. This paper, includes the concepts of strength, plasticity, malleability, stiffness, elasticity, brittleness, ductility, toughness, resilience, fatigue, creep and shown how improper understanding of properties can lead to have confusion. The engineering concepts of mechanical. properties dominate the teaching in the technological universities over natural sciences.

2 **Mechanical Properties Definition :** Strength and Stress-Strain Curve Strength of the materials refers to the ability of a material to resist the externally applied forces without breaking or yielding. The maximum stress is that any material withstands before destructive is called its ultimate strength (D). Fig 1 shows the stress and strain relationship. Stress and strain curve of the material obtained during tensile test describe its ductility and yield strength. According to Fig 1, upto the elastic limit, the elasticity of material, that means the material would return to its original dimension, would be maintained, over it the plasticity would follow. Once the material exceeds the ultimate stress point (D), necking starts to have on the specimen. The strain hardening is kept between yield points to ultimate tensile strength. A material obeys hooks law upto proportional limit accurately. The stress and strain curve is used to obtain Young's modulus of materials by comparing stress and strain value upto elastic limit. In the figure, A-B range is measured as elastic limit. The Ability of materials to sustain loads without undue failure or distortion is known as strength and it is known that the ability of a material to provide an equal reaction to an applied force (tensile, compression, shear) without rupture. Simply, the strength is a maximum resistance by the material to the deformation. Similarly, tenacity is the ability of a material to resist rupture due to a tensile force.

Fig 1



3 **Stiffness** It is the ability of a material to resist deformation under stress. Modulus of elasticity is the measure of stiffness. Material which suffers slight deformation under load has a high degree of stiffness or rigidity. Steel beam is stiffer or more rigid than aluminium beam. Finally, it means that the ability of material to resist elastic deflection is known as stiffness.

4 **Elasticity** It is the property of materials to regain its original shape after deformation when the external forces are removed. Example is the extension or compression of a spring. This property is desirable for materials used in tools and machines. Steel is more elastic than rubber. Elasticity is a tensile property of the material. Proportional limit and elastic limit indicate elasticity. It is also known as Nonpermanent deformation. It consists of two sub properties within this elastic region. They are proportional limit and elastic limit. Proportional limit is the maximum stress under which a material will maintain a perfectly uniform rate of strain to stress. Proportional limit applications are precision instruments, springs etc... The greatest stress that a material can endure without taking up some permanent set is called elastic limit. Beyond the elastic limit, material does not regain its original form and permanent set occurs.

5 **Plasticity** It is the ability of material to undergo some degree of permanent deformation without rupture or failure. That means, this is the property of a material to deform permanently under the application of a load. Plastic deformation will take place only after the elastic range has been exceeded by the process of slipping when the shear stress on the slip plane reaches a critical value. Displacement caused by slipping is permanent and the crystal planes do not return to their original positions even after the removal of the stresses. Applications are forming, shaping, extruding, hot & cold working process, forging, ornamental work, stamping, rolling, drawing, pressing, etc.. Aluminium is a good plasticity material.

6 **Ductility** It is the property of a material which enables it to draw out into thin wire with the application of a tensile force. Ductile material must be both strong and plastic. Ductile materials are gold (most ductile material), mild steel, copper, aluminium, nickel, zinc, tin. Ductility usually measured by the terms, percentage elongation and percentage reduction in area. Ductility is thought of as a tensile quality. Ductile material combines the properties of plasticity and tensile strength. It is also mentioned as a capacity of a material to undergo deformation under tension without rupture or the ability of amaterial to withstand cold deformation without fracture. Ductility of a material is to stretch under the application of tensile load and retain the deformed shape on the removal of the load. If subjected to a shock load the material would yield and become deformed. Ductile material can be worked into a shape without loss of strength. All materials which are formed by drawing are required to be ductile, e.g.- drawing into wire form. Brittleness Breaking of a material with little permanent distortion simply states the property of brittleness. Brittle materials when subjected to tensile loads snap off without giving any sensible elongation. Usually the tensile strength of brittle materials is only a fraction of their compressive strength. Examples of brittle materials are glass, bricks, cast iron etc… It is also a tendency of a material to fracture when subjected to shock loading or a blow. Material that shatters is also a brittle material.

7 **Malleability** It is the ability of materials to be rolled, flattened or hammered into thin sheets without cracking by hot or cold working. Malleable material should be plastic but it is not essential to be strong and malleability is considered as a compressive quality. Examples for malleability Al, Cu, Sn, Pb, soft steel, wrought iron. This is the property of a material to deform permanently under the application of a compressive load. A material which is forged to its final shape is required to be malleable. Forging, Rolling processes are malleability.

8 **Toughness and Testing** It is the ability of a material to withstand bending without fracture due to high impact loads. Toughness of material decreases when it is heated. It is also measured by the amount of energy that a unit volume of the material has absorbed after being stressed up to failure point and is the area under stress strain curve. For example, if a load is suddenly applied to a piece of mild steel and then to a piece of glass, the mild steel will absorb much more energy before failure occurs. Thus mild steel is said to be much tougher than a glass. This property is desirable in parts subjected to shock and impact loads. Notch toughness is the measure of the metal's resistance to brittle fracture in presence of flaw or notch and fast loading conditions. Examples are Mn-steel, wrought iron, MS, etc…it can be also defined as property of absorbing energy before fracture. To the opposite of brittleness, the ability of a material is to resist fracture under shock loading. Basically, two main impact tests for measuring the toughness of material in Joule are available namely Izod and Charpy test. Fig 2 shows the three types of Notches used for fracture study. U type notch specimens can also be used for testing. In case of ductile materials, when the material is stressed, it plastically deforms by absorbing high energy and then the material fractures. But in the case of brittle materials, the cohesive strength of the material exceeds before getting plastically deformed and hence absorbs less energy before getting fractured. There are factors responsible for brittle behaviour; they are notch, low temperature, thickness and microstructure. When temperature falling, the failure mode of certain materials changes from ductile to brittle. For FCC materials,

if the temperature increases, the energy absorbed also slightly increases. The factors responsible for the Charpy impact test are ductility, yield strength, notch, temperature, and fracture mechanism. Fig 3, shows the working procedure of impact testing. The pivoting arm is raised to a specific height, which is the potential energy and then this arm gets released. The arm swings down hitting a notched sample, available on the specimen holding vise, and breaking the specimen. The energy absorbed by the sample is measured from the height the arm swings to after hitting the sample. The fracture energy (Joule) is determined from the swing-up angle of the hammer and its swing-down angle. A notched sample is generally used to determine impact energy and notch sensitivity. Some of the standards are followed worldwide for the test they are ASTM D6110, ASTM E23, and ASTM D256 etc..., Fig 4 depicts the difference between Izod and Charpy test. In Charpy test (Fig 4 a), a test specimen having a V-shaped notch (Fig 5) is placed on the holder in such position that the notched section is in the center of the holder and the specimen is broken by striking the back of the notched section with the hammer. The Charpy impact value (kJ/m2) is calculated by dividing the fracture energy by the cross-section area of the specimen. If a test specimen having a V shaped notch is fixed vertically, and the specimen is broken by striking it from the same side as that of the notch by the use of the hammer, this is called Izod test (Fig 4b). The Izod impact energy value (J/m,) is calculated by dividing the fracture energy by the width of the specimen.

Fig 2

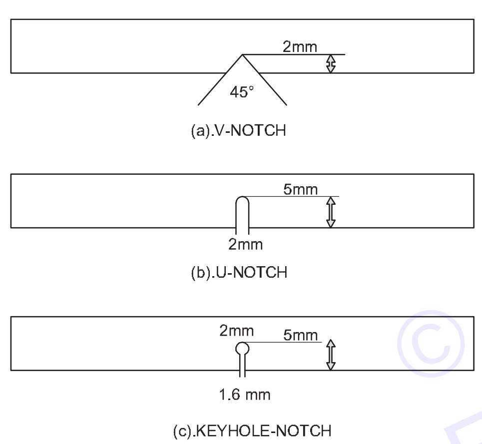


Fig 3

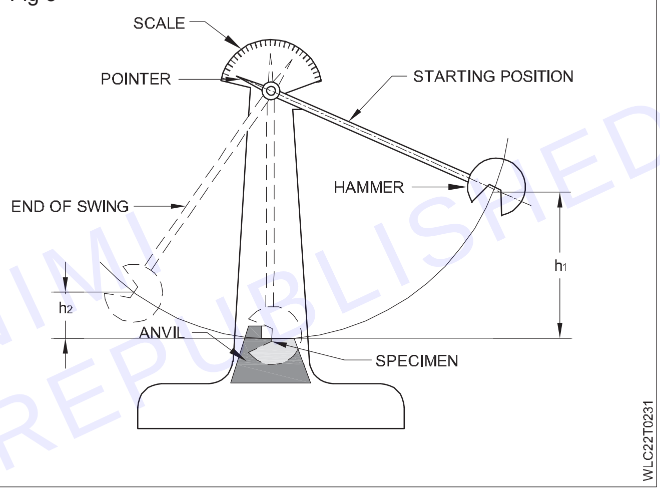


Fig 4

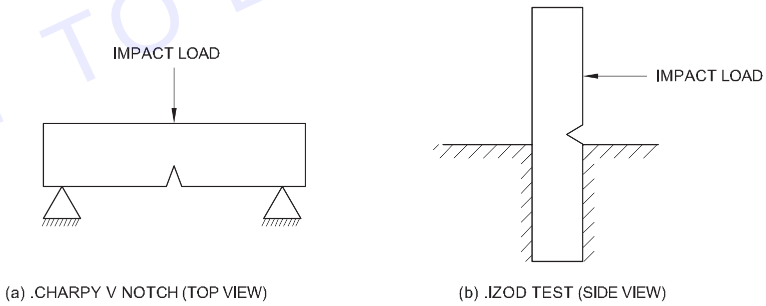
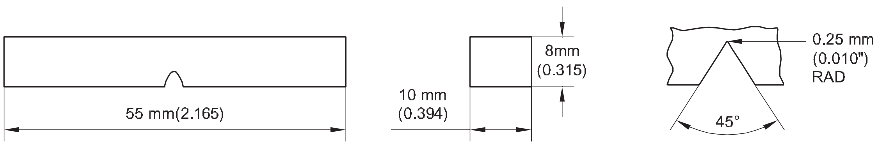


Fig 5

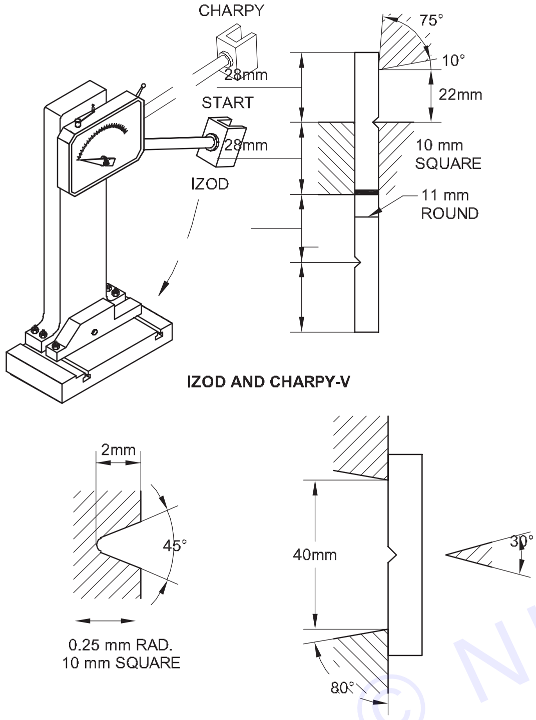


9 Resilience The property of a material to absorb energy and to resist shock and impact loads are known as resilience. Generally, it is mentioned by the amount of energy absorbed per unit volume within elastic limit. This is essential for spring materials. Two kind of resilience are available. Proof resilience: Maximum energy which can be stored in a body up to elastic limit is called the proof resilience. But the Proof resilience per unit volume is called modulus of resilience.

Impact test:

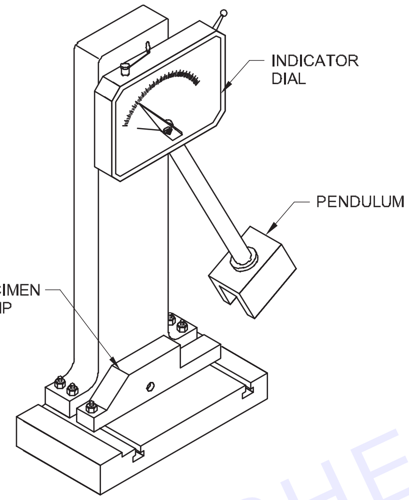
Impact test: Impact means application of a sudden force on an object. In an impact test of a weld, a test specimen (Fig. 6) is prepared from a test plate. This is further machined to have a V notch as in Fig.6. The test specimen with 10 mm square cross-section is used for charpy V impact test and one with 11 mm diameter circular cross-section is used for the izod impact test. Fig 7 shows an impact testing machine.

Fig 6



IZOD AND CHARPY - V MACHINE AND SPECIMENS IMPACT TEST

Fig 7



A CHARPY IMPACT TESTING MACHINE

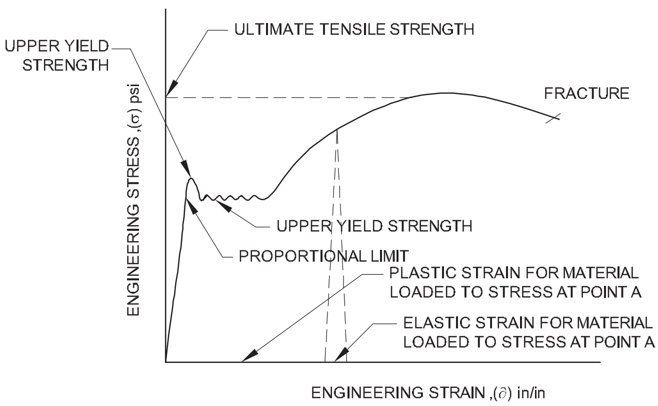
IN THIS TESTER THE PENDULUM IS LIFTEDAND DROPED AGAINST THE TEST SPECIMEN WHICH IS HELD IN THE CLAMP. THE IMPACT FORCE IS REGISTERED BY THE DIAL INDICATOR.

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 - 400 C which are subjected to severe dynamic loading.

Tensile : Introduction The Tensile test is used to obtain basic design information on the strength of materials. When the standard methods of test are employed the results are acceptable criteria of quality of materials and a given level of quality means satisfactory behavior in service.

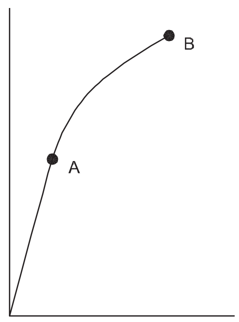
They typical stress-strain diagram with some of common nomenclature for a typical low carbon steel specimen is shown in Fig 8 and Fig 9 shows a typical stress - strain diagram for brittle materials

Fig 8



ENGINEERING STRESS - STRAIN DIAGRAM FOR CARBON STEEL SHOWING IMPORTANT PROPERTIES

Fig 9



TYPICAL STRESS - STRAIN DIAGRAM FOR A BRITTLE MATERIAL.

Hardness Test : Hardness is defined as the resistance of a material to permanent deformation such as indentation, wear, abrasion, scratch. Principally, the importance of hardness testing has to do with the relationship between hardness and other properties of material. For example, both the hardness test and the tensile test measure the resistance of a metal to plastic flow, and results of these tests may closely parallel each other. The hardness test is preferred because it is simple, easy, and relatively nondestructive. There are many hardness tests currently in use. The necessity for all these different hardness tests is due to the need for categorizing the great range of hardness from soft rubber to hard ceramics.

THEORY

Current practice divides hardness testing into two categories: macrohardness and microhardness. Macrohardness refers to testing with applied loads on the indenter of more than 1 kg and covers, for example, the testing of tools, dies, and sheet material in the heavier gages. In microhardness testing, applied loads are 1 kg and below, and material being tested is very thin (down to 0.0125 mm, or 0.0005 in.). Applications include extremely small parts, thin superficially hardened parts, plated surfaces, and individual constituents of materials.

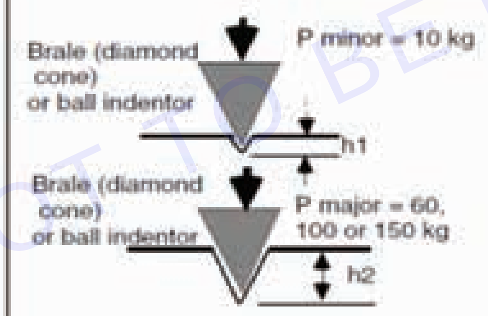
1 Macro Hardness Testers Loads > 1 kg • Rockwell • Brinell • Vickers

2 Micro Hardness Testers < 1 kg • Knoop diamond • Vickers diamond pyramid

3.1 Macro Hardness Test Methods

3.1.1 Rockwell Hardness Test The Rockwell hardness test method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load F0 (Fig 10A) usually 10 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration (Fig 10B). When equilibrium has again been reach, the additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration (Fig 10C). The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

Fig 10



Rockwell Scale (X =)	Indentor	Pmajor (kg)
A	Brale (diamond)	60
B	1/16" ball	100
C	Brale (diamond)	150
D	Brale (diamond)	100
E	1/8" ball	100
F	1/8" ball	60
M	1/4" ball	100
R	1/2" ball	60

$$HRX = R_x = M - \frac{(h_2 - h_1)}{0.002}$$

M = 100 for A, C, and D scales

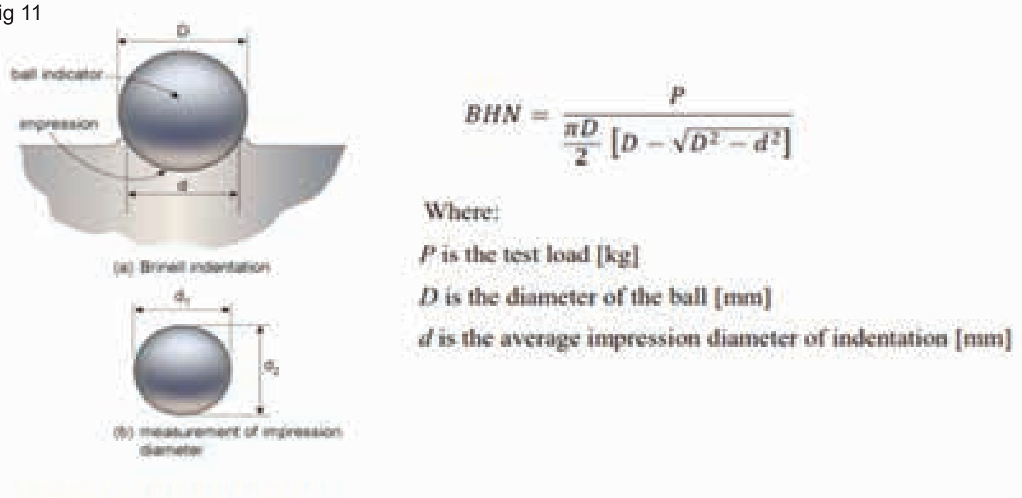
M = 130 for B, E, M, R, etc. scales

There are several considerations for Rockwell hardness test - Require clean and well positioned indenter and anvil - The test sample should be clean, dry, smooth and oxide-free surface - The surface should be flat and perpendicular to the indenter

3 - Low reading of hardness value might be expected in cylindrical surfaces - Specimen thickness should be 10 times higher than the depth of the indenter - The spacing between the indentations should be 3 to 5 times of the indentation diameter - Loading speed should be standardized.

3.1.2 The Brinell Hardness Test The Brinell hardness test method consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball subjected to a load of 3000 kg. For softer materials the load can be reduced to 1500 kg or 500 kg to avoid excessive indentation. The full load is normally applied for 10 to 15 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals. The diameter of the indentation left in the test material is measured with a low powered microscope. The Brinell harness number is calculated by dividing the load applied by the surface area of the indentation. When the indentor is retracted two diameters of the impression, d1 and d2, are measured using a microscope with a calibrated graticule and then averaged as shown in Fig 11.

Fig 11



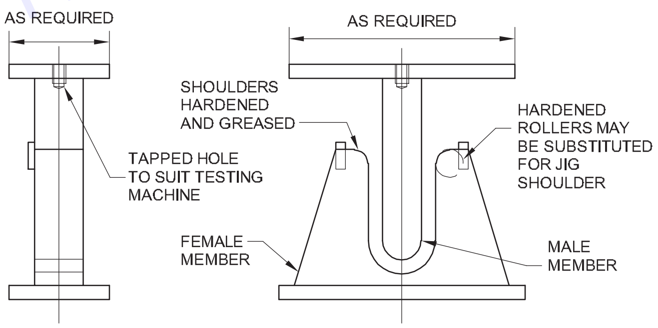
Brinell Principle

The diameter of the impression is the average of two readings at right angles and the use of a Brinell hardness number table can simplify the determination of the Brinell hardness. A well structured Brinell hardness number reveals the test conditions, and looks like this, "75 HB 10/500/30" which means that a Brinell Hardness of 75 was obtained using a 10mm diameter hardened steel with a 500 kilogram load applied for a period of 30 seconds. On tests of extremely hard metals a tungsten carbide ball is substituted for the steel ball. Compared to the other hardness test methods, the Brinell ball makes the deepest and widest indentation, so the test averages the hardness over a wider amount of material, which will more accurately account for multiple grain structures and any irregularities in the uniformity of the material. This method is the best for achieving the bulk or macro-hardness of a material, particularly those materials with heterogeneous structures.

Guided bend test: A guided bend test is one in which the specimen as in Fig 12.

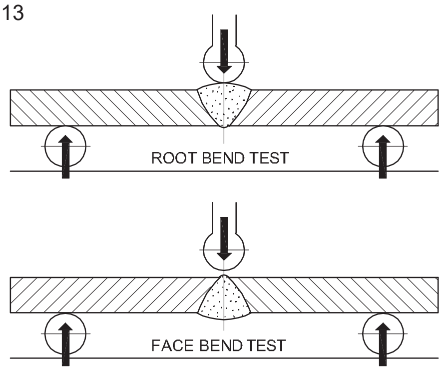
There are two types of specimens prepared for this - one for face bend and the other for root bend. (Fig 13) This test measures the ductility of the weld metal in a butt joint in a plate. This test shows most weld faults quite accurately and it is very fast. A sample specimen can be tested on destruction to determine (a) the physical condition of the weld and thus check on the weld procedure and (b) the welder's capability.

Fig 12



JIG FOR GUIDED BEND TEST

Fig 13



WLC22T0235

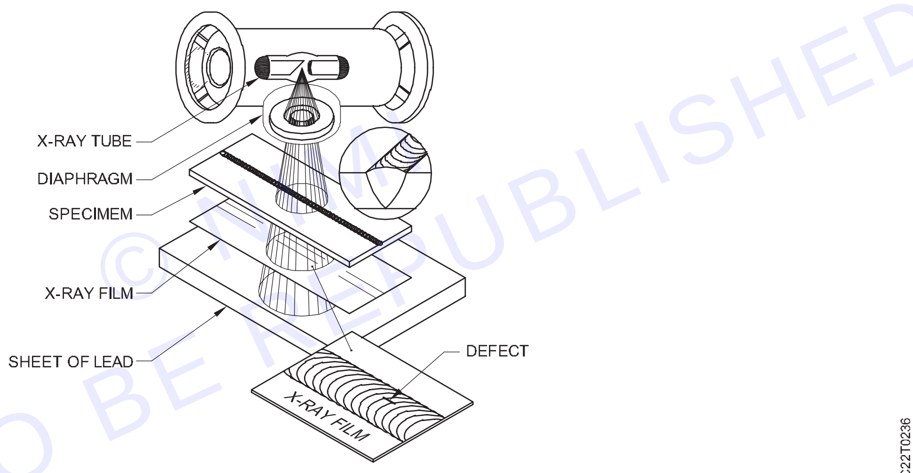
Radiographic testing (RT) - Principles - Advantages - Limitations - Basic Radiation Physics - X-Rays - Gama Rays - Radiographic Techniques - Radiographic Interpretation and Evaluation

Objectives : At the end of this lesson you shall be able to
- describe the principal of RT
- explain the advantage and limitation
- explain the radiographic testing techniques.

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 penetrate 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 pen stock pipes and nuclear vessels.

X-Ray Tube : A Tungsten filament fixed in a cup shaped cathode is heated by means of a low voltage current. Electrons are liberated and they are accelerated by increasing the potential difference between the cathode and a slanting edged anode. The place of impingement is made of tungsten to stand the heat as well as to provide a metal target of high atomic number. Heat produced is dissipated through the anode and removed by forced o natural cooling. The assembly is enclosed in a vacuum

Pulse Echo Method : In pulse echo method flaws are detected and their sizes estimated by comparing the intensity of reflected sound from an interface (either with in the test piece or at the back surface) with the intensity of sound reflected from a reference interface of know size or from the back surface (back reflection) serves as a reference point for time of flight measurements that enable the depth of some internal flaws to be measured. It is necessary that an internal flaw reflect at least part of the sound energy on to the receiving transducer for such depth measurements to be made. Most pulse echo systems consist of electronic clock, electronic signal generator or pulsar, Ascending transducer, A receiving transducer, An echo signal amplifier, and a display device.

Through Transmission Method : In Through Transmission method flaws are detected by comparing the intensity of ultrasound transmitted through the test piece with the intensity transmitted through a reference standard made of the same material. Transmission testing requires two search units, one to transmit the ultrasonic waves and one to receive them. The main application of transmission method is the inspection of plate for cracks or laminations that have relatively large dimensions compared to the size of the search unites.

Testing of Welds : Before actually commencing the examination of welds it is necessary that aspects like visual conditions of the weld surface, couplants & the parent metal in the scanning zone be considered.

The visual appearance of the weld should be checked for shape of the weld, e.g. surface curvature, degree of root penetration, backing ring, different parent metal thicknesses, and extent of the reinforcement, presence undercuts, weld finish and alignment of parts.

Couplants : A coolant, usually a liquid or semi-liquid is required between the face of the probe and the test surface to permit transmission of the acoustic energy from the transducer to the material under test. Typical couplants include water, oil, grease and glycerin.

Defect Detection : To detect all possible defects, the weld is to be examined over its entire cross section and along the length specified. For the detection of longitudinal defects the shear wave prove is placed on contract surface and kept perpendicular to the weld centerline. To examine the entire weld, the probe is moved over the scanning zone.

Defect Location: The accurate determination of the position of a defect in a welded joint is important not only when repairs have top be made but, in an ultrasonic examination it can give, together with defect orientation useful information for the determination of the type of defect. The position of a defect is determined by the distance (Projected path length between prove index and reflector) and depth from the surface. The distance and the depth can be easily calculated from the path length prove angle and thickness.

Defect Identification: Important indication with regard to the shape and orientation of a defect can be obtain from the appearance of the signal and its behavior when the defect is scanned from various directions. The echo signals obtained from the planar defects, such as cracks and lack of sidewall fusion will mostly appear as sharp and narrow indications. They are characterized by their directionality to the incident beam in both directions Thio-Sulphate are the two chemicals popularly used. Hardening agents are added top harden the gelatin which is very soft until this treatment.

Thorough washing in flowing water removes the chemicals embedded in the gelatin. The films are dried in a Just free chamber at 50° C and they are ready for evaluation.

Image Quality Indicators (IQI)

As a check on the adequacy of the radiographic technique, a standard test piece, called a pentameter, (IQIs) is placed on the source side of the specimen. The pentameter is of a simple geometric shape, made of a material radio graphically similar to the specimen itself, and usually contains some simple structure such as strips wires etc. Its thickness is a definite proportion (e.g.2%) of the specimen thickness. The radiographic technique may be considered satisfactory if the penetrameter and its structures are show clearly in the radiograph. If the radiographic procedure has been able to demonstrate a 2% difference in specimen thickness, (i.e. it shows the structure of a 2% penetrameter) the penetrameter sensitivity is considered satisfactory. Wire type, step wedge and plate hole are the widely used types of penetrometers and are covered by different codes.

It should be remembered that even if a certain hole in a penetrometer is visible in a radiograph, the cavity of the same diameter and thickness in the specimen may not be visible, the penetrometer holes having sharp boundaries, given un abrupt through small change in metal thickness, while a natural cavity with more or less rounded sides gives a gradual change. Therefore the image of the hole will be sharper and more easily seen in the radiograph than the image of the cavity. Similarly, a fine crack may be of considerable extent, but if the X- rays happen to pass from tube to film normal to the plane of the crack, its image on the film may not be visible because of the very gradual transition in photographic density. Thus a penetrameter is used to indicate the quality of the radiographic technique and not as a measure of sizes of the cavity which can be shown. A thin stock or a uniform block may be used to keep the penetrameter on, when the object to be radio graphed is not suitable to keep the IQI directly over it.

Radiographic Interpretation:

The interpretation of a radiograph involves the following three distinct stages:

Verification that the pattern of the radiographic image in conformity with the shape of the part and that it is related to the particular specimen under consideration.

Recognition of any spurious effects in the radiograph arising from faulty exposure, handling of processing methods, and Identification of any internal flaws in the specimen by their characteristic appearance in the radiograph. A fourth and culminating stage exist that it is concerned with the assessment of the provable effect of any defect upon the serviceability of the specimen.

The interpreter should have in mind the fundamental principles of the formation of radiographic images. Useful indications are provided by

a The shape of the image

b The distribution of density of the image

c The direction of the incident rays upon the test object and upon the film.

To fulfill his task, the interpreter should know the fundamental characteristics of glass envelope. X-rays produced leave the tube through a thinner glass window.

A KV control increases or decreases the applied voltage and the penetration is controlled by KV. Higher the KV. greater the penetration.

A current control knob and meter top increase or decrease current supplied to filament. Increase current supplied to filament. Increase of milliamp rage results in the hotter filament, more election emission and hence larger quantity of X-rays. This decides the duration of exposure. A time controlled switch to control the exposure is provide in the control panel.

film is used as the recording medium in radiography resembling a photographic film. The differences are due top the penetrating nature of the energy involved and service conditions.

The base is made of polyesters and provides a transparent medium over which the sensitive emulsion may be coated. The industrial radiographic film has a thicker and tougher base than the photographic film since they are subjected to lot of handling during exposure.

Density : The function of emulsion coating is to produce opaque deposits when exposed to light or radiation. The extent of deposit is expressed as density.

Density D= Log (li/lt)

Li = Intensity of Incident light

Li = Intensity of the emergent light Optimum density for an industrial radiograph is 2 to 4.

Exposure : It is the product of intensity of radiation and duration for which the energy was action on the film. To express radiographic exposure, one has to give Kilo voltage, Mill amperes and Time in case of X-rays and type of source, its strength in curies and exposure time in minutes for an isotope source.

Speed : Speed of the film is measured in terms of the log of exposure needed to produce a density of 1.0 in Medical and 2.0 in Industrial radiographic film above the base density. The grain size of the Silver Halide Crystals embedded in the emulsion control the speed. The larger the grain, the faster is the film. Sensitivity decreases with increase in grain size.

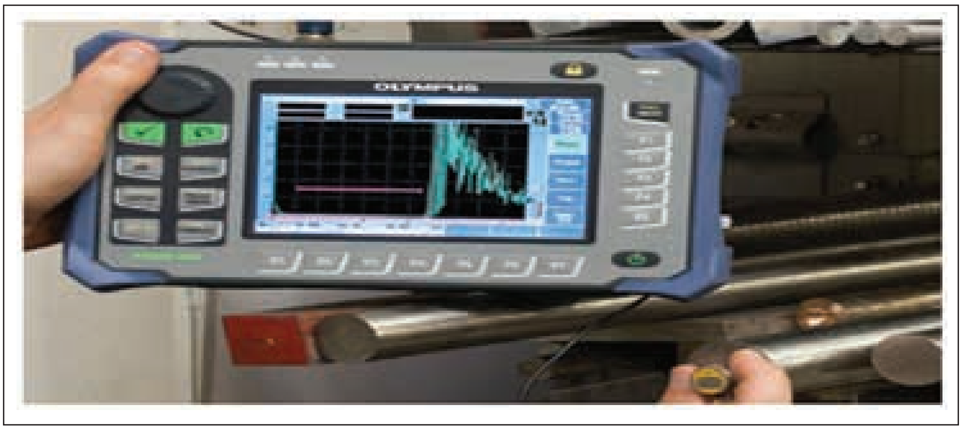
Ultrasonic testing (UT) principles - Advantage - Limitations Measuring Techniques- Standard reference blocks - Contact Testing procedure - Indications and interpretations

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

- describe the principal of UTI
- explain the UTI equipments and machinery
- Explain the UTI measuring techniques.

Ultrasonic Testing :

Introduction: Mechanical vibrations which have frequency higher than the audible range of human car viz. 20 to 20 KHz are called ultrasonic waves. Unlike electromagnetic radiations, these waves require a medium and velocity of propagation depends on the elasticity of the medium.



The Principle : In ultrasonic testing, an ultrasound transducer connected to a diagnostic machine is passed over the object being inspected. The transducer is typically separated from the test object by a couplant (such as oil) or by water, as in immersion testing.

There are two methods of receiving the ultrasound waveform, reflection and attenuation. In reflection (or pulse-echo) mode, the transducer performs both the sending and the receiving of the pulsed waves as the “sound” is reflected back to the device. Reflected ultrasound comes from an interface, such as the back wall of the object or from an imperfection within the object. The diagnostic machine displays these results in the form of a signal with an amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection. In attenuation (or through-transmission) mode, a transmitter sends ultrasound through one surface, and a separate receiver detects the amount that has reached it on another surface after traveling through the medium. Imperfections or other conditions in the space between the transmitter and receiver reduce the amount of sound transmitted, thus revealing their presence.

Advantages:

- High penetrating power, which allows the detection of flaws deep in the part.
- High sensitivity, permitting the detection of extremely small flaws.
- Only one surface need be accessible.
- Greater accuracy than other non-destructive methods in determining the depth of internal flaws and the thickness of parts with parallel surfaces.
- Some capability of estimating the size, orientation, shape and nature of defects.
- Non-hazardous to operations or to nearby personnel and has no effect on equipment and materials in the vicinity.
- Capable of portable or highly automated operation.

Disadvantages:

- Manual operation requires careful attention by experienced technicians
- Extensive technical knowledge is required for the development of inspection procedures.
- Parts that are rough, irregular in shape, very small or thin, or not homogeneous are difficult to inspect.
- Surface must be prepared by cleaning and removing loose scale, paint, etc, although paint that is properly bonded to a surface usually need not be removed.
- Couplants are needed to provide effective transfer of ultrasonic wave energy between transducers and parts being inspected unless a non-contact technique is used. Non-contact techniques inclined Laser and Electro Magnetic Acoustic Transducers (UMAT)
- Inspected items must be water resistant, when using water based couplants that do not contain rust inhibitors,
- inspected items must be water resistant, when using water based couplants that do not contain rust inhibitors,

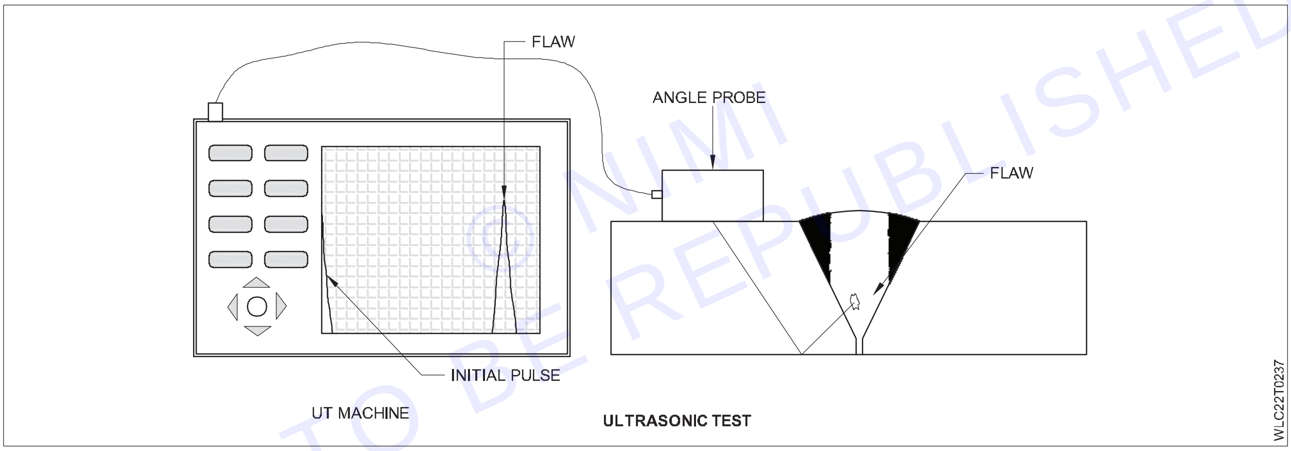
In Ultrasonic testing : very short ultrasonic pulse-waves with centre frequencies nagging from 0.5-15 Mitz and occasionally up to 50 MHz are launched into materials to detect internal flaws or to characterise materials. The technique is also commonly used to determine the thickness of the test object, for example, to monitor pipework corrosion. Ultrasonic testing is often performed on steel and other metals and alloys, though it can also be used on concrete, wood and composites, albeit with less resolution. It is a form of non-destructive testing sued in many industries including aerospace, automotive and Most common modes of propagation of ultrasonic waves are: i) Longitudinal waves ii) Transverse wave Surface or Rayleigh waves.

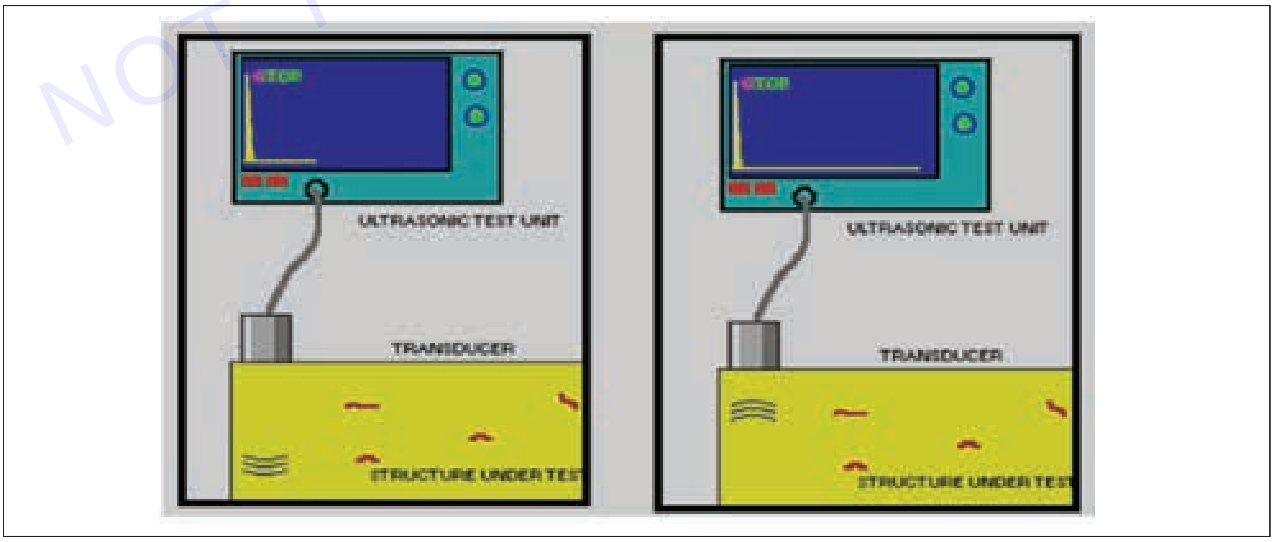
Longitudinal Waves : These waves travel through the medium as a series of alternate compressions and rarefaction in which the particles transmitting the wave vibrate back and forth in the direction of travel of the waves. Longitudinal ultrasonic waves are readily propagated in liquids and gases as well as in elastic solids. The velocity of longitudinal waves is about 5920/sec. In steel.

Transverse Waves : In transverse or shear waves, each particle vibrates up and down in a plane perpendicular to the direction of propagation. The velocity of transverse waves is about 50% of the longitudinal wave velocity for the same material.

Surface or Rayleigh Waves And Plate or Lamb Waves:

These are another type of waves used in the inspection of surface soundness of metals. These waves travel along with flat or curved surfaces of relatively thick solid parts. Lamb waves, also know, as plate waves are another type of ultrasonic waves used in the non-destructive inspection of metals. These are propagated in metals that arte only few wavelengths in thickness.





Major Variables : Sensitivity or the ability to detect a very small discontinuity is generally increases by using relatively high frequencies (short wave lengths). Resolution, is the ability of the systems to give simultaneous, separate indications from discontinuities that are close together in depth. Resolution is directly preoperational so probe bandwidth and inversely related to pulse length but is not affected by frequency.

Penetration, or maximum depth (range in a material from which useful indications can be detected is reduced by the use of high frequencies. This effect is most pronounced in the inspection of metal that has course grain structure or minute in homogeneities, because of the scattering of the ultrasonic waves. With the decrease in frequency, the shape of an ultrasonic beam increasingly departs from the ideal of zero beams spread.

Acoustic-Impedance: The acoustic impedance is Zap x V where V-Velocity and p-, density of material

Laws Of Ultrasound : At any angle other than normal the angle of incidence is equal to angle of reflection the refraction angle is known as Snell's law and is

Sin A/Sin B=V1/V2]

A-Angle of incidence, Bangle of refraction,

VI-velocity of sound in the medium!

V2. velocity of sound in Medium2

Additionally, mode conversion takes place at the interface when the longitudinal wave is refracted as. longitudinal and transverse waves.

Attenuation : This intensity of an ultrasonic beam that is received by a transducer is considerably less than the intensity of the initial transmission. There is a loss in the energy due to absorption of sound in the material. This coos is known as attenuation.

Probes : Generation as well detection of ultrasonic waves for inspection is accomplished by means of a transducer element which is contained with a device most often referred to as a search unit or a probe. The active element in a search unit is a piezo electric crystal. This crystal works on the principle an electrical charge when pressure is applied to it. Conversely, when an electrical deforms. The most common types of piezo-electric materials used for Ultrasonic search units are quartz, lithium sulphate, polarized ceramics such as barium titanate, lend zirconated titanate and lead metaniobate.

Probe Types : Search units are of many types and shapes. Variation in search unit construction includes transducer element material, transducer element thickness, surface area and shape; and type of backing material and degree of loading. The basic types are normal beam, angle beam, and Transmitter and receiver probes.

Reference Blocks : Ultrasonic inspection is basically a comparison process and requires the use of reference blocks for calibration of the equipment and probe set up before put to use on the actual job. The calibration is done with standard reference blocks. The most widely used reference blocks is Sulzer's block, ASTM block, IIW block, miniature angle beam block etc. The calibration of the set up is done to check the following.

Time base linearity, Resolution, Sensitivity, Beam spread, Beam angle. Dead zone probe index and Penetration power.

Inspection Methods :

A Ultrasonic inspection can be performed by Pulse Echo Method

B Through Transmission Method

Ultrasonic technique in which flaws are detected by measuring intensity and time of flight of reflected sound waves having single frequency is called pulse echo method of ultrasonic testing which is most widely used perpendicular to their main dimension. Orbiting the probe from the position which ensures maximum echo height will result in a sudden amplitude drop. Noticeable difference in echo height may be obtained by successive use of different probe angles. When the defect orientation is perpendicular to the plate surface about the same echo height will be noticed with scanning from both sides of the weld. An inclined orientation may result in an echo height difference.

The echo height obtained from slag inclusions does not necessarily differ from those received from cracks or lack of fusion but may be distinguished by different echo shapes and directional sensitivity. Because of the rough surface of this type of discontinuity the defect intercepts successive regions in the beam and gives rise to a succession of echo signals An orbital movement with the prove will cause little change in this echo appearance. The individual; signals of which the echo is composed however, will change and consequently you there will be a variation of echo height. A scan from the opposite side of the weld is likely to give a similar echo appearance.

Spherically shaped discontinuities such as gas pores reflect only a small part of the incident beams in the direction of the receiver. Moreover, the dimensions of this type of defect are small. Low amplitude signals of narrow echo shape characterize this type of defect. The echo will remain almost constant when the prove is moved around the defect and when scanning from the opposite side. In the event of porosity a number of these small echoes may appear close together depending on the number and distribution of the pores.

Certification methods for welding inspectors Codes and standards for welding inspection

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

- describe the certificate method inspection code and standards
- explain the inspectors standard test.

Introduction: The purpose of welding inspection is to determine if a weldment meets the acceptance requirements of a code, standard or other document. The welding Inspector must be familiar with welding processes, welding procedures, welder qualification, materials, non-destructive and destructive testing of welds, be able to read drawings, prepare and keep records, prepare and make reports and make responsible judgements and decisions.

IIW India's National Welding Inspectors Certification Scheme (NWICS) is a comprehensive scheme which provides for examination and certification of personnel seeking to demonstrate their competence and knowledge in the field of welding inspection. The scheme is managed by the Governing Board of IIW India's Authorised Nominated Body (ANB-India) for personnel education, qualification and certification. IIW India is in the process of transferring accreditation from NABET to NABCB (both divisions of QCI) as a conformity assessment body (CAB) as per ISO/IEC: 17024-2012 for certification of personnel. IIW India's ANB understands the importance of impartiality, managing conflict of interest, ensuring security and confidentiality in all its activities in accordance with ISO/IEC: 17024.

Scope of certification: This specification establishes the requirements for the IIW India-ANB Division to certify welding inspectors, supervisors, engineers, quality control co-ordinators and examiners with respect to his / her competency in carrying out welding inspection functions in fabrication and construction industry covering the following:

1 Working safety

2 Review & preparation of required documentation

3 Inspection of weld joints before, during and after welding

4 Evaluation and acceptance of weld joints based on Destructive & Non-Destructive test results/reports

Levels of Certification: IIW India's NWICS program provides for 3 (three) levels of certification

1 Basic level (NWIC - Basic)

2 Standard level (NWIC - Standard)

3 Advanced level (NWIC - Advanced)

Role and functions of Welding Inspectors: The candidate should be able to carry out the following activities at different levels of certification.

1 Welding Inspector - Basic level

2 To independently carry out before, during and post-weld visual inspection and dimensional checks of weldments against specification requirements and drawings.

3 To carry out the following functions under the supervision of a Welding Inspector – Standard level or Welding Inspector - Advanced level

- Understand the application of various standards, codes, specifications, welding symbols, drawings, WPS and statutory/regulatory requirements.
- Verify the compliance of raw materials & consumables, certificates against the applicable standards, codes & specifications.
- Verify that joint dimensions, edge preparation, fit up, welding equipment and weld preparations are in accordance with the drawings, standards and process requirements.
- Verify the compliance of pre-heat procedures against the applicable standards.
- To carry out in-process surveillance during welding to verify compliance with specified procedure including pre-heat, welding parameters, inter-pass temperature control and any post-heat requirements.

- Understand and ensure compliance of applicable safety requirements

1 Welding Inspector - Standard level

2 Supervise the activities of Welding Inspectors - Basic level as given in A, b) above

3 Independently carry out the following functions

- All functions carried out by a Welding Inspector - Basic level as given in A, b) 1 to 6 above
- Develop, comment and review quality control plans and inspection & testing plans based on product standards, codes, specifications, drawings and statutory/regulatory requirements.
- Review welding procedures (WPS) for compliance with code and contract requirements and verify welding procedure qualification (WPQR) compliance.
- Witness procedure qualification test including testing of specimen and verify compliance with WPQRs, WPSs and Welders Qualification against applicable standards for conventional welding processes. (e.g. arc welding processes, steels, aluminium alloys etc.)
- Verify the compliance of PWHT procedures against the applicable standards.
- Verify NDT procedure compliance
- Take decisions on acceptance of quality documents related to welded fabrication (eg NDT, material testing, production testing, etc.)
- Take decisions based on quality documents (e.g. NDT, Material Testing, production testing, etc.) according to the requirements defined for the construction
- Implement weld inspection quality assurance plans
- Evaluation & acceptance of welded fabrication on the basis of DT & NDT test reports.
- Conduct surveillance and audit of suppliers and vendors
- Report on all the above actions.
- Training and evaluation of Welding Inspectors - Basic level

1 Welding Inspector - Advanced level

2 Supervise the activities of Welding Inspectors - Basic and Standard levels as given in A, b) above and B b) above

3 Independently carry out the following functions

- All functions carried out by a Welding Inspector - Basic level as given in A, b) 1 to 6 above and Welding Inspector - Standard level as given B b) 1 to 13 above
- Verify base material and filler material compatibility
- Witness procedure qualification test including testing of specimen and verify compliance with WPQRs, WPSs.
- Conduct Welders Qualification tests and qualify the same against applicable standards for conventional welding processes. (e.g. arc welding processes, steels, aluminium alloys etc.)
- Write Welding Procedures Specifications and Welder Performance Qualification
- Prepare visual inspection, NDT and destructive testing requirements
- Identification of weld defects and determination of their acceptability including Radiographic film interpretation for carbon, low alloy and stainless steels.
- Final acceptance and certification that all requirements specified for the weldment have been met
- Prepare welding inspection quality assurance plans, audit and surveillance plans along with documentation and control requirements.
- Maintenance of comprehensive inspection reports
- Training and evaluation of Welding Inspectors – Standard level

- Provide technical leadership and guidance to team of Welding Inspectors

Required competence and examination: IIW India ANB's certification process for Welding Inspectors requires that ANB India conducts an examination comprising of theory, practical and viva-voce to determine a candidate's knowledge & competence in welding technology, welding inspection and related technical areas commensurate with the level of certification.

The candidate should be able to demonstrate appropriate level of knowledge & skill in welding inspection covering the following:

1 Codes and standards

2 Raw Material, Control and Traceability

- Knowledge of materials and their behaviour during welding

1 Conventional welding and cutting processes and equipment

2 Safety practices during welding & cutting

3 Conventional DT and NDT methods including integrity testing.

- Joint types, welding positions and welding symbols.
- Welding qualification – procedure and performance

1 Detection and interpretation of discontinuities through VT & PT.

2 Interpretation and evaluation of RT & UT reports.

3 Comment on & review the quality control documents viz. QAPs, WPSs, PQRs, WPQs, MTCs, DT & NDT reports

- Carry out inspection of welded fabrications before, during and after welding including Dimensional Inspection PMI and PWHT as per the requirements of relevant standards.
- Communicate effectively orally and written and prepare reports

Details of the theoretical and practical knowledge and competency requirements along with examination procedure and requirements for each of the three levels are given as Annexure 1 to this certification scheme.

ANB India suggests that candidates undergo a training program at an ANB India Approved Training Centre, at the appropriate level as preparation for appearing for the examinations.

Pre-requisites: Qualification, experience and visual acuity requirements for candidates for access to the various levels of certification are as given below.

1 Qualification & Experience

Basic Level: The candidate should possess any of following combination of Educational Qualification and experience as tabulated below:

Sl No	Educational Qualification	Experience
1	Class VIII	5 Yrs. Industrial experience out of which 3 yrs in welding area /inspection / NDT of welds
2	Class X (With Sc. &Math) / ITI (Mech.)	3 Yrs. Industrial experience out of which 2 yrs in welding area /inspection / NDT of welds
3	Class XII / IWS/IWIP(B) diploma or any equivalent Welding Inspectors course	2 Yrs. Industrial experience out of which 1 yr in welding technology / inspection / NDT of welds
4	MSc/BE/ IWE/ BSc /Diploma in Engg. / IWT, IWIP (S) diploma or equivalent Welding Inspectors course	6 months Industrial experience in welding technology / inspection / NDT of welds, desirable but not essential

Standard Level: The candidate should possess any of following combination of Educational Qualification and experience as tabulated below:

Sl No	Educational Qualification	Experience
1	Class VIII	8 Yrs. Industrial experience out of which 5 yrs in welding area/ inspection / NDT of welds
2	Class X (With Sc. &Math) / ITI (Mech.)	5 Yrs. Industrial experience out of which 3 yrs in welding area/ inspection / NDT of welds
3	Class XII / IWS /NWICS – B / IWIP(B) diploma or equivalent Welding Inspectors course	3 Yrs. Industrial experience out of which 2 yrs in welding technology/ inspection /NDT of welds
4	BSc /Diploma in Engg. / IWT, IWIP (S) diploma	2 Yrs. Industrial experience in welding technology / inspection / NDT of welds.
5	MSc/BE/ IWE	1 Yr. Industrial experience in welding technology / inspection / NDT of welds.

Advanced Level: The candidate must possess NWICS – Standard level or equivalent certification along with any of following combination of Educational qualification and experience as tabulated below:

Sl No	Educational Qualification	Experience
1	Class X (With Sc. &Math) / ITI (Mech.)	10 Yrs. Industrial experience out of which 5 yrs in welding area /inspection /NDT of welds
2	IWS /IWIP(S) / Class XII (with Sc & Maths)	5 Yrs. Industrial experience out of which 3 yrs in welding technology/inspection / NDT of welds
3	BSc /Diploma in Engg. / IWT	3 Yrs. Industrial experience out of which 2 yrs in welding technology/inspection / NDT of welds
4	MSc/BE/IWE / IWIP (C)	2 Yrs. Industrial experience out of which 1 yr in welding technology/inspection / NDT of welds

1 The candidate should also possess the following minimum standard of vision acuity level certified by a registered ophthalmologist / optometrist / eye specialist:

2 Near Vision- Jaeger J2 or better with correction (not more than 12 months old)

3 Colour Vision- As per ISHARAS chart (not more than 12 months old).

Required code of conduct:

- Considering the importance of quality of welded fabrication and also the consequences of its failure to individual life and society, the candidate should act with complete integrity and in a professional manner in welding inspection and acceptance of the final product.
- Undertake and perform welding inspection assignments only when qualified / certified to do so.
- The candidate should behave in a professional and disciplined manner which will not affect the safety and security of his fellow members associated in the manufacturing of the final product.
- The candidates behavior towards his/her superiors, peers and sub-ordinates should be in line with organization's protocol.
- The candidates shall avoid any conflict of interest with the employer or the client and shall disclose any business association or circumstance that might be so considered.

Validity of Certification

The certificate is valid for an initial period of five (5) years from the dated of certification and maybe renewed for a further period of five (5) years on application by the candidate subject to re-assessment of continued competency by ANB India. Re –certification will be required after ten (10) years of initial certification.