WELDER

NSQF LEVEL - 4

1st Semester

TRADE THEORY

SECTOR: Fabrication

Directorate General of Training

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

NATIONAL INSTRUCTIONAL
MEDIA INSTITUTE, CHENNAI

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by 2020 to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of Mentor Councils comprising various stakeholder's viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, an autonomous body under the Directorate General of Training (DGT), Ministry of Skill Development & Entrepreneurship is entrusted with developing producing and disseminating Instructional Media Packages (IMPs) required for ITIs and other related institutions.

The institute has now come up with instructional material to suit the revised curriculum for **Welder 1st Semester Trade Theory NSQF Level - 4 in Fabrication Sector under Semester Pattern.** The NSQF Level - 4 Trade Theory will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF Level - 4 trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF Level - 4 the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

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

Jai Hind

ASHEESH SHARMA
Joint Secretary
Ministry of Skill Development & Entrepreneurship,
Government of India.

New Delhi - 110 001

PREFACE

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

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

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

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

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

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

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

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

R. P. DHINGRA
EXECUTIVE DIRECTOR

Chennai - 600 032

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisations to bring out this Instructional Material **(Trade Theory)** for the trade of **Welder** under **Fabrication** Sector.

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

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

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

INTRODUCTION

This manual for trade practical is intended for use in the ITI workshop. It consists of a series of practical exercises that are to be completed by the trainees during the first semester of course is the **Welder trade under Fabrication Sector. It is National Skills Qualifications Framework (NSQF) - Level 4,** supplemented and supported by instructions/information to assist the trainees in performing the exercise. The exercises are designed to ensure that all the skills prescribed in the syllabus are covered including the allied trades.The syllabus for the1st Semester **Welder** Trade under **Fabrication Sector** Trade Theory is divided into six modules.The allocation of time for the various modules is given below:

Module 1 - Induction Training and Welding Process	16 Exercises	117 Hrs
Module 2 - Welding Techiniques	08 Exercises	75 Hrs
Module 3 - Weldability of steel (OAW, SMAW)	32 Exercises	333 Hrs
Total	56 Exercises	525 Hrs

The syllabus and the content in the modules are interlinked. As the number of workstations available in the electrical section is limited by the machinery and equipment, it is necessary to interpolate the exercises in the modules to form a proper teaching and learning sequence. The sequence of instruction is given in the schedule of instruction which is incorporated in the Instructor's Guide. With 25 practical hours a week of 5 working days 100 hours of practical per month is available.

Contents of Trade Theory

The procedure for working through the 64 exercises for the 1st semester with the specific objectives as the learning out comes at the end of each exercise is given is this book.

The skill objectives and tools/instruments, equipment/machines and materials required to perform the exercise are given in the beginning of each exercise.Skill training in the shop floor is planned through a series of practical exercises/experiments to support the related theory to make the trainees get hands on trainning in the Electrician trade along with the relevant cognitive skills appropriate for the level. A minimum number of projects have been included to make the training more effective and develop attitude to work in a team. Pictorial, schematic, wiring and circuit diagrams have been included in the exercises, wherever necessary, to assist the trainees broaden their views. The symbols used in the diagrams comply with the Bureau of Indian Standards (BIS) specifications.

Illustrations in this manual, help trainess visual perspective of the ideas and concepts.The procedures to be followed for completing the exercises is also given. Different forms of intermediate test questions have been included in the exercises, to enhance the trainee to trainee and trainee to instructor interactions.

Skill Information

Skill areas which are repetitive in nature are given as separate skill information sheets. Skills which are to be developed in specific areas are included in the exercises itself. Some subexercises are developed to fulfill the sequence of exercises in keeping with the syllabus.

This manual on trade practical forms part of the Written Instructional Material (WIM). Which includes manual on trade theory and assignment/test.

CONTENTS

Importance of welder trade training

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

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

Competencies achieved

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

1 welding of M.S. sheet and M.S. pipe by Gas welding process.
2 Welding of M.S. plate in all position by SMAW processs.
3 Staight, bevel & circular cutting on MS. plate by Oxy-acetylene cutting process.
4 Repair & Maintenance works
5 GMAW welding on M.S sheet & M.S plate.
6 Operating skills of spot welding machine, PUG cutting machine,
7 Welding C.I using SMAW process.

Further learning pathways

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

Employment Opportunities

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

1 Structural fabrication like bridges, Roof structures, Building & construction.
2 Automobile and allied industries
3 Site construction activities for power stations, process industries and mining.
4 Service industries like road transportation and railways.
5 Ship building and repair
6 Infrastructure and defence organizations
7 In public sector industries like BHEL, NTPC, etc and private industries in India & Abroad.
8 Petrochemical industries like ONGC, LOCL, and HPCL etc
9 Self employment

General discipline in the Institute

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

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

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

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

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

Do not be late to the theory and practical classes.

Do not unnecessarily interfere in other's activities.

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

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

Be interested in all the training activities.

Do not make noise or be playful while undergoing training.

Keep the institute premises neat and avoid polluting the environment.

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

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

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

Prepare well before writing a test/examination.

Aviod any malpractice during the test/examination.

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

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

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Elementary first aid

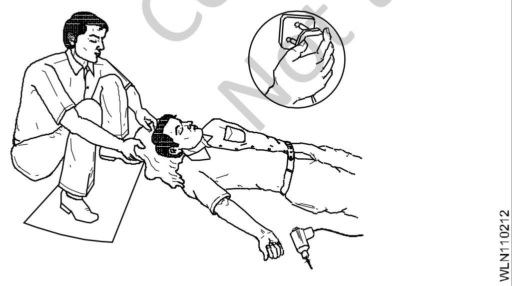
Objectives : At the end of this lesson you shall be able to
- **understand the first aid treatment to be given for**
- **breathing problems**
- **electric shock**
- **burns caused by direct flame or by chemical**
- **large wounds with or without severe bleeding**
- **eye injuries due to hot flying particles.**

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

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

Fig 1

Fig 2



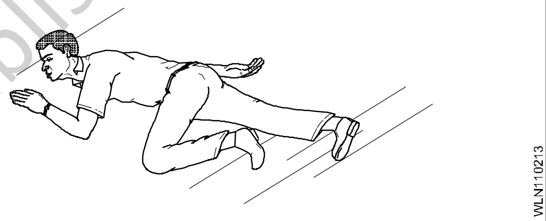
If you remain un-insulated, do not touch the victim with your bare hands until the circuit is made dead or he is moved away from the equipment.

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

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

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

Fig 3

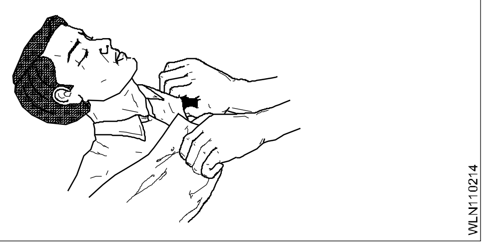


Keep a constant check on the breathing and pulse rate.

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

Send for help.

Fig 4



Do not give an unconscious person anything by mouth.
Do not leave an unconscious person unattended.

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

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

Other factors that contribute to the severity of shocks are:

-the age of the person

-not wearing insulating footwear or wearing wet footwear

-Weather condition

-floor is wet

- main voltage etc.

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

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

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

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

Treatment for electric shock:

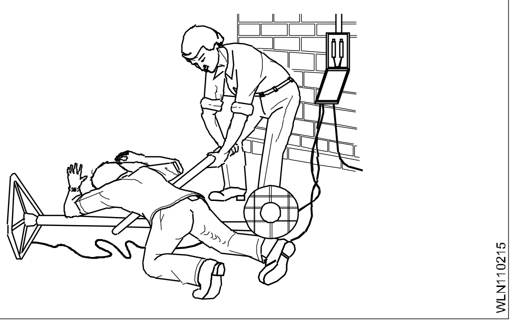
Prompt treatment is essential.

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

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

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

Fig 5



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

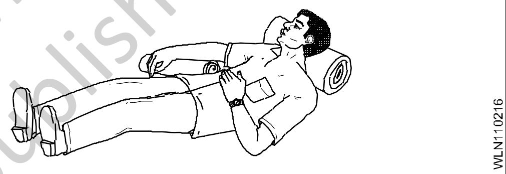
Burns and scalds: Burns are very painful. If a large area of the body is burnt, give no treatment, except to exclude the air. eg, by covering with water, clean paper, or a clean shirt. This relieves the pain.

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

Immediate action: Always in cases of severe bleeding:

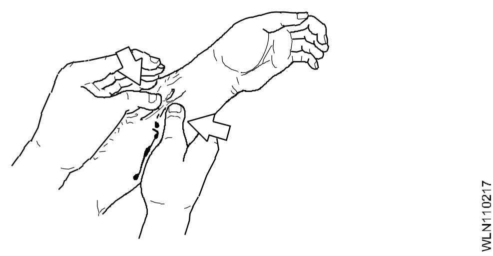
- make the patient lie down and rest
- if possible, raise the injured part above the level of the body(Fig,6)
- apply pressure on the wound
- Call for assistance.

Fig 6



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

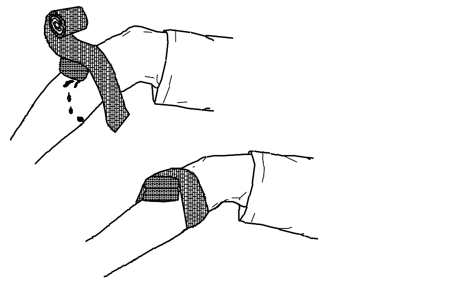
Fig 7



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

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

Fig 8



Follow the right methods of artifical respiration.

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

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Safety rules for gas cylinders

Objectives : At the end of this lesson you shall be able to
- **stae various improper practices, while working in gas cylinders**
- **state different precautions to be taken for the gas cylinders**

oxy- acetylene equipment is safe if it is properly handled. but it may become a great destructive power if handled carelessly. It is important that the operator be familiar with all the safety rules before handling gas cylinders.

Keep the cylinders free of oil, grease or any type of lubrication.

Check leakage before use.

Open cylinder valves slowly.

Never fall or trip over gas cylinders.

A valve broken in the oxygen cylinder will cause it to become a rocket with tremendous force.

keep the gas cylinders away from exposure to high temperature.

Remember the pressure in the gas cylinders increases with the temperature.

Store full and empty gas cylinders separately in a well ventilated place.

Mark the empty cylinders (MT/EMPTY)with chalk.

If a cylinder leaks due to defective valve or safety plug, do not try to repair it yourself, but move it to a safe area with a tag to indicate the fault and then inform the supplier to pick it up.

When the cylinders are not in use or they are being moved, at on the valve protection caps.

Cylinders should always be kept in upright position and properly chained when in use.

Close the cylinder valves both when the gases are full or empty.

Never remove the valves protection cap while lifting cylinders.

Avoid exposing the cylinders to furness heat, open fire or sparks from the torch.

Never move a cylinder by dragging. sliding or rolling it on its sides.

Never apply undue force to open or close a cylinder valve.

Avoid the use of hammer or wrench.

Always use a proper cylinder (or spindle) key to open or close the cylinder valves.

Do not remove the cylinder key from the cylinder valve when it is in use. It may be needed immediately to close the gas in case of emergency.

Smoking or naked lights should be strictly prohibited near gas cylinders.

Never strike an arc or direct gas flame on a gas cylinder.

Safety procedure for handling an internally fired dissolved acetylene (D A) cylinder

In the case of severe backfire of flashback the DA cylinder may catch fire.

Close the blowpipe valve immediately (oxygen first).

No damage will occur to the cylinder if the backfire is arrested at the blowpipe.

The signs of severe backfire or flashback are:

- a squeezing or hissing noise in the blowpipe
- a heavy black smoke and sparks coming out of the nozzie
- over heating of the blowpipe handle.

To control this:

- Close the cylinder valves
- Disconnect the regulator from the cylinder valve
- Check the hosepipes and blowpipe before re-use.

If the cylinder catch fire externally due to the leakage of gas at the connection:

- Close the cylinder valve immediately(wearing asbestos gloves as a safety measure)
- Use carbon dioxide fire extinguisher to extinguish the fire

- rectify the leakage thoroughly before putting into further use.

If the cylinder becomes overheated due to internal or external fire:

- close the cylinder valve
- detach the regulator from the cylinder
- remove the cylinder to an open space, away rom smoking or naked light
- cool the cylinder by spraying with water
- inform the gas cylinder supplier immediately.

Never keep such defective cylinders with the other cylinders.

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Importance of welding in Industry

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

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

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

So all industries are using welding for the fabrication of various structures.

Advantages of welding over methods of joining metals

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

Comparison between welding and other metal joining methods

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

The temporary joints can be separated if:

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

Advantages of welding

Welding is superior to other metal joining methods because it:

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

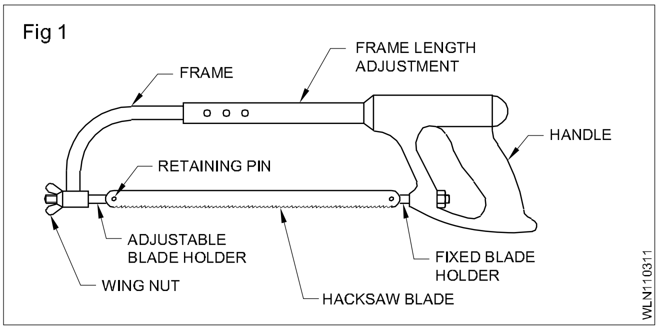
it is the strongest joint and any type of metal of any thickness can be joined.

Hacksaw frames and blades

objectives: At the end of this lesson you shall be able to
- **identify the parts of a hacksaw frame**
- **specify hacksaw blades**
- **state the different types of hacksaw frames and their uses.**

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

Fig 1



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

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

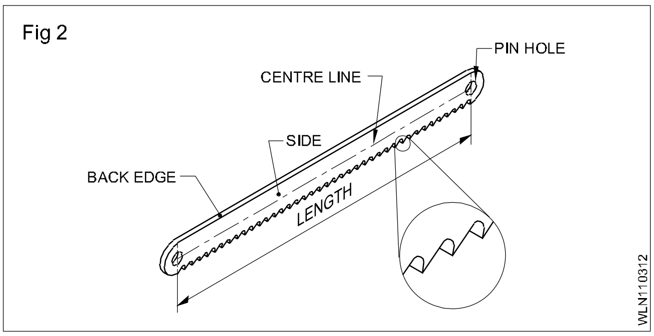
Adjustable frame (Flat type): Different standard lengths of blades can be fitted to this frame.

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

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

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

Fig 2



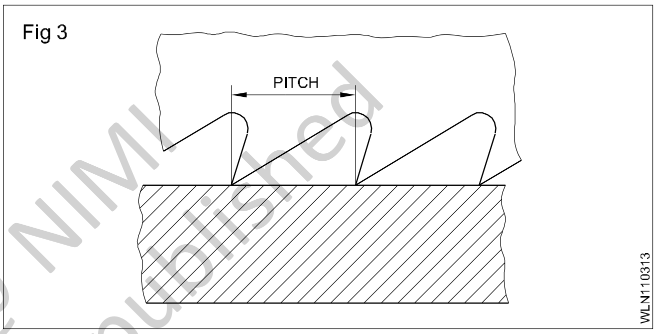
Type of Hacksaw Blades: Two types of hacksaw blades are available - all hard blades and flexible blades.

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

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

Pitch of Blade (Fig.3): The distance between adjacent teeth is known as the 'pitch' of the blade.

Fig 3



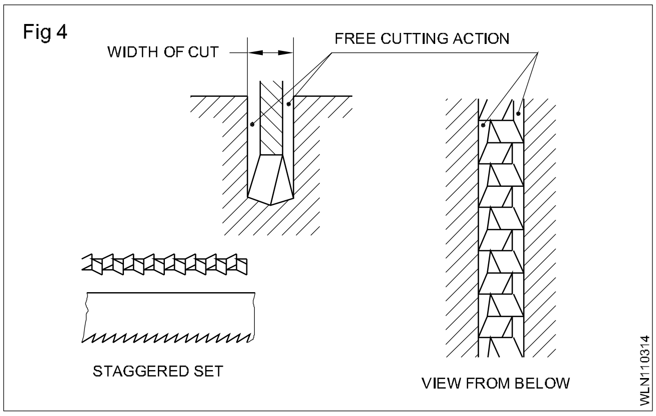
Classification	pitch
Coarse	1.8 mm
Medium	1.4 mm & 1.0 mm
Fine	0.8 mm

Hacksaw blades are specified according to the length, pitch and type.

Setting of the saw: To prevent the saw blade bending between the cut edges when penetrating into the material and to allow free movement of the blade, the width of cut is to be broader than the thickness of the saw blade. This is achieved by the setting of the saw teeth. There are two types of saw settings.

Staggered set (Fig.4): Alternate teeth or groups of teeth are staggered. This arrangement helps for cutting, and provides for good chip clearance.

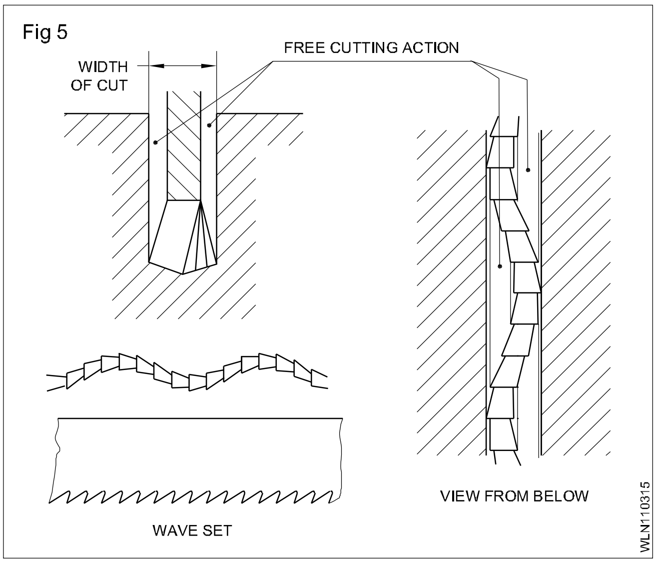
Wave Set (Fig.5): In this, the teeth of the blade are arranged in a wave form.



The set of blades can be classified as follows.

Pitch	Type of Set
0.8 mm	Wave set
1.0 mm	Wave or staggered

Over 1.0 mm staggered



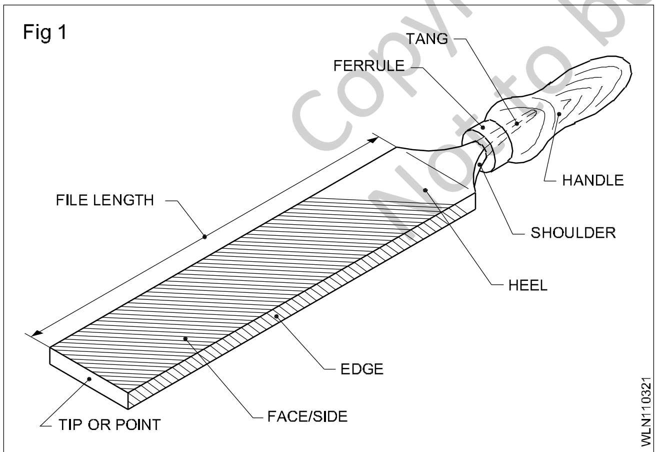
For best result, the blade with the right pitch should be selected and fitted correctly onto the hacksaw frame.

Files - Grades and specification

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

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

Tip or point: The end opposite to tang



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

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

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

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

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

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

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

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

— — — — — — — —

Cut of files

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

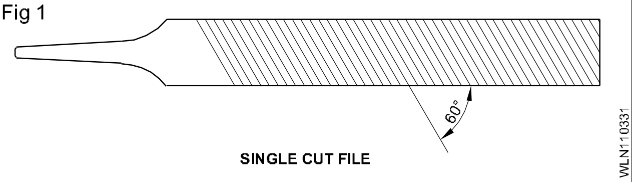
The teeth of a file is formed by cuts made on its face. Files have cuts of different types. Files with different cuts have different uses.

Type of cuts: Basically there are four types.

Single cut, Double cut, Rasp cut and curved cut.

Single cut File (Fig. 1): a single cut file has rows of teeth cut in one direction across its face. The teeth are at an angle of 60° to the center line. It can cut chips as wide as the cut of the file. Files with this cut are useful for filing soft metals like brass, aluminium, bronze and copper.

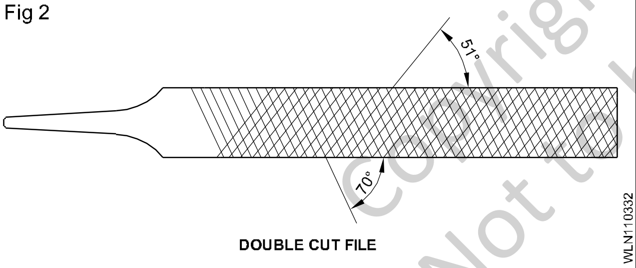
Fig 1



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

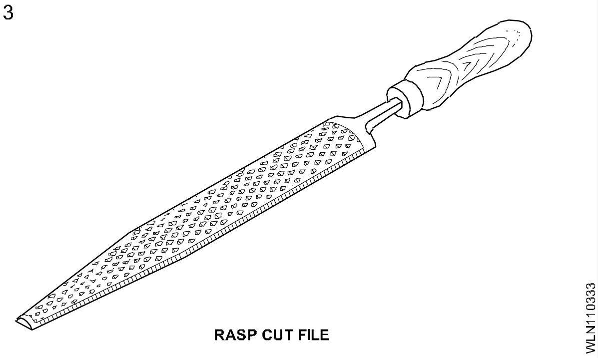
Double cut cile (Fig.2): A double cut file has two rows of teeth cut diagonal to each other. The first row of teeth is known as OVERCUT and they are cut at an angle of 70° The other cut, mde diagonal to this, is known as UPCUT, and is at an angle of 51°. This removes stock faster than the single cut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

Fig 2



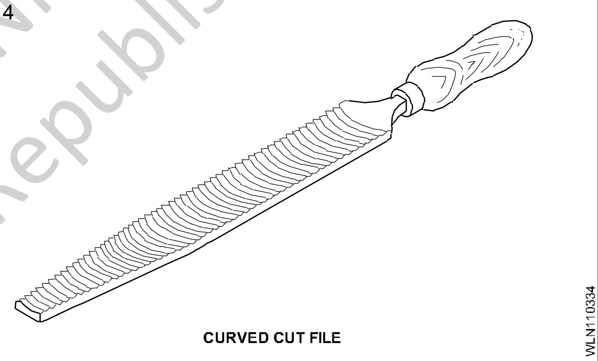
Rasp Cut File (Fig.3): The rasp cut has individual, sharp, pointed teeth in a line, and is useful for filing wood, leather and other soft materials. These files are available only in half round shape.

Fig 3



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

Fig 4



The selection of a file with a particular type of cut is based on the material to be filed. Single cut files are used for filing soft materials.

File specifications and grades

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

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

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

Length is the distance from the tip of a file to the heel. Fig 1 under lesson parts of a File.

File grades are determined by the spacing of the teeth.

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

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

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

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

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

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

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

— — — — — — — —

File shapes

Objectives: At the end of this lesson you shall be able to
- **state the features of flat and hand files**
- **state the application of flat and hand files.**

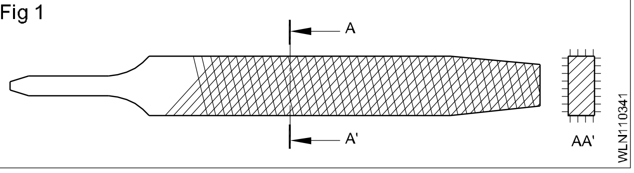
Files are made in different shapes so as to be able to file and finish components to different shapes,

The shape of files is usually specified by their cross section as flat, square, triangular, round, half round and knife edge.

The files useful for this this execise i,e., filing to square are flat files and hand files.

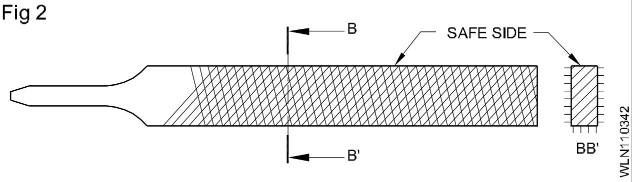
Flat files (Fig. 1): These files are of a rectangular cross section. The edges along the width of these files are parallel up to two-thirds of the length. and then they taper towards the point. The faces are double cut, and the edges single cut. These file are used for general purpose work. They are useful for filing and finishing external and internal surfaces.

Fig 1



Hand files (Fig. 2): These files are similar to the flat files in their cross section. The edges along the width are parallel throughout the length. The faces are double cut.

Fig 2



One edge is single cut whereas the other is safe edge. Because of the safe edge, they are useful for filing surfaces which are at rigt angles to surfaces already finished.

Cleaning of files

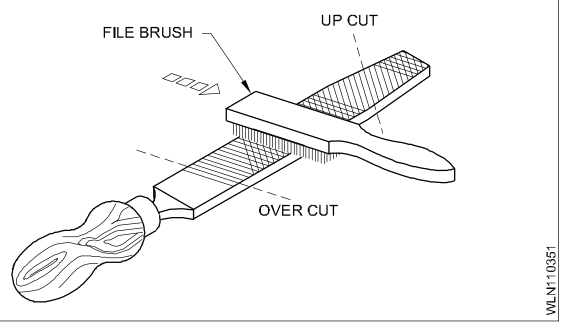
Objectives: At the end of this lesson you shall be able to
- **understand how to clean files**

During filing, the metal chips (Filings) will clog between the teeth of the files. This is known as 'pinning' of the files. Files which are pinned will produce scratches on the surface being filed, and also will not bite well to cut the metal properly.

Method of removing pinning: Pinning of the files is removed by using a file brush. (File card)

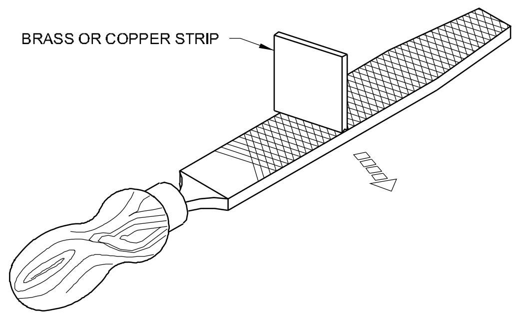
Press the file brush on the surface of pinned file and pull it along the direction of the overcut. (Fig. 1)

Fig 1



When filing a work piece to a smooth finish more' pinning' will take place because the pitch and depth of the teeth are less. The file can also be cleaned by rubbing a copper or brass strip over the pinned surface. (Fig. 2)

Fig 2



Application of chalk on the face of the file will help reduce the penetration of the teeth and 'pinning'.

Clean the file frequently in order to remove the filings embedded in the chalk powder.

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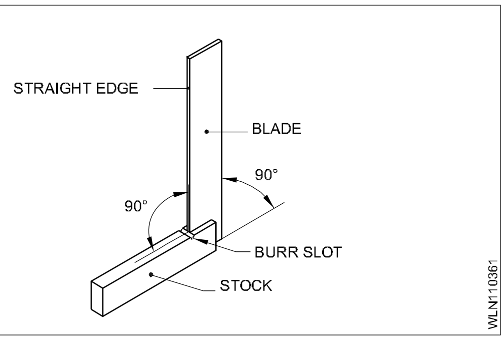
Try square

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

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

Fig 1



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

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

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

Fig 2

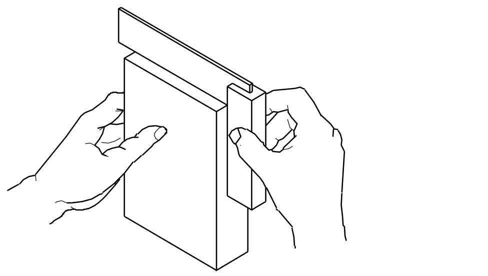


Fig 3

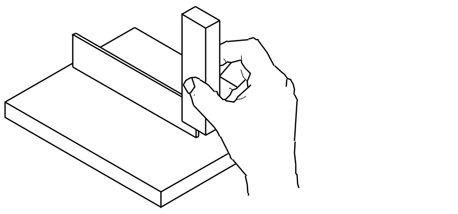


Fig 4

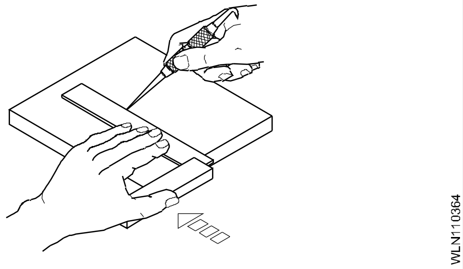
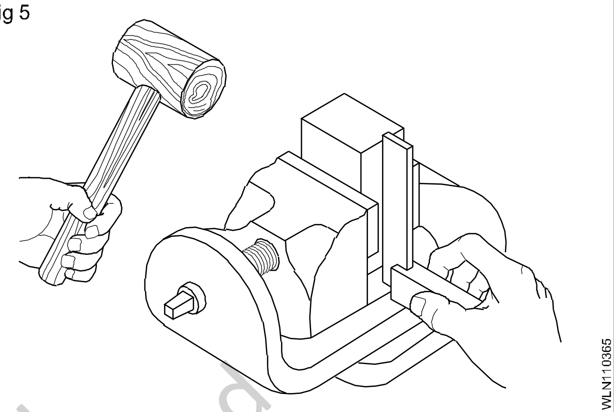


Fig 5



Mallets

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

- **state the different types of mallets**
- **state the uses of mallets**
- **state the care and maintenance.**

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

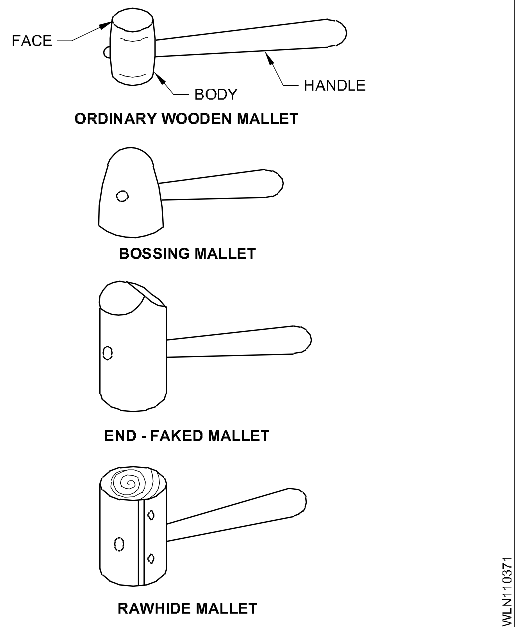
These are made of hard wood

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

Types (Fig. 1)

- Ordinary mallet
- Bossing mallet
- End-faked mallet
- Raw hide mallet,

Fig 1



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

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

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

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Bench Vice

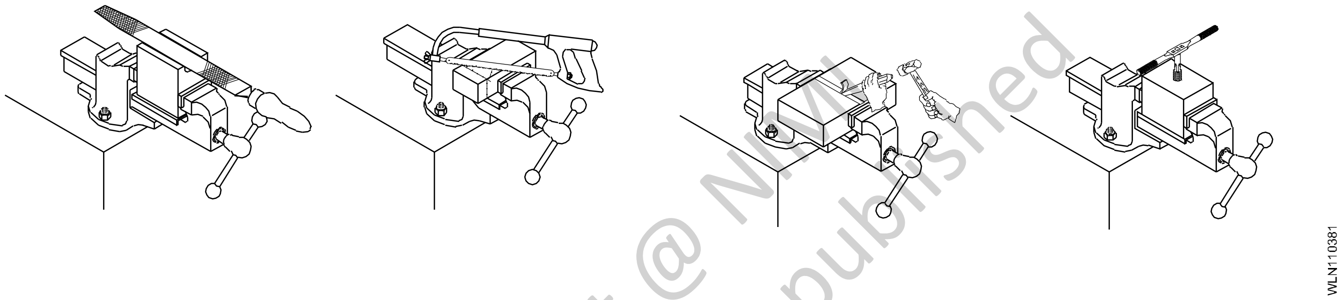
Objectives: At the end of this lesson you shall be able to
- **name the parts and uses of a bench vice**
- **specify the size of a bench vice**
- **state the uses of vice clamps.**

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

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

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

Fig 1

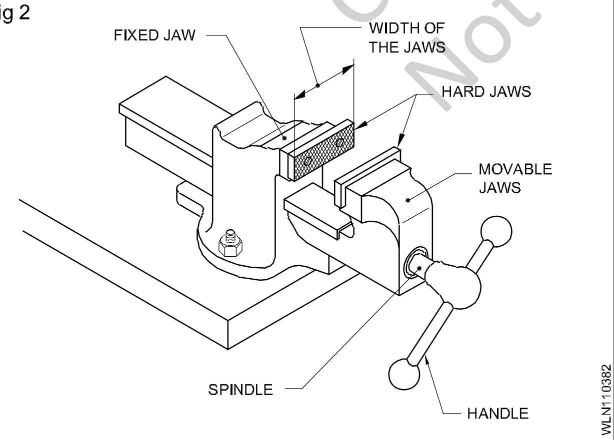


Parts of a bench vice (Fig 2)

The following are the parts of vice:

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

Fig 2

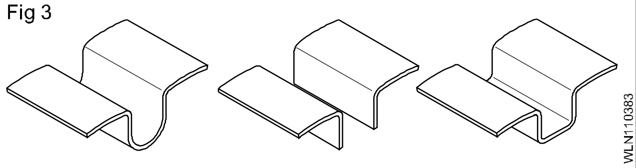


The box nut and the spring are the internal parts,

Vice clamp or soft jaws(Fig 3)

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

Fig 3



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

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Introduction and definition of welding

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

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

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

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

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

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

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

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

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

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

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

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Safety in Shielded Metal Arc Welding

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

Non-fusion welding

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

Example: Soldering, Brazing and Bronze welding.

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

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

1 Safety apparels
   - a Leather apron
   - b Leather gloves
   - c Leather cape with sleeves
   - d Industrial safety shoes

2 a Hand screen
   - b Adjustable helmet
   - c Portable fire proof canvas screens

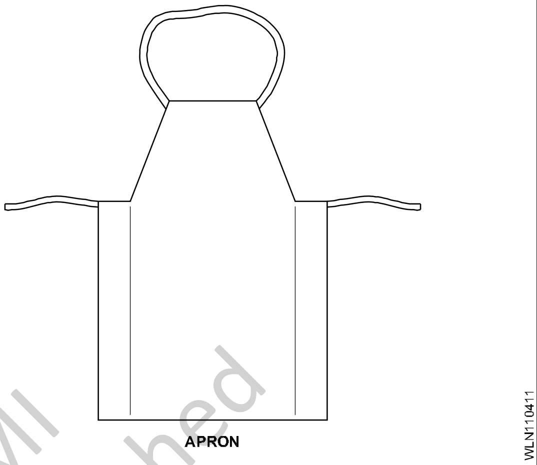
3 Chipping/grinding goggles

4 Respirator and exhaust ducting

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

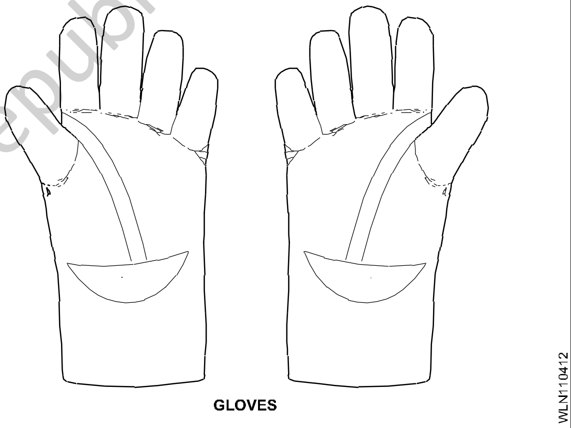
All the above safety apparels should not be loose while wearing them and suitable size has to be selected by the welder.

Fig 1



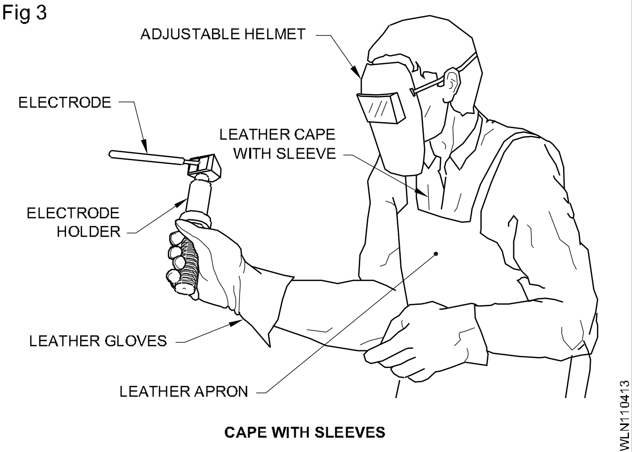
APRON

Fig 2



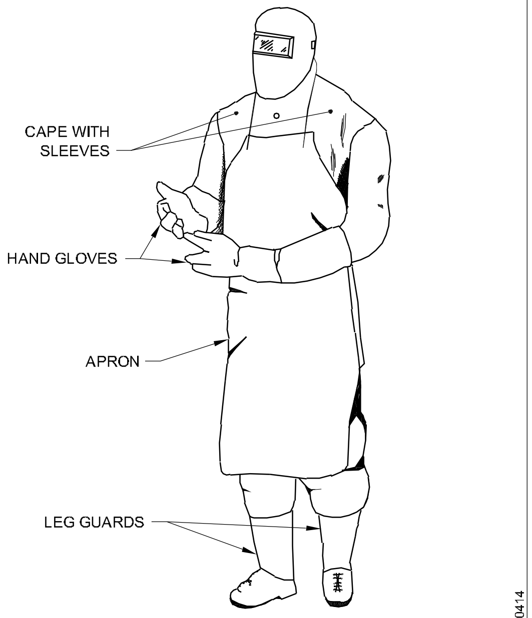
GLOVES

Fig 3



CAPE WITH SLEEVES

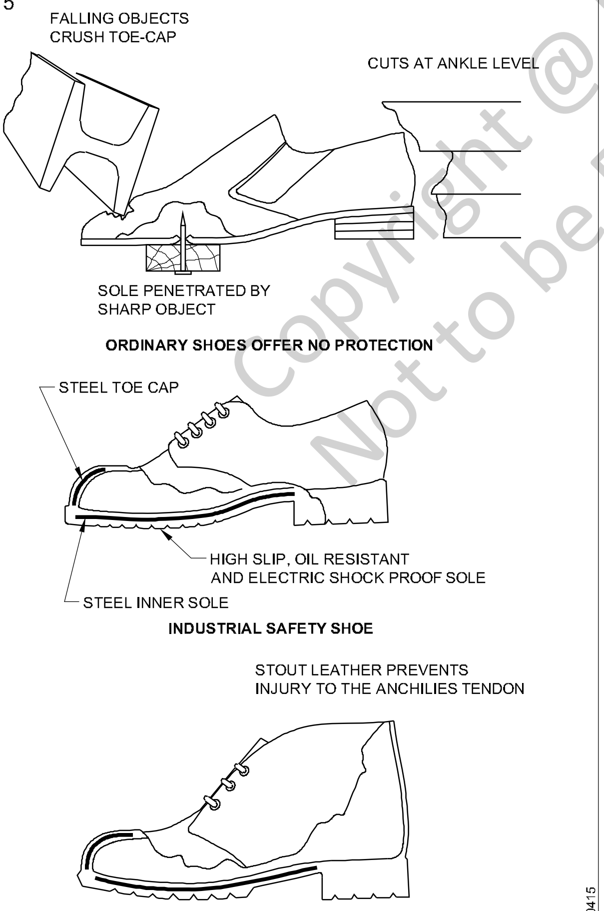
Fig 4



LEG GUARDS

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

Fig 5



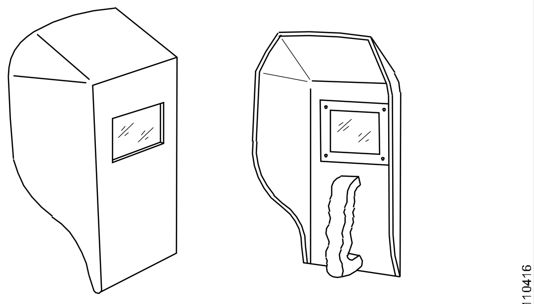
INDUSTRIAL SAFETY BOOT

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

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

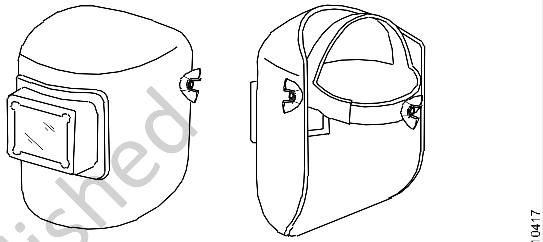
A helmet screen is designed to wear on the head. (fig. 7)

Fig 6



HAND SCREEN

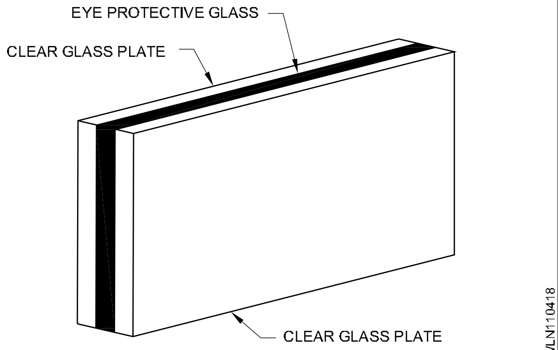
Fig 7



WELDING HELMET

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

Fig 8



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

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

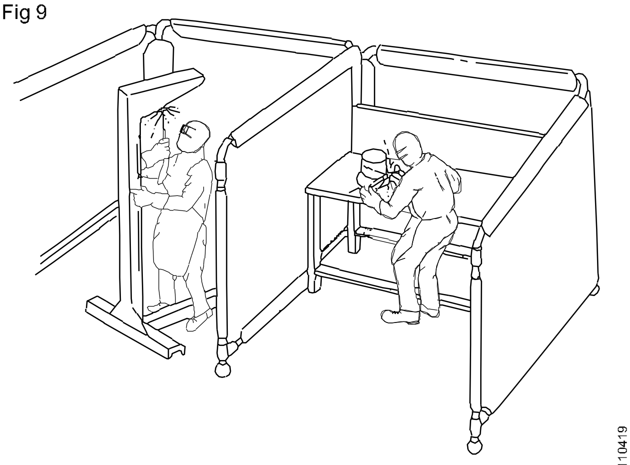
Table 1

Recommendations of filter glasses for manual metal arc welding

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

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

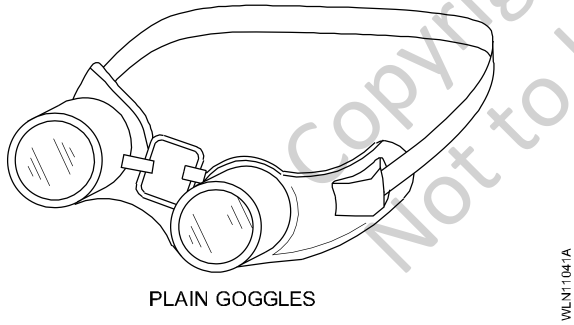
Fig 9



PORTABLE FIREPROOF CANVAS SCREENING

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

Fig 10



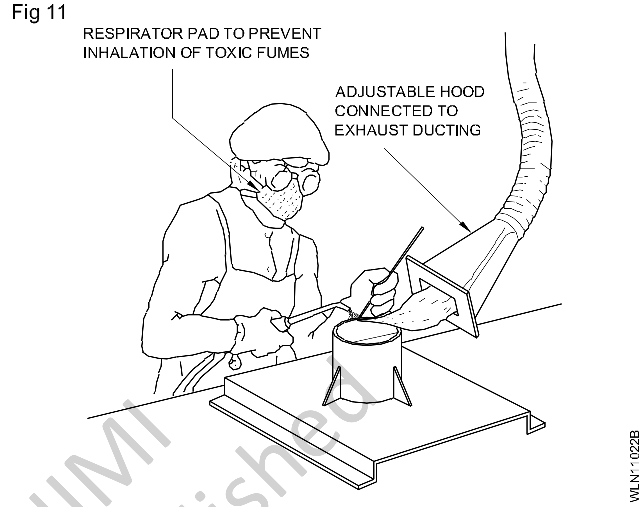
PLAIN GOGGLES

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

It is designed for comfortable fit, proper ventilaon and full protection from all sides.

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

Fig 11



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

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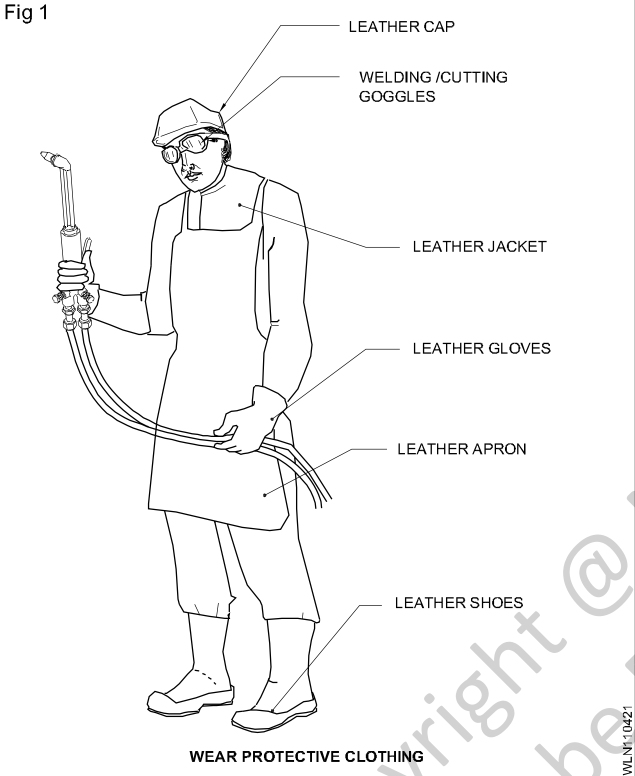
Safety in Gas cutting process

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

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

safety for the operator (Fig 1**)**

Fig 1



WEAR PROTECTIVE CLOTHING

Always use safety apparel

goggles, gloves and other protective clothing must be warn.

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

> **Ensure that the combustible material is atleast 3 metres away from the cutting operation area.**

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

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

protect yourself and others from the flying sparks.

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

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

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

> **Keep fire- fighting equipment handy and ready.**

Fig 2

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Fig 3

Length measurement

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

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

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

Length - SI UNITS and MULTIPLES

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

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

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

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

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

Fig 1

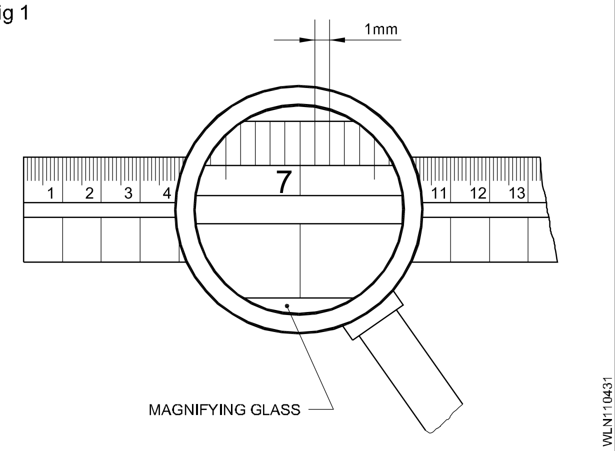
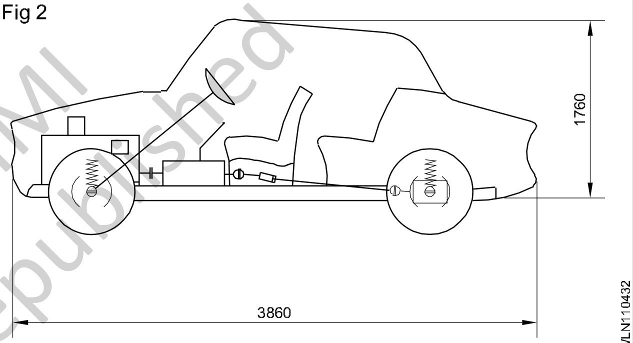


Fig 2

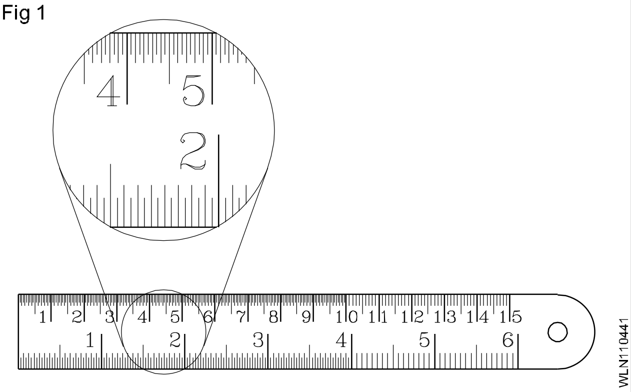


Steel rule

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

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

Fig 1



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

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

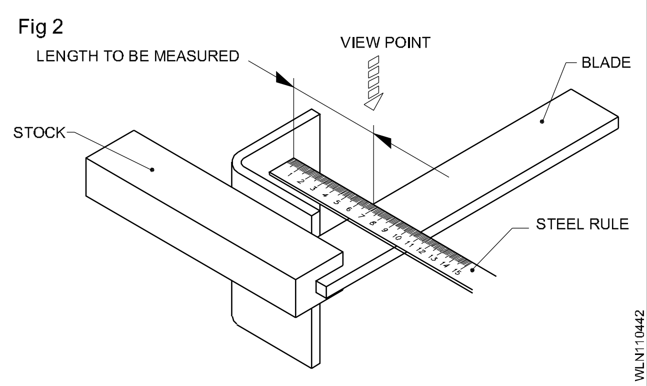
Steel rule in English measure, they can also be furnished with metric and English graduation in a complete range of size 150, 300, 500 and 1000 mm. (Fig 2)

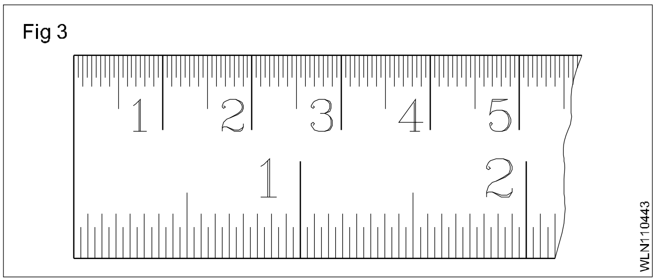
Other types of rule

- narrow steel rules

- short steel rules

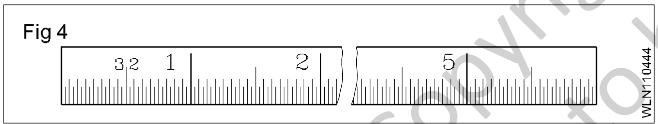
- full flexible steel rule with tapered end.

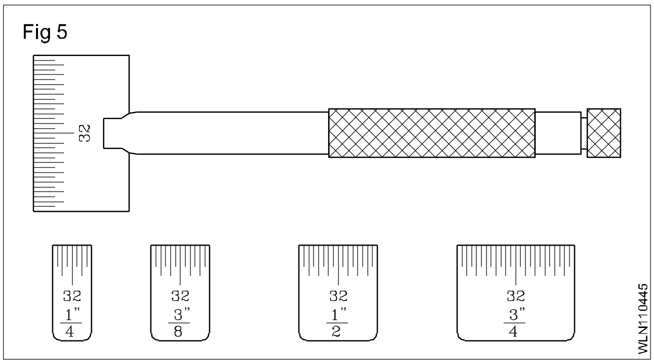




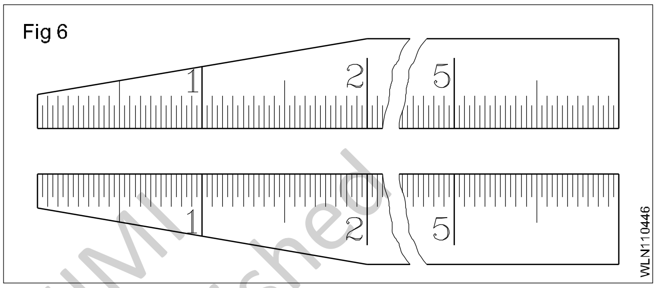
Narrow steel rule: Narrow steel rule is used to measure the depth of key-ways and depth of smaller dia, blind holes and other jobs, where the ordinary steel rule can not reach. Width appoximately 5mm thickness to 2mm. (Fig 3)

Short steel rule (Fig 4): This set of five small rules together with a holder is extremely useful for measurements in confined or hard to reach locations which prevent use of ordinary steel rules. It is used suitably for measuring grooves, short shoulder, recesses, key ways etc, in machining operation on shapers, millers and tool and die work.





The rules are easily inserted in the slotted end of the holder and are rigidly clamped in place by a slight turn of the knurreled nut at the end of the handle. Five rule lengths are provided 1/4", 3/8", 1/2", 3/4", and 1" and each rule is graduated in 32" nds on the reverse side.



Steel rule with tapered end: This rule is a favorite with all mechanics since its tapered end permits measuring of inside size of small holes, narrow sots, grooves, recesses etc. This rule has a taper from 1/2 inch width at the 2 inch graduation to 1/8 inch width at the end. (Fig 6)

For maintaining the accuracy of a steel rule, it is important to see to it that its edges and surfaces are protected from damage and rust.

Do not place a steel rule with other cutting tools. Apply a thin layer of oil when not in use.

— — — — — — — —

Types of calipers

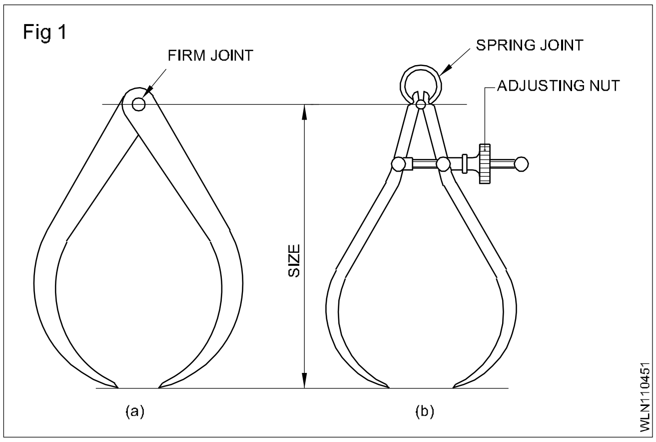
Objectives: At the end of this lesson you shall be able to
- **name the commonly used calipers**
- **state the advantages of spring joint calipers.**

Calipers are indirect measuring instruments used for transferring measurements from a steel rule to a job, and vice versa.

Calipers are classified according to their joints and their legs.

Joint

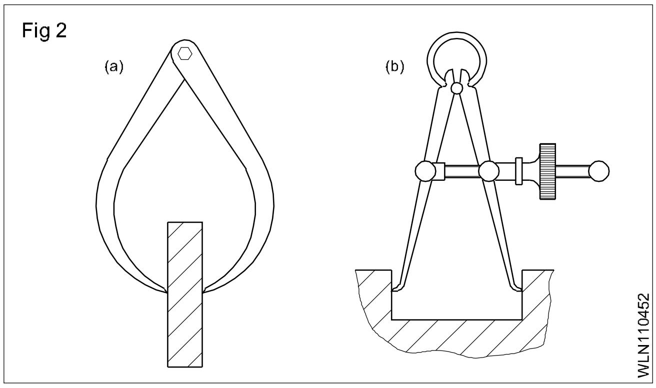
- Firm joint calipers (Fig 1a)
- Spring joint calipers (Fig 1b)



Legs

- Outside caliper for external measurement. (Figs 2a)

- inside caliper for internal measurement(Fig 2b)



Calipers are used along with steel rules, and the accuracy is limited to 0.5 mm; Parallelism of jobs etc. can be checked with higher accuracy by using calipers with sensitive feel.

Spring joint calipers have the advantage of quick setting with the help of an adjusting nut. For setting a firm joint caliper, tap the leg lightly on a wooden surface.

— — — — — — — — —

Marking media

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

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

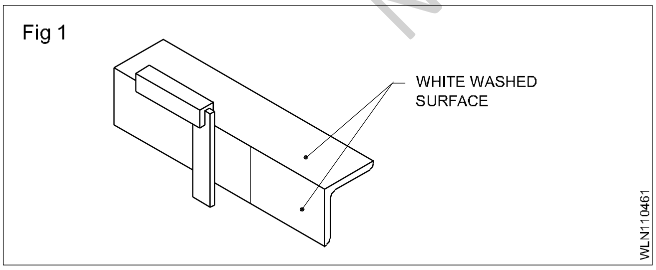
Whitewash: White wash is prepared in many ways

Chalk powder mixed with water

Chalk mixed with methylated spirit

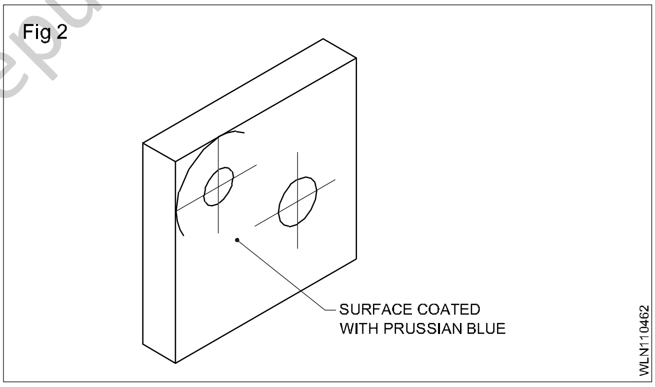
White lead powder mixed with turpentine.

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



Whitewash is not recommended for workpieces of high accuracy.

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



Copper Sulphate: The solution is prepared by mixing copper sulphate in water and a few drops of nitric acid. The copper sulphate is used on filed or machine-finished surfaces. Copper sulphate sticks to the finished surfaces well.

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

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

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

Jenny calipers

Objectives: At the end of this lesson you shall be able to
- **state the uses of a jenny caliper**
- **state the two types of legs of a jenny caliper.**

Jenny calipers have one leg with an adjustable divider point while the other is a bent leg. (Fig 1) These are available in sizes pf 150mm, 200mm, 250mm and 300mm.

Jenny calipers are used:

-for marking lines parallel to the inside and outside edges (Fig 2)

-for finding the center of round bars. (Fig 3)

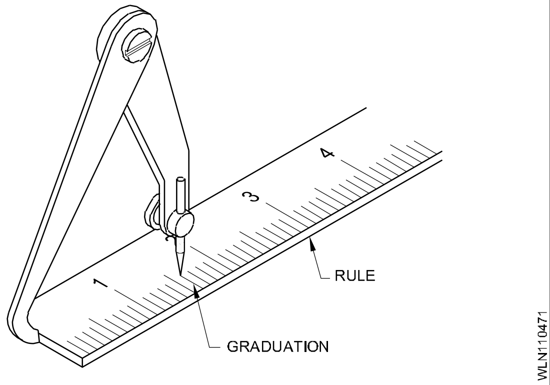


Fig 1

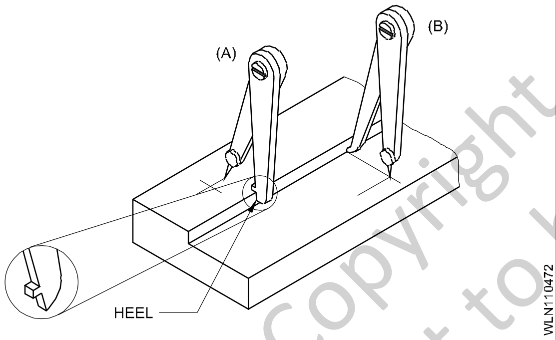


Fig 2

These calipers are avilable with the usual bent leg or with a heel.

Calipers with bent leg (Fig 2B) are used for drawing lines parallel along an inside edge. and the heel type (Fig 2A) is used for drawing parallel lines along the outer edges.

The other names for this callper are:

- hemaphrodite callpers
- leg and point calipers
- odd leg caliper

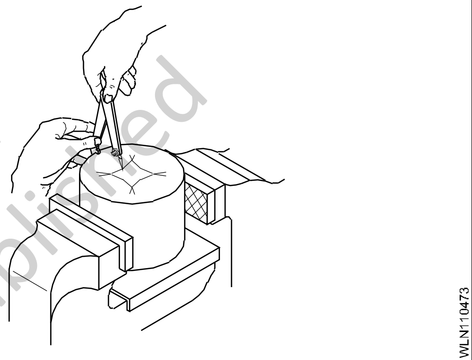


Fig 3

Scribers

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

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

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

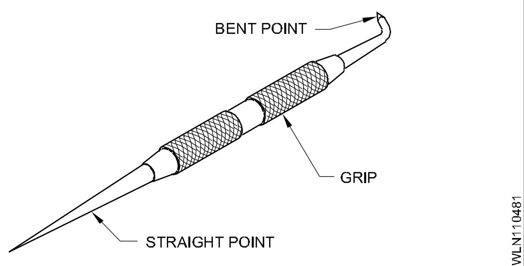
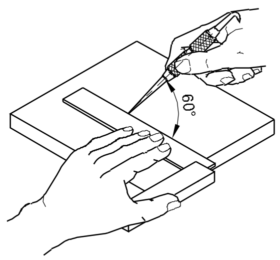


Fig 1

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

Fig 2



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

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

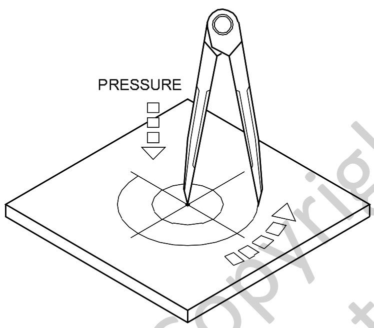
— — — — — — — —

Dividers

Objectives: At the end of this lesson you shall be able to
- **identify the parts of a divider**
- **state the uses of dividers**
- **state the specifications of dividers**
- **state some important hints on divider points.**

Dividers are used for scribing circles, arc and for transferring and stepping of distances. (Fig 1,2 and 3)

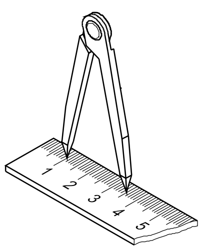
Fig 1



FIRM JOINT DIVIDER

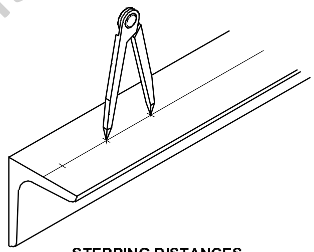
Dividers are available with firm joints and spring joints. (Fig 1& 4). The measurements are set on the dividers with a steel rule. (fig 2)

Fig 2



The sizes of dividers range between 50 mm to 200 mm.

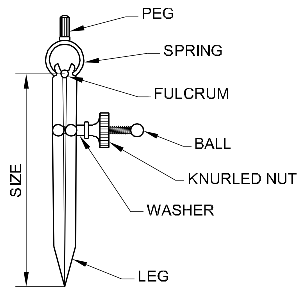
Fig 3



STEPPING DISTANCES

The distance from the point to the centre of the fulcrum roller (pivot) is the size of the divider. (Fig 4)

Fig 4

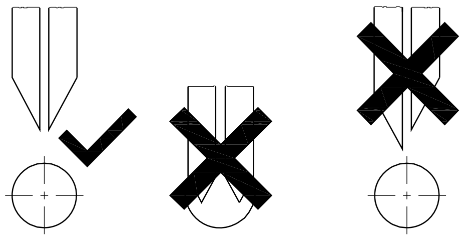


SPRING JOINT DIVIDER

For the correct location and seating of the divider point prick punch marks of 30° are used.

The two legs of the divider should always be of equal length. (Fig 5) Dividers are specified by the type of their joints and length.

Fig 5



The divider point should be kept sharp in order to produce fine lines, frequent sharpening with an oilstone is better than sharpening by grinding. Sharpening by grinding will make the points soft.

— — — — — — — —

Surface gauges

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

- **state the constructional features of surface guages**
- **name the types of surface guages**
- **state the uses of surface guages**
- **state the advantages of universal surface guages.**

The surface guage is one of the most common marking tools used for:-

- Scribing lines parallel to a datum surface. (Figs 1&2)

Fig 1

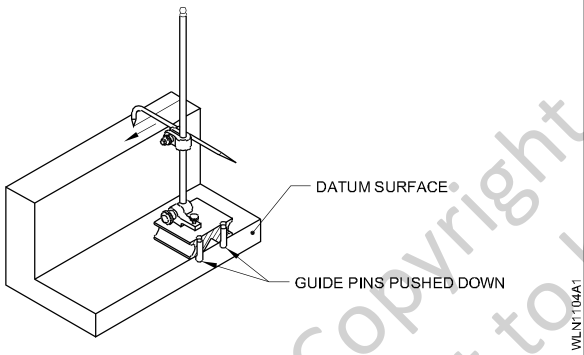
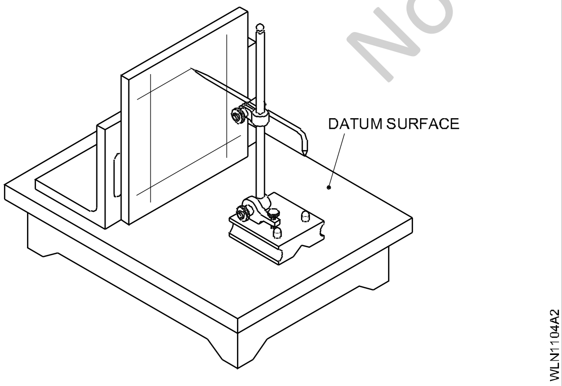
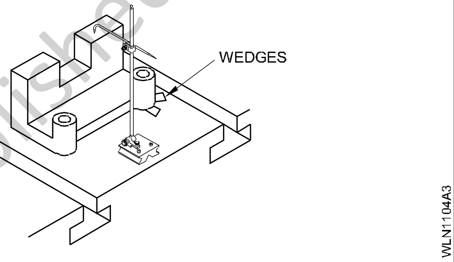


Fig 2



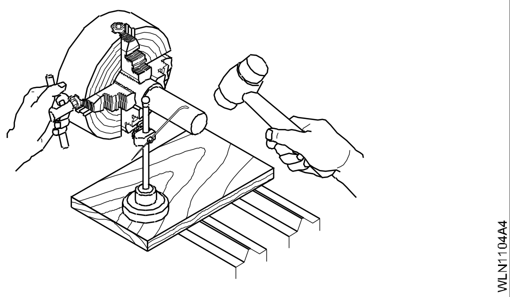
- setting jobs on machines parallel to a datum surface and checking the height and parallelism of jobs (Fig 3)

Fig 3



- setting jobs concentric to the machine spindle. (Fig 4)

Fig 4



Types of surface guages: Surface gauges/scribing blocks are of two types,

- fixed and univesal

Surface guage - Fixed type (Fig 5): The fixed type of surface guages consist of a heavy flat base and a spindle, fixed upright, to which a scriber is attached with a snug and a clamp nut.

Fig 5

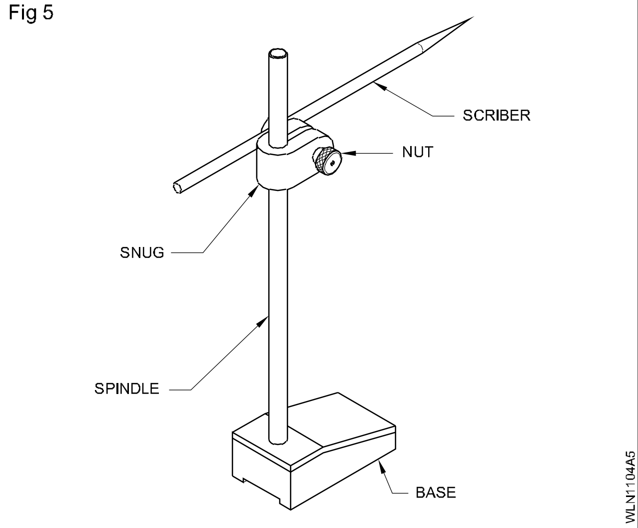
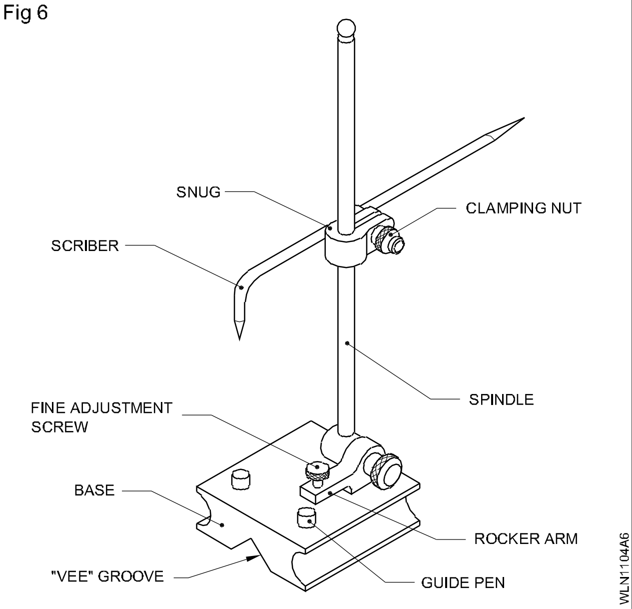


Fig 6



Universal Surface Guage (Fig 6**):** This has the following

- The spindle can be set to any position.
- fine adjustrments can be made quickly.
- Can also be used on cylindrical datum surfaces.

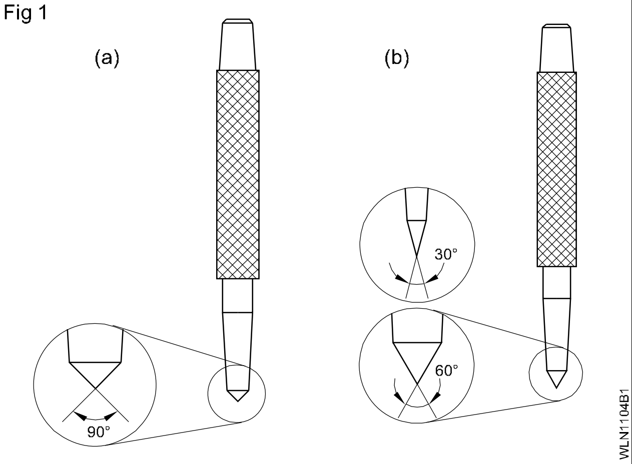
Types of marking punches

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

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

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

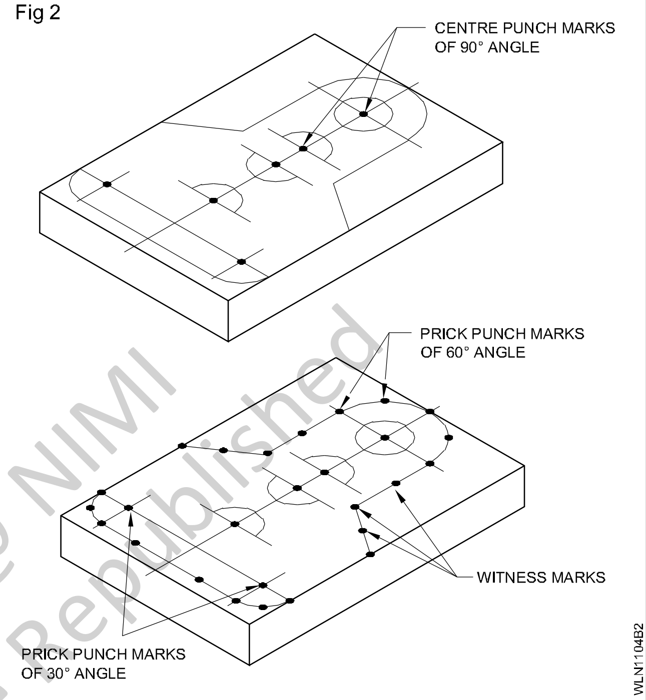
Fig 1



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

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

Fig 2



Angular measuring instruments (Semi-precision)

Objectives: At the end of this lesson you shall be able to
- **state the names of semi-precision angular measuring instruments**
- **differentiate between bevel and universal bevel gauges**
- **state the features of bevel protractors.**

The most common instruments used to check angles are the:

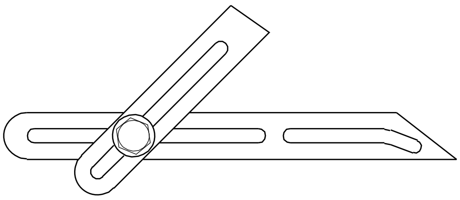
- bevel or bevel gauge (Fig 1)

- Universal bevel gauge (Fig 2)

- bevel protractor. (Fig 3)

Bevel gauges (Fig 1): The bevel gauges cannot measure angle directly. they are. therefore, indirect angular measuring instruments. The angles can be set and measured with bevel protractors.

Fig 1

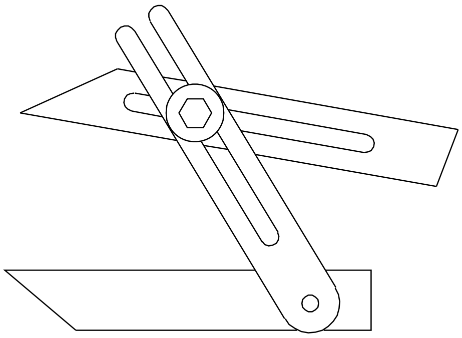


BEVEL

universal bevel gauges (Fig 2**):** The universal bevel gauge has an additional blade. This helps in measuring angles which cannot be checked with an ordinary bevel gauge.

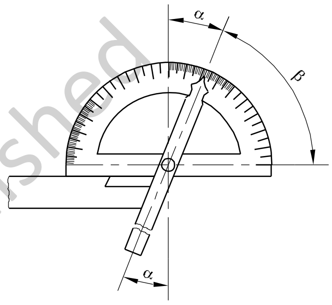
Bevel protractor (Fig 3**):** The bevel protractor is a direct angular measuring instrument, and has graduation marked from 0° to 180°. This instrument can measure angle within an accuracy of 1.0°.

Fig 2



UNIVERSAL BEVEL

Fig 3



BEVEL PROTRACTOR

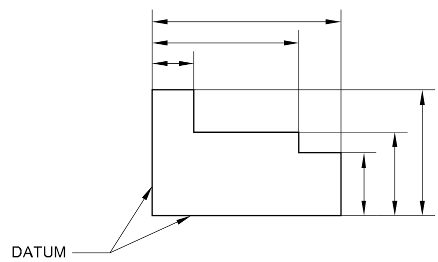
Datum

Objectives: At the end of this lesson you shall be able to
- **state the need for datum while marking**
- **name the different datum references.**

Say, the height of a person is measured from the floor on which he stands, the floor then becomes the datum of the common basis for measurement.

A datum is a referable surface. Line of point, and its purpose is to provide a common position from which measurements may be taken. The datum may be an edge or centre line depending on the shape of the work. For positioning a point, two datum references are required. (Fig 1,2 and 3)

Fig 1



EDGE DATUM

Fig 2

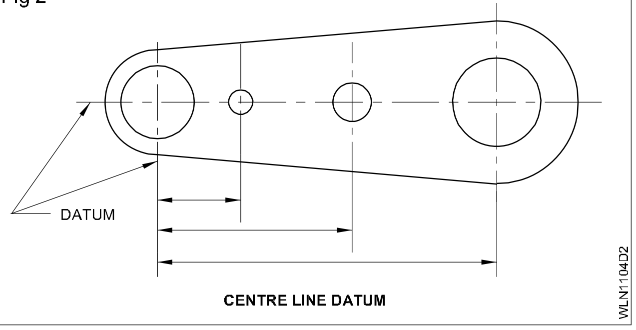
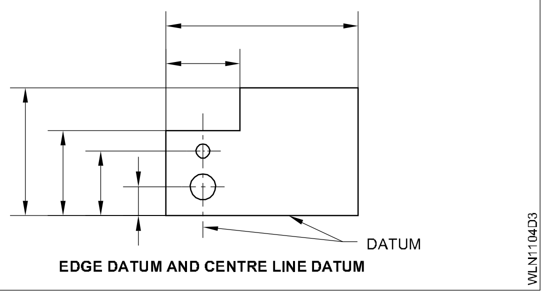
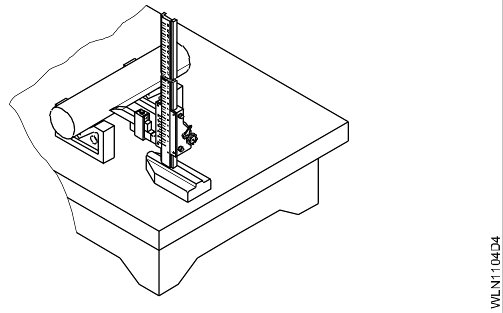


Fig 3



Marking tables, surface plates, angle plates, ‘V’ blocks, and parallel blocks serve as a datum. (Fig 4) Marking tables are made up of cast iron since they are i)Self lubricating ii) Easy to cast and iii) cheaper.

Fig 4



Hammer

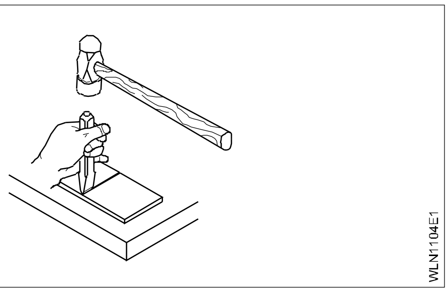
Objectives: At the end of this lesson you shall be able to
- **state the uses of an engineer’s hammer**
- **identify the parts of an engineer’s hammer and state their functions**
- **name the types of engineer’s hammers**
- **specify the engineer’s hammer.**

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

punching
bending
straightening
chipping
forging
riveting.

(See fig 1.)

Fig 1



Major parts of a hammer

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

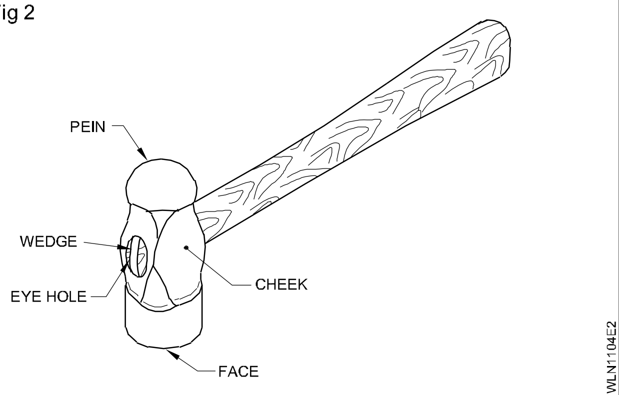
The head is made of dorp-forged carbon steel, while the wooden handle must be capable of absorbing shock.

The parts of a hammer-head are the

face
pein
cheek
eye hole.

(See fig 2.)

Fig 2



Face

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

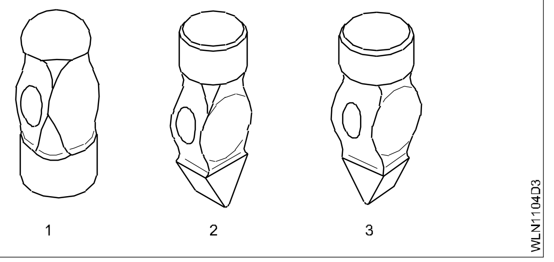
pein

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

ball pein
cross pein
straight pein. (Fig 3)

The face and the pein are hardened.

Fig 3



Cheek

The cheek is the middle portion of the hammer-head. The weight of the hammer is stamped here.
This protion of the hammer-head is left soft

Eye hole

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

Specification

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

Fig 4

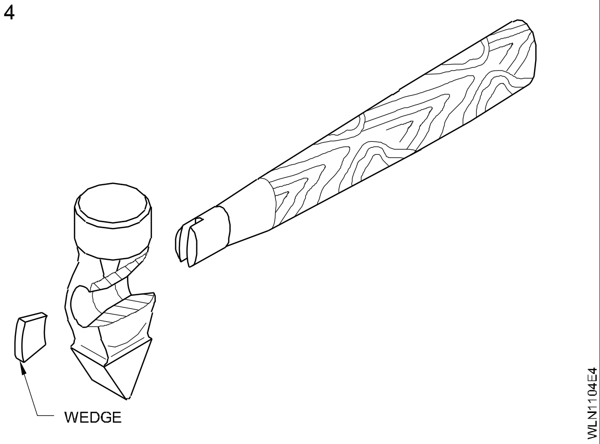
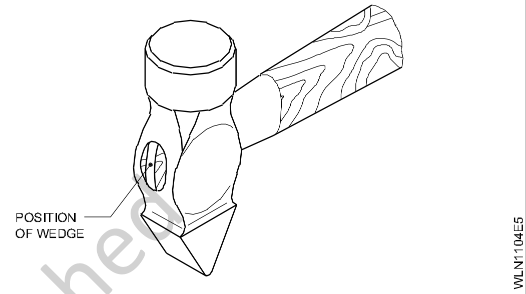


Fig 5



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

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

Before Using a Hammer

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

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

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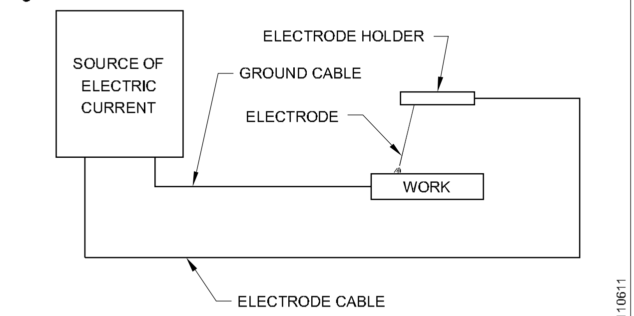
Arc welding machines

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

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

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

Fig 1

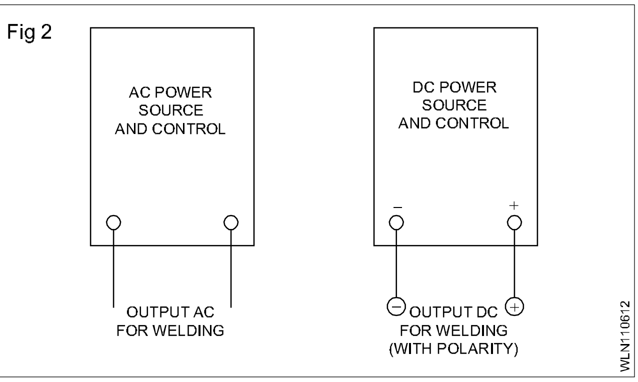


SIMPLE WELDING CIRCUIT

Necessity

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

Fig 2



Type (Fig 2): Basically power sources are:

- alternating currernt welding machine
- direct current welding machine.

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

DC machines

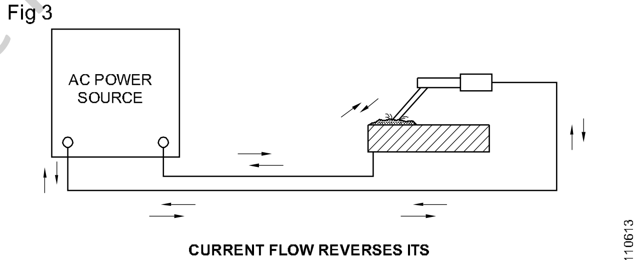
- Motor generator set
- Engine generator set
- Rectifier set

AC machines

- Transformer sets

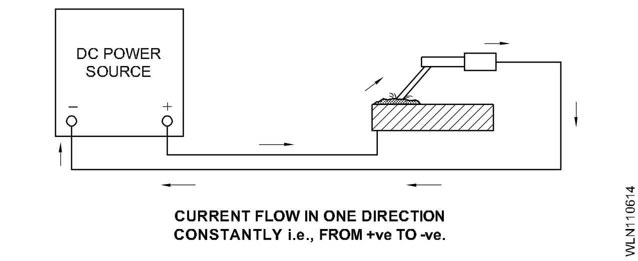
> **AC means alternating current. It changes or reverses its dirction of flow of current 50 times per second, if it is 50 cycles/sec. (Fig.3)**
>
> **DC means direct current. it flows steadily and constantly in one direction. (Fig.4)**

Fig 3



CURRENT FLOW REVERSES ITS DIRECTION 50 CYCLES / SEC.

Fig 4



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

Care and maintenace of arc welding machines and accessories

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

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

Maintain the cooling oil in the transformer welding set.

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

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

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

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

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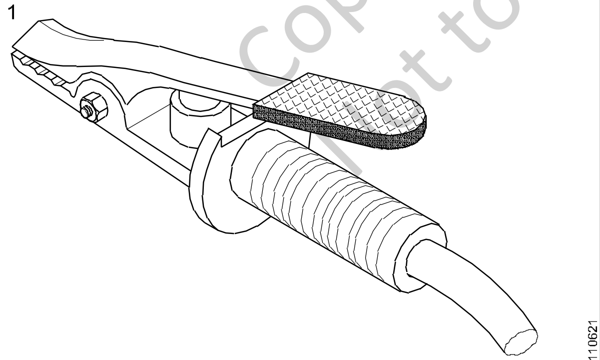
Arc welding accessories

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

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

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

Fig 1



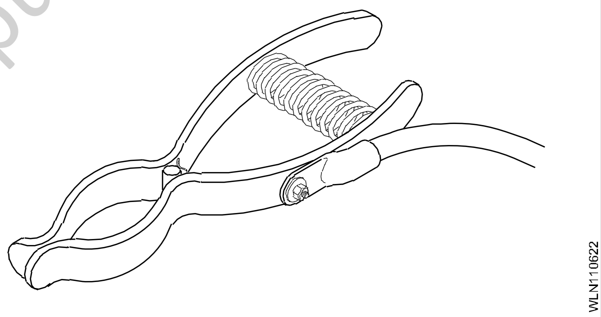
ELECTRODE HOLDER

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

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

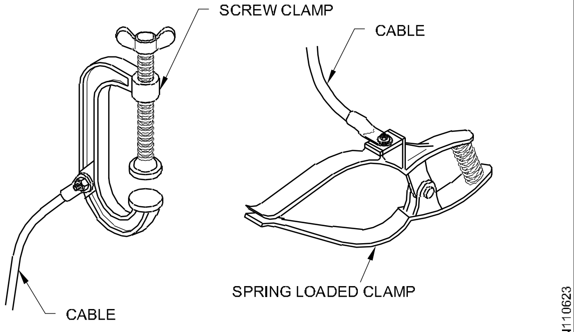
Earth clamp (fig 2): It is used to connect the earth cable firmly to the job on welding table. It is also made of copper/ copper alloys.

Fig 2



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

Fig 3



WORK CABLE ATTACHMENTS

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

— — — — — — — —

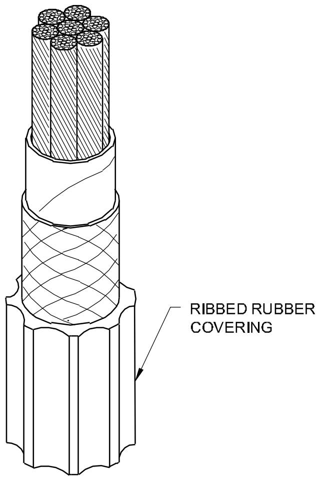
The lead from the welding machine to the electrode-holder is called electrode cable.

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

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

Welding cables are made in various sizes (cross-sections)

Fig 4



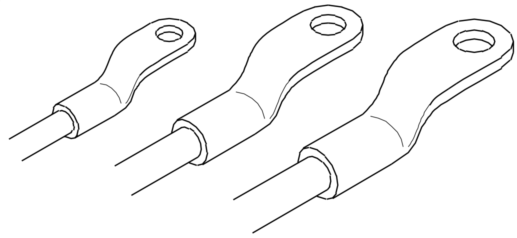
WELDING CABLE WITH HEAVY RIBBED OUTER RUBBER COVERING

i.e. 300, 400, 600 amps etc.

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

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

Fig 5



LUGS FOR WELDING LEADS

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

Loose joints or bad contacts cause overheating of the cables.

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

TABLE 1

Recommendations of copper cable for arc welding

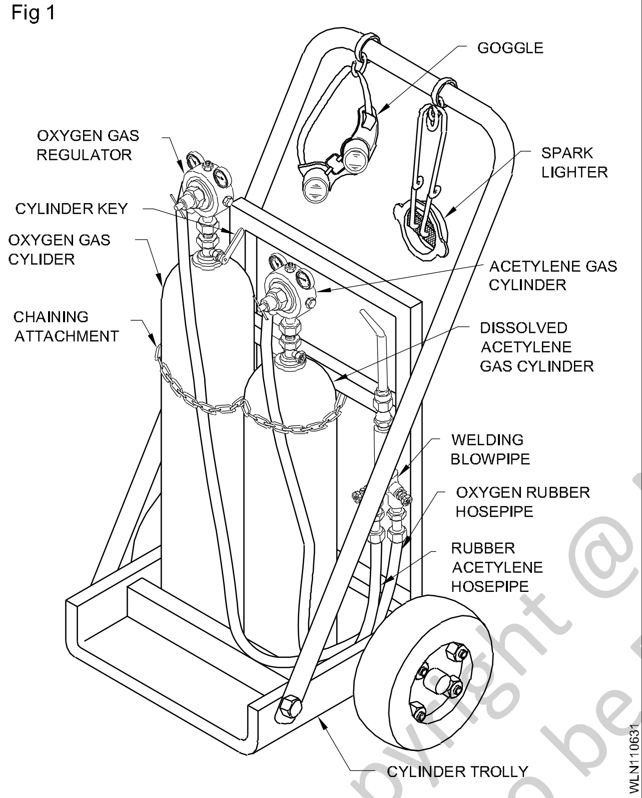
Cable dia. (mm)	Lengths of cable in metres current capacity in amperes 0 - 15	15 - 30	30 - 75
24.0	600	600	400
21.0	500	400	300
19.0	400	350	300
18.0	300	300	200
16.5	250	200	175
15.5	200	195	150
14.5	150	150	100
13.5	125	100	75

High pressure oxy-acetylene welding equipment and accessories

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

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

Fig 1



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

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

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

Fig 2

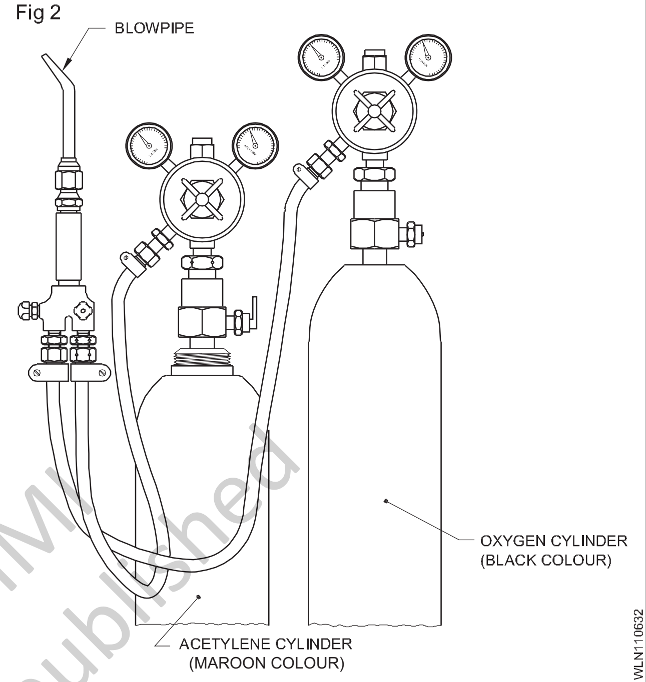
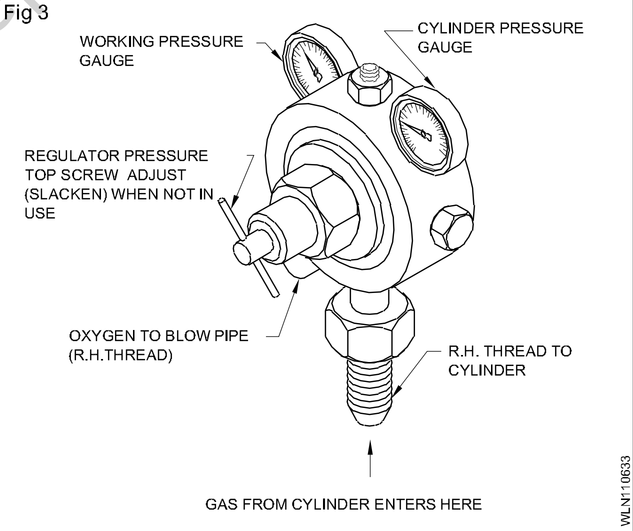
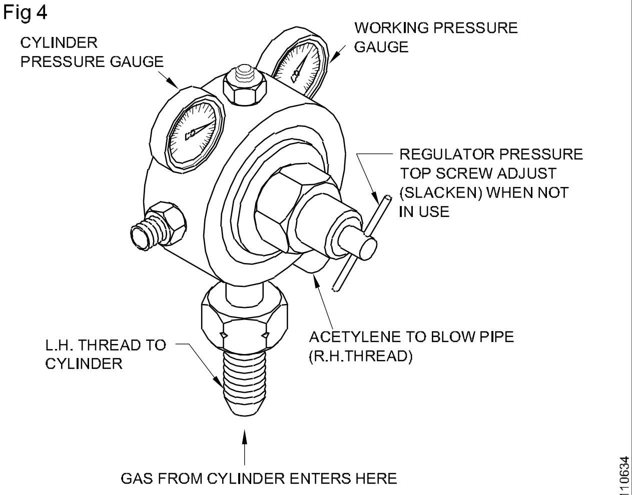


Fig 3



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

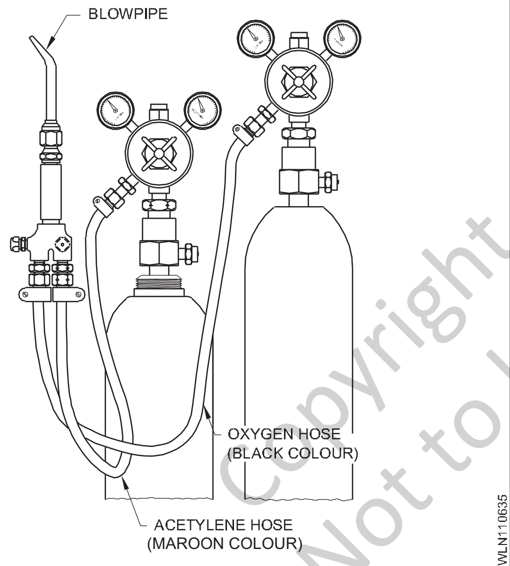
Fig 4



ACETYLENE PRESSURE REGULATOR

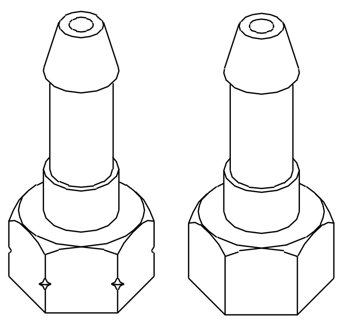
Rubber hose-pipes and connections: These are used to carry gas from the regulator to the blowpipe. These are made of strong canvas rubber having good flexibility. Hosepipes which carry oxygen are black in colur and the acetylene hoses are of maroon colour (Fig 5)

Fig 5



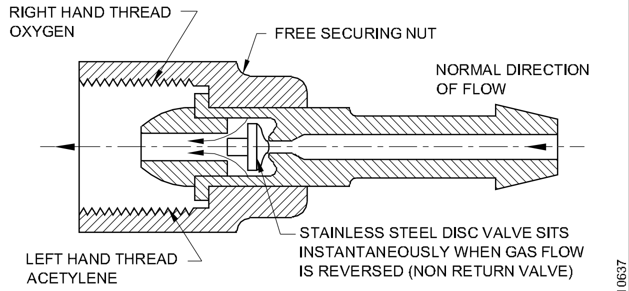
Rubber hoses are connected to regulators with the help of unions. These unions are right hand threaded for oxygen and left hand threaded for acetylene. Acetylene hose unions have a groove cut on the corners. (Fig 6)

Fig 6



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

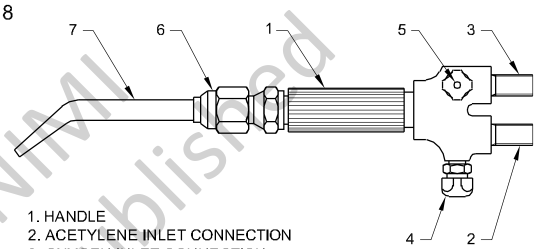
Fig 7



HOSE PROTECTOR

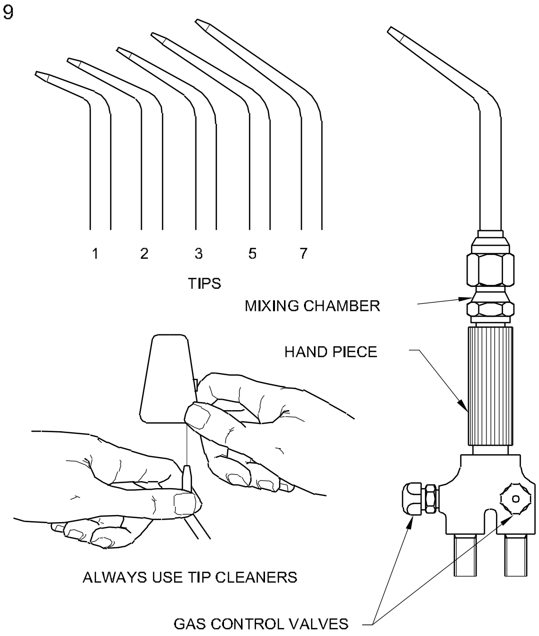
Blowpipre and nozzle: Blowipipes are used to control and mix the oxygen and acetylene gases to the required proportion. (Fig 8)

Fig 8



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

Fig 9



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

TABLE 1

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

— — — — — — — — —

Gas welding hand tools

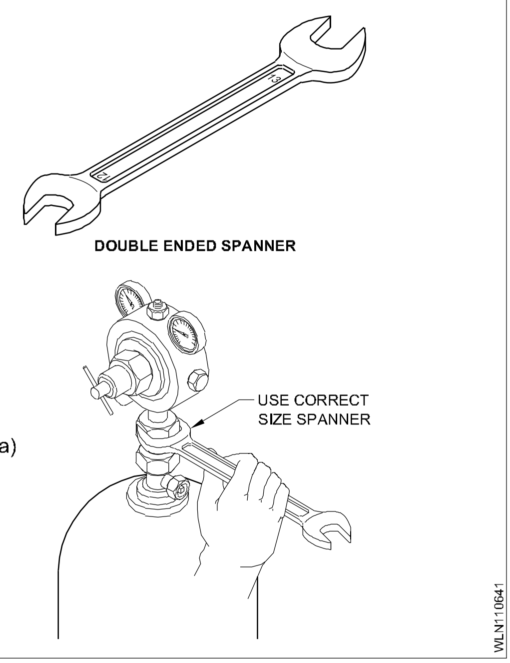
Objectives: At the end of this lesson you shall be able to
- **identify and name the hand tools used by a welder**
- **state their uses**
- **state the care and maintenance to keep the hand tool in good working condition.**

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

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

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

Fig 1



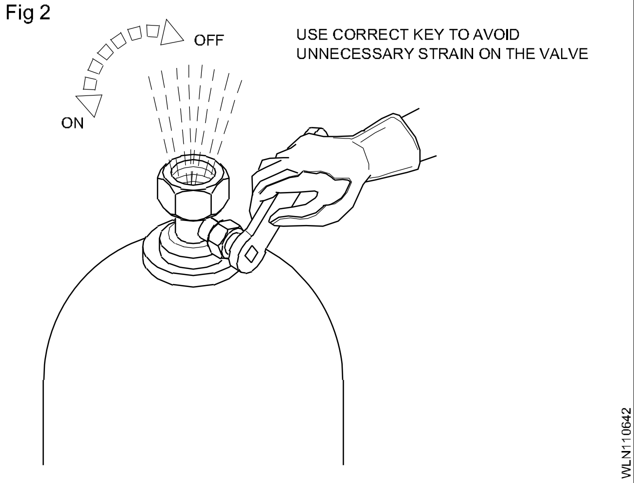
Cylinder Key: A cylinder key is shown in Fig.2. It is used to open or close the gas cylinder valve socket to permit or stop the gas flow from the cylinder to the regulator.

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

Nozzle or tip cleaner

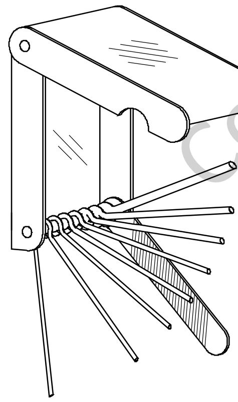
Cleaning the tip: All welding torch tips are made of copper. They can be damaged by the slightest rough handling. Dropping, tapping or chopping with the tip on the work may damage the tip beyond repair.

Fig 2



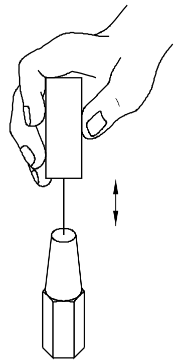
Tip cleaner: A Special tip cleaner is supplied with the torch container. For each tip there is a kind of drill and a smooth file Fig.3.

Fig 3



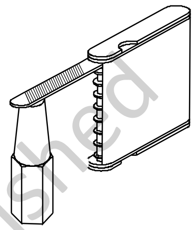
Before cleaning the tip, select the correct drill and move it, without turning, up and down through the tip Fig.4.

Fig 4



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

Fig 5



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

Fig 6

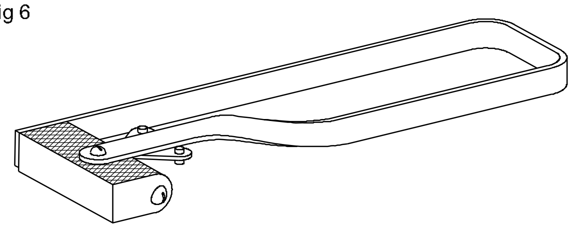
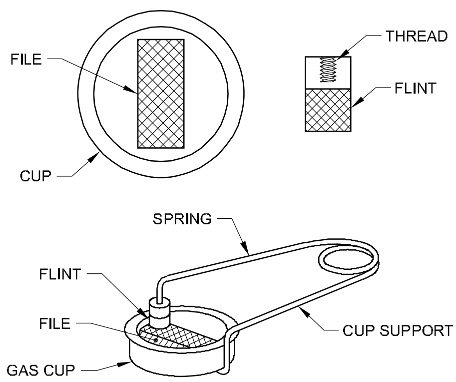
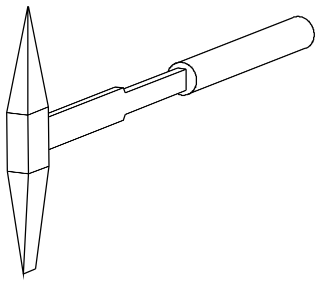


Fig 7



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

Fig 8



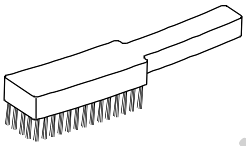
CHIPPING HAMMER

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

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

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

Fig 9



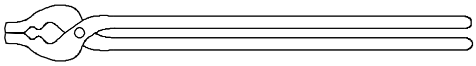
WIRE BRUSH

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

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

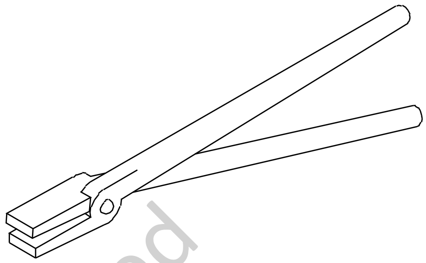
Tongs: Fig.10 and Fig.11 show a pair of tongs used to hold hot work pieces and to hold the job in position.

Fig 10



TONGS

Fig 11



TONGS

Various welding processes and their application

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

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

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

Electric welding processes can be classified as:-

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

Electric arc welding can be futher classified as:

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

Electric resistance welding can be further classified as:

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

Gas welding processes can be classified as:

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

The other welding processes are:

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

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

SCAW	Shielded Carbon Arc
SW	Stud Arc
TW	Thermit
UW	Ulrosonic

Applications of Various welding processes

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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Shielded Metal ARC Welding

Objectives: At the end of this lesson you shall be able to
- **state the types and classify electric welding processes**
- **state the principle of electric arc welding**

Electric welding: This is a process of welding in which the heat energy is obtained from electricity.

When electric current passes through a, medium material it generates heat.

The amount of heat generated depends upon:

- the amount of current passing through the medium
- the changes taking place in the medium
- the resistance of the medium.

By adjusting current and resistance, sufficient heat can be produced to melt the metals.

Principle of shielded Metal Arc Welding

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

The flux covering melts during welding and forms gas and slag to shield the arc molten weld pool. The flux also provides a method of a adding scavengers, deoxidizers and alloying elements to the weld metal

Various Name Stick Electrode welding,

Electric Arc welding,

Shielded Metal Arc welding (SMAW)

Manual Metal Arc welding (MMAw)

Popularly known as Arc welding

It is a manual & ancient welding process, 100 years old

Main parts in SMAW

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

Types of power source

1 AC welding Transformer

2 DC motor Generator

3 Rectifier set

4 Inverter

SMAW advantages / Disadvantages

Advantages:

1 Field or shop use; less sensitive to wind and dirt

2 Wide range of conusumables

3 All positional; flexible

4 Very portable; can reach limited access areas

5 Simple, inexpensive equipment

Disadvantages:

1 High skill factor

2 Slag inculsions

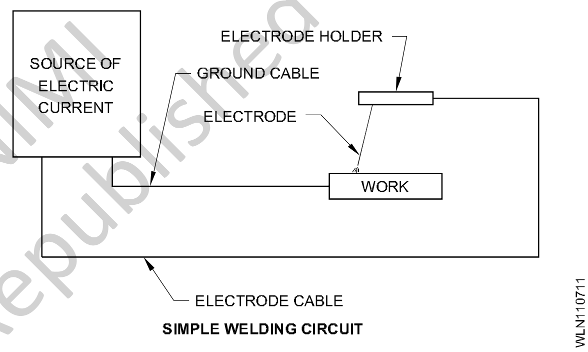
3 Low deposition rate and operating factor

4 High level of fume

5 Hydrogen control

6 Can't weld low melting point (e.g.pb,sn,zn) or reactive metals (e.g.ti)

Fig 1



SIMPLE WELDING CIRCUIT

Welding Terms & Its Definition

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

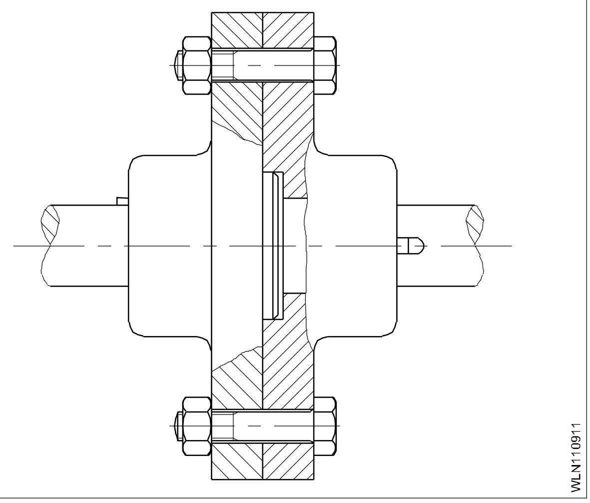
25. **Electrode** (Flux coated) A metal stick which is coated with flux and having parts indicated as stub end, tip,bare/ core wire and flux coating. The size of this is determined by size of bare/core wire diameter. (This is used in shielded Metal Arc welding as consumable material).

Bolted Joints

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

Bolts and nuts (Fig 1)

Fig 1



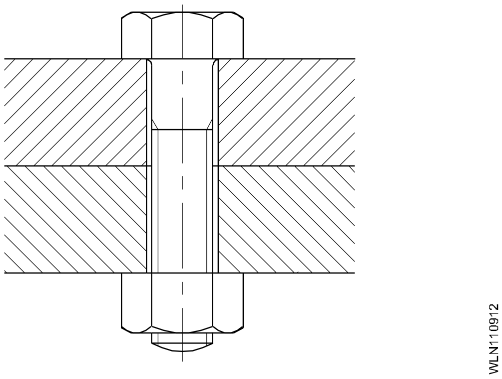
These are generally used to clamp two parts together.

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

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

Bolts with clearance hole (Fig 2)

Fig 2

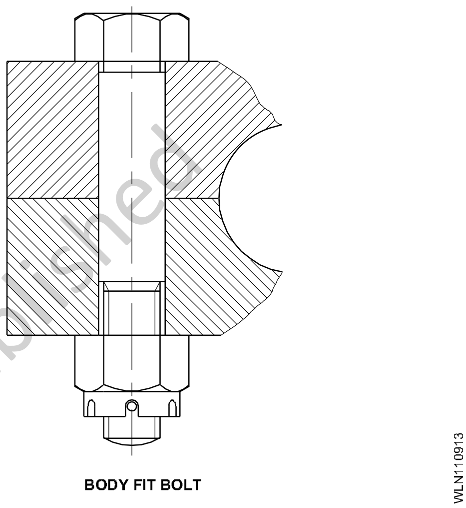


This is the most common type of fastening arrangement using bolts. The size of the hole is slightly larger than the belt (Clearance hole).

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

Body fit bolt (Fig 3)

Fig 3

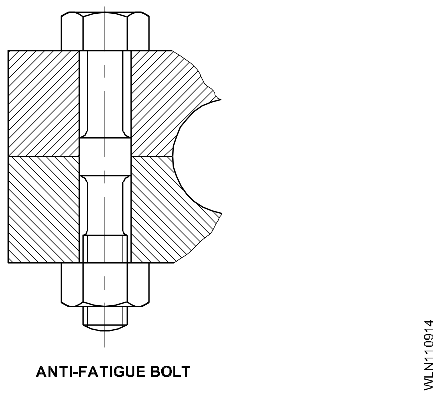


This type of bolt assembly is used when the relative movement between the workpieces has to be prevented. The diameter of the threaded portion is slightly smaller than the shank diameter of the bolt.

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

Anti-fatigue bolt (Fig 4)

Fig 4

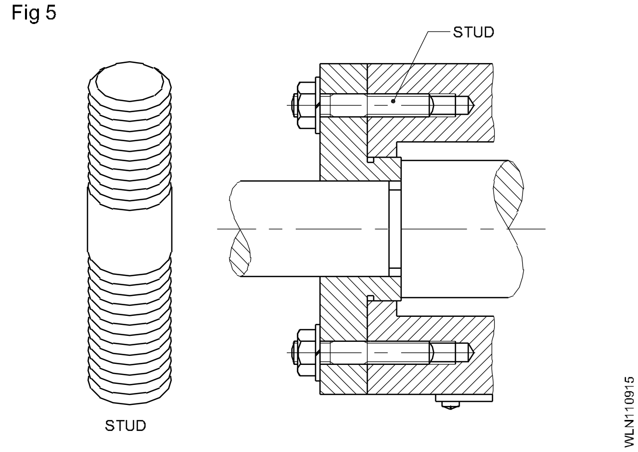


This type of bolt is used when the assembly is subjected to alternating load conditions continuously . Connecting rod with big ends in engine assembly are examples of this application.

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

Studs (Fig 5)

Fig 5



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

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

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

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

Example

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

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

Explanation about property class.

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

NOTE

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

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

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

Rivet Joines

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

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

- brazing is not suitable,

- the structure changes owing to welding heat,

- the distortion due to welding cannot be easily removed etc.

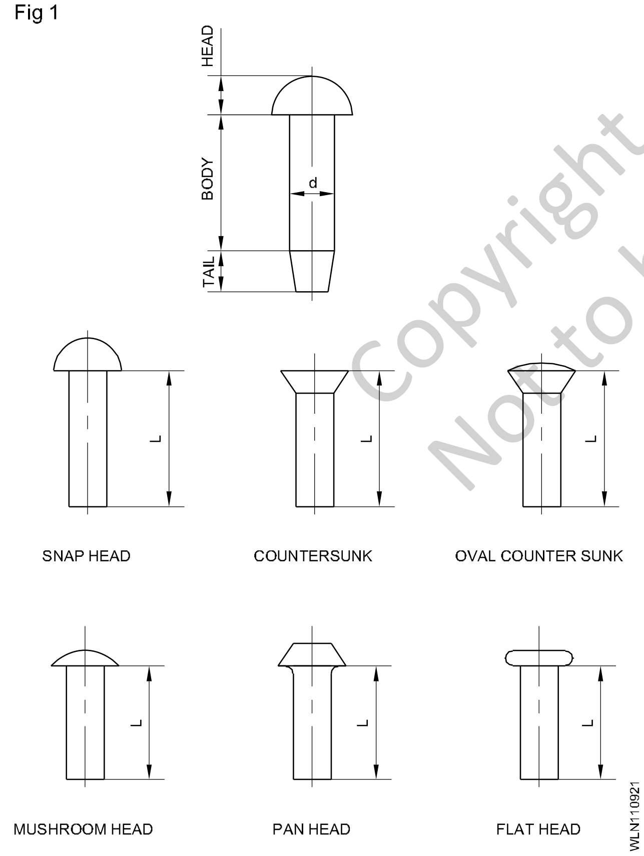
Specification of rivets

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

Rivets

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

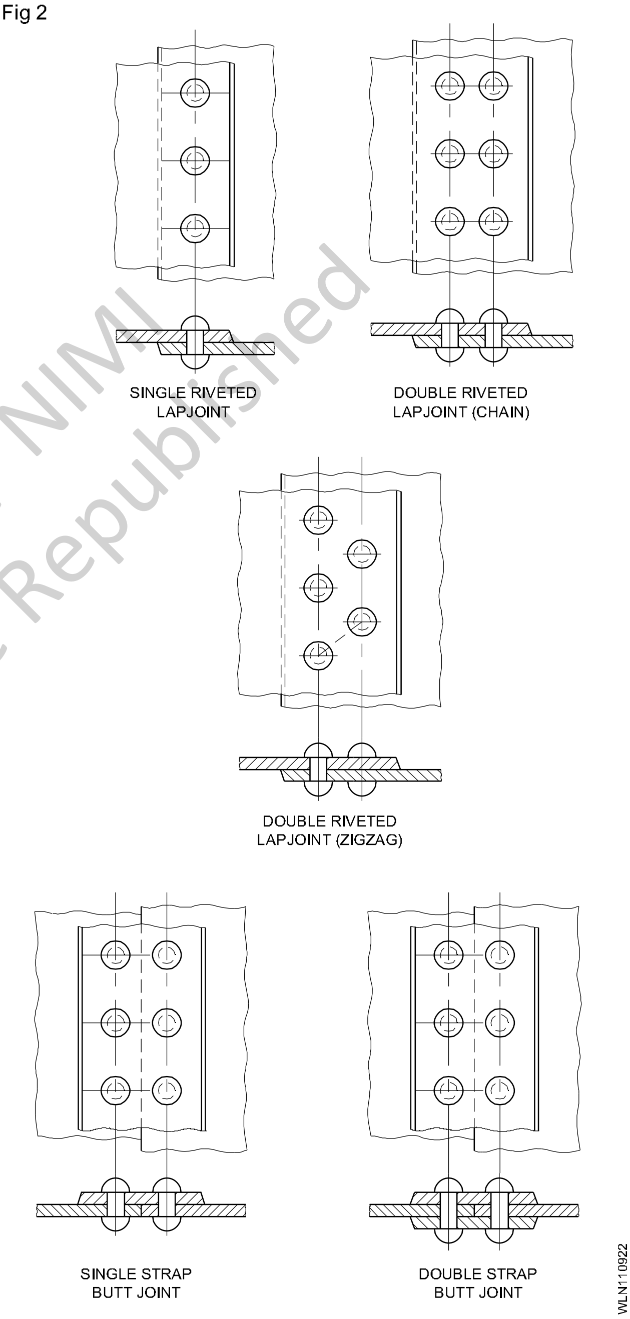
Fig 1



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

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

Fig 2



Rivet joints (Fig 2)

Rivet joints are classified as lap joints and butt joints.

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

Rivet interference

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

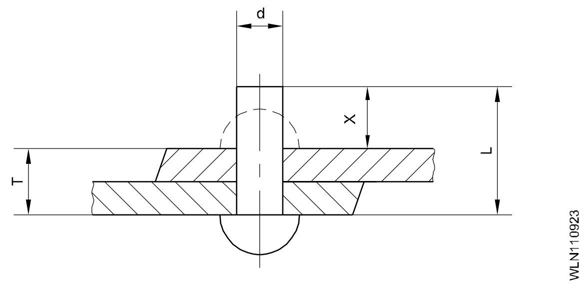
When forming a round head (Fig 3) the interference X is given as

X = d X (1.3, -- 1.6)

where = rivet interference(mm)

d = rivet diameter (mm)

Fig 3



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

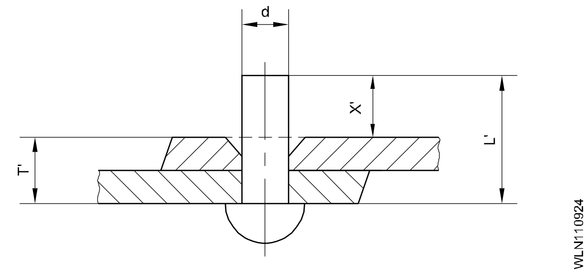
L = T + d (1.3 - 1.6)

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

L' = T + d (0.8 - 1.2)

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

Fig 4



Soldering

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

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

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

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

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

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

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

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

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

Soldering iron (soldering bit)

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

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

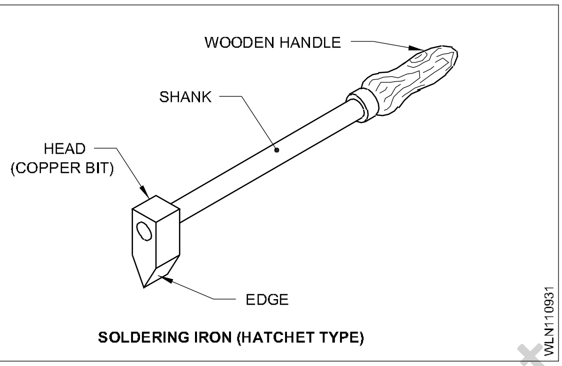
Soldering irons are normally made of copper or copper alloys. So they are also called as copper bits.

Copper is the preferred material for soldering bit because

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

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

Fig 1



SOLDERING IRON (HATCHET TYPE)

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

SOLDERING COPPER BIT

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

They are

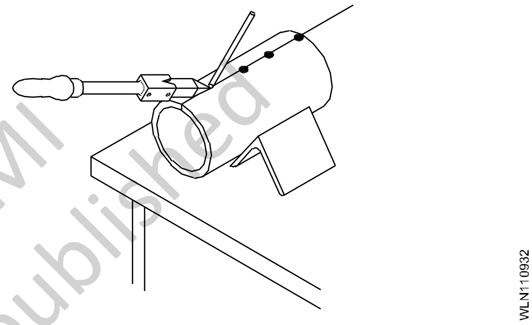
- The pointed soldering copper bit.
- The electric soldering copper bit.
- The gas heated soldering copper bit .
- Straight soldering copper bit.
- Hatchet soldering copper bit.
- Adjustable copper bit
- Handy soldering copper bit.

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

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

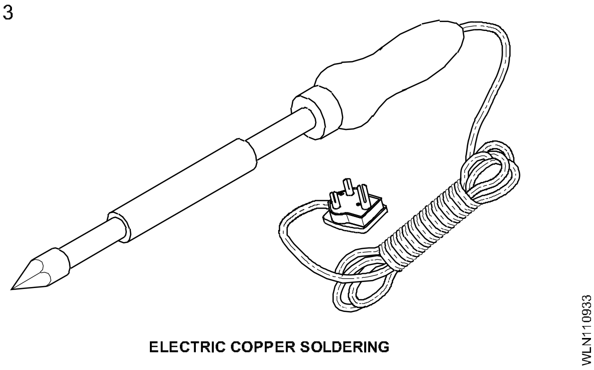
Point soldering copper bit: This is also called a square pointed soldering iron, The edge is shaped to an angle on four sides to from a pyramid. This is used for tacking and soldering. (Fig 2)

Fig 2



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

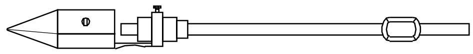
Fig 3



ELECTRIC COPPER SOLDERING

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

Fig 4

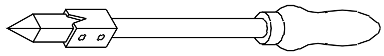


GAS HEATED SOLDERING COPPER BIT

WLN110934

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

Fig 5

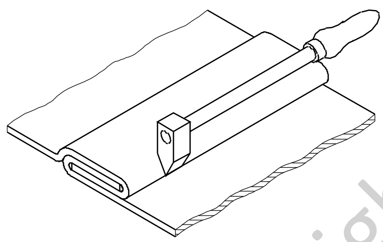


STRAIGHT SOLDERING COPPER WITH HANDLE

WLN110935

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

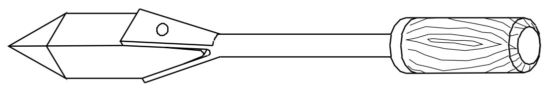
Fig 6



WLN110936

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

Fig 7

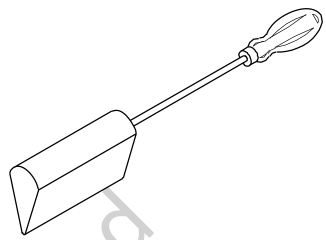


ADJUSTABLE SOLDERING BIT

WLN110937

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

Fig 8



HANDY SOLDERING COPPER BIT

WLN110938

Solder

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

Solder is a bonding filler metal used in soldering process.

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

TYPES OF SOLDERS

There are two types of solders.

- Soft solder
- Hard solder

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

In the composition of soft solder, tin is always stated first.

WARNING

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

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

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

Soldering Flux

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

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

Function of the fluxes:

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

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

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

Selection of flux: The following criterias are important for selecting a flux.

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

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

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

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

DIFFERENT TYPES OF FLUXES

(A) Inorganic fluxes

1 Hydrochloric acid: Concentrated hydrochloric acid is a liquid which fumes when it comes into contact with air. After mixing with water 2 or 3 times the quantity of the acid, it is used as dilute hydrochloric acid. Hydrochlotic acid combines with zinc farmaing zinc chloride and acts as a flux. So it cannot be used as a flux for sheet metals other than zinc iron or galvanised sheet this is also known as muriatic acid.

2 Zinc chloride: Zinc chloride is produced by adding small pieces of clean zinc to hybrochloric acid. It gives off hydrogen gas and heat after a vigorous bubbling action, thus producing zinc chloride. The zinc chloride is prepared in heat resisting glass beakers in small quantities.(Fig1)

3 Ammonium chloride or sal-Ammoniac: It is a solid white crystalline substance used when soldering copper, brass, iron and steel. It is used in the form of powder mixed with water. It is also used as a cleaning agent in dipping solution.

4 **Phosphoric acid:** It is mainly used as flux for stainless steel. It is extremely reactive. It is stored in plastic containers because it attacks glass.

(B) Organic fluxes

1 Resin: it is an amber coloured substance extracted from pine tree sap. It is available in paster or powder form.

Resin used for soldering copper, brass, bronze, tin plate, cadmium, nickel, silver and some alloys of these metals. This is used extensively for electrical soldering work.

2 **Tallow:** It is a form of animal fat. It is used when soldering lead, brass and copper.

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

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

Portable hand forge with blower

Objectives: At the end of this lesson you shall be able to
- **state the purpose of hand forge**
- **describe the constructional feature of hand forge**
- **state the fuel used in hand forge.**

Hand forge: It is used for heating the soldering bit.

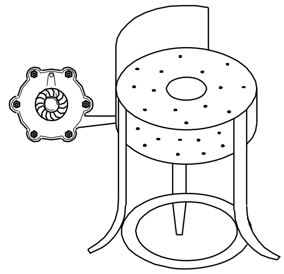
It is made of mild steel plates and angles. It is generally round in shape, the hand blower is attached to it for air supply.

A perforated plate is fixed at the bottom to remove burnt residuals.

The fuel zone is built up with fire bricks and coated with the mixture of clay and sand, providing space at the centre for fuel, (Fig 1)

The fuel used for firing is mainly charcoal. The charcoal is prepared from hard wood.

Fig 1



HAND FORGE

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Dipping solution

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

It is used to dissolve oxides from solder coated faces of the copper bit before applying it to the workpiece.

It is made of

1 Dissolving sal-ammoniac powder in water.

2 Dilute zinc-chloride with water,

3 Adding commercial flux with zine chloride or ammonium chloride as active ingredients to water.

A mixture of approximately one part of active component and four parts of water is satisfactory as the acidity of the solution should not be strong

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Safety pracautions in soldering

Objectives: At the end of this lesson you shall be able to
- **follow safety precautions in soldering to avoid injuries/acccidents.**

Safety precautions followed while soldering

1 Wear safety glasses to protect your eyes from solder splattering and flux.

2 Be careful while storing hot soldering irons after use to avoid burns.

3 Wash your hands thoroughly after using soft solder because it is poisonous.

4 Tin the soldering iron in a well ventilated area to exhaust fumes coming out while soldering.

5 Wear safety goggles when using acids for cleaning.

6 When making acid solution, always pour acid into water slowly.

7 Never pour water into the acid.

8 All inorganic fluxes are poisonous.

9 Wear goggles and gloves while handling corrosive flux.

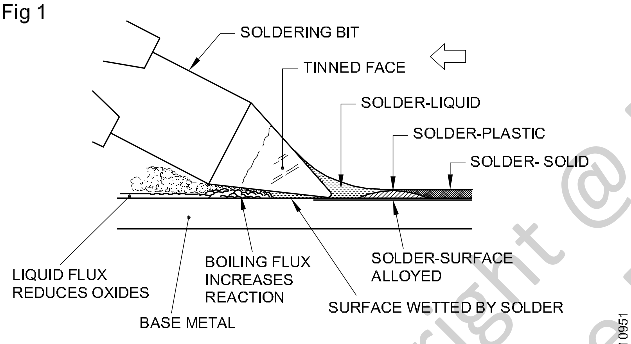
Soft soldering

Objectives: At the end of this lesson you shall be able to
- **explain soft soldering process**
- **state the melting characteristics of soft solders**
- **state the essential features of the soldering technique**
- **explain the importance of the attitude of the bit**
- **state the importance of movement of the bit in soldering**
- **state the characteristics of the soldered seams to be observed while inspection.**

Soft soldering involves the process.

- Preparing the workpiece.
- Select the correct soft solder.
- Preparing the soldering iron.
- Select and apply suitable flux.
- heat the soldering iron bit and the workpiece to the correct temperature.
- manipulating the soldering iron on the workpiece skillfully as shown in Fig 1.
- Complete the job to a satisfactory standard.

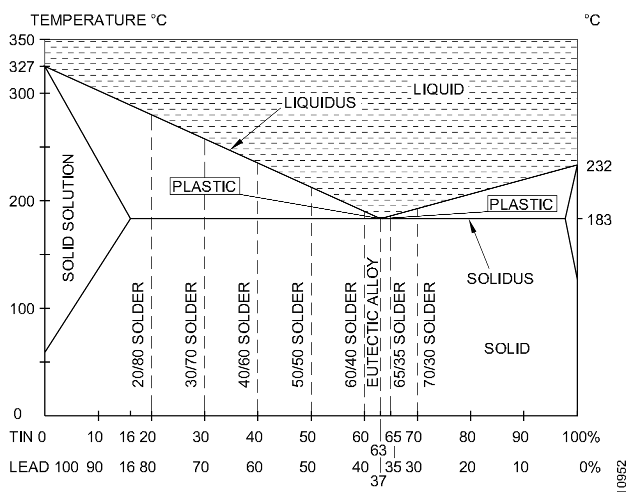
Fig 1



THE SOFT SOLDERING PROCESS

Melting characteristics of soft solders: The eutectic alloy of tins lead solder is a mixture of 63% tin and 37% lead. 63/37 solder melts at 183°C and is the lowest melting point of alloy series as shown in fig 2.

Fig 2



MELTING CHARACTERISTICS OF TIN-LEAD SOLDER

Soldering Techniques: The following features are essential to do soldering.

- Correct joint design
- Preparation of the joint
- Selection of the solder
- Selection and preparation of the soldering iron.
- Copper bit heating
- Soldering bit manipulation
- Cleaning after soldering
- Inspection of the seam.

Attitude of the bit: The soldering iron bit should be placed in a position that enables sufficient heat and solder to flow into the joint.

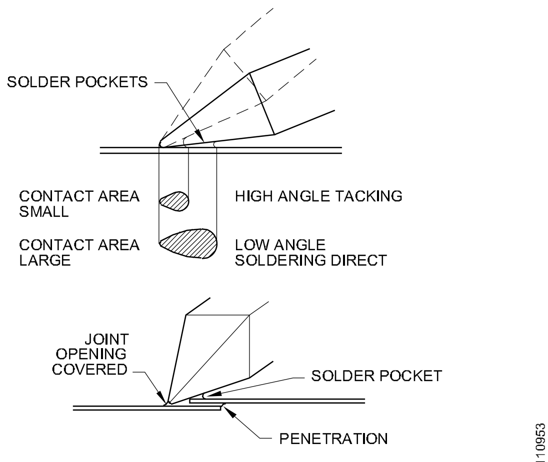
The angle between a working face of the bit and the joint surface should be filled with a pocket of solder. (Fig 3)

Any variation of this angle will control the amount of heat and solder which is transferred onto the lapped surfaces.

Contact between the molten solder and the joint opening is essential for the penetration of the solder into the joint as shown in figure.

Successful use of the soldering iron is influenced by the attitude of the bit and the movement of the bit on the workpiece.

Fig 3

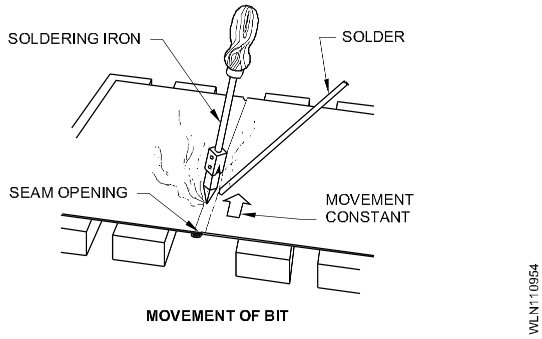


ATTITUDE OF BIT

Movement of the bit: The bit movement along the line of the seam, must be constant and consistent with a smooth flow of solder. When sweating wide overlaps, in addition to the progressive movement along the seam, it is required to move the bit back and forth across the seam. (Fig 4)

The pattern of the bit movement ensures successful heating of the solder deposited, when the point of the bit covering the joint opening penetrates through the lap as shown in figure.

Fig 4



MOVEMENT OF BIT

Flux residues and stains should be removed from the seam, to keep clean dry surfaces for paint finishes.

Inspection of the seam: A soldered seam should have the following characteristics.

- The solder has penetrated the lapped surface.
- The joint gap is sealed with a neat smooth fillet of the solder.
- The upper surfaces of the seam must be smooth, thin coating of solder, with tidy solder margins with uniform width.

Visual inspection is good to rectify the faults of the solder. However, physical testing for air or water tight seam is specified often. Leaks, detected by the tests are corrected by re-cleaning, re-fluxing and re-soldering of the faulty joint in the soldered seam.

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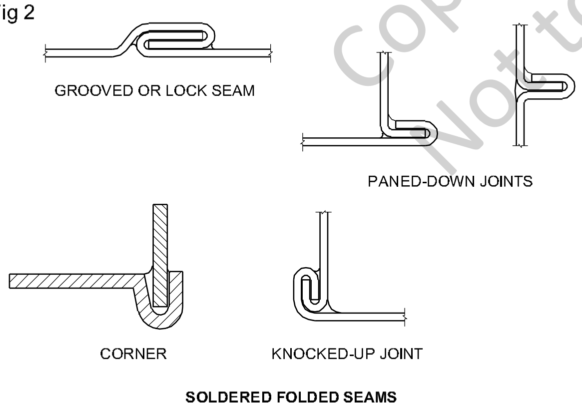
Soldered joint

Objectives: At the end of this lesson you shall be able to
- **state the types of the soldered joints**
- **state the points to be considered for correct joint design.**

Types of soldered joints: Sheet metal components are joined together by soldered joints. In many cases, the edges are joined by sheet metal mechanical joints and then soldered to make the joint stronger and leak proof.

Fig 1 shows soldered lap joints.

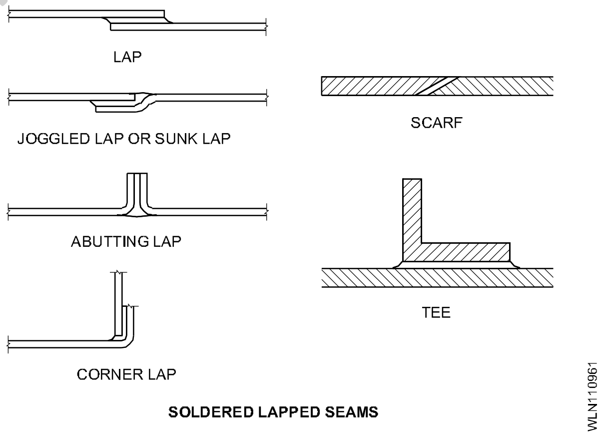
Fig 2



SOLDERED FOLDED SEAMS

Fig 2 shows soldered seams.

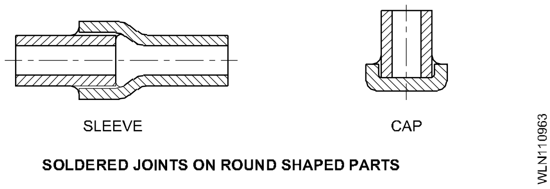
Fig 1



SOLDERED LAPPED SEAMS

Fig 3 shows soldered joint on round shaped parts.

Fig 3



SOLDERED JOINTS ON ROUND SHAPED PARTS

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Correct joint design: Sheet metal joints with overlapping surfaces are ideal for joining or sealing with solder. Close fitting of lapped sufaces are essential for the flow of mobilized solder in into the joint by capillary action.

Joint design suitable for silver brazing or soldering mainly depends on the type of assembly and its intended use following conditions.

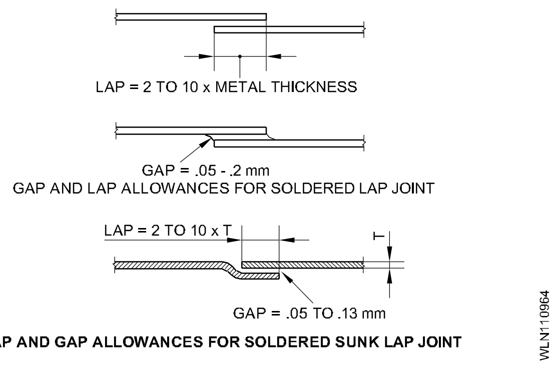
Maximum strength can be achieved by observing the following conditions.

- A suitable filler alloy must be used. Component metal is of major consideration.
- Joint clearances should be minimum. Close fitting surfaces helps capillary flow and gaps between 0.05 and 0.13 mm should be used.
- The solder must contact lapped surface suficiently. Lap width is commonly made 2 to 10 times the component metal thickness. In case of unqual thickness, the lap size is based on the thinner materials.
- Workpieces must be firmly supported. It is essential to prevent the movement for the control of the solder application, alignment and accuracy of the componet assembly.

Sheet metal joints both lapped and folded, are suitable for silver soldering application as shown in fig 4.

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

Fig 4

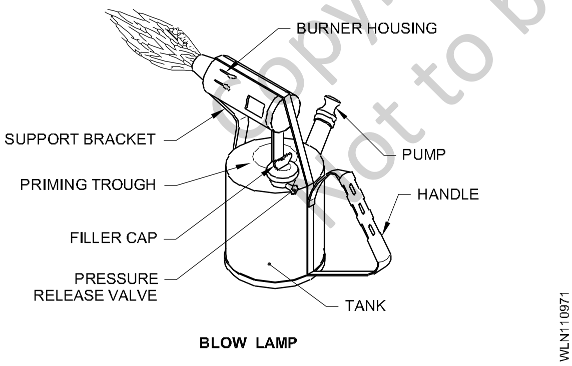


Blow lamp

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

In blow lamp (Fig 1) the kerosene is pressurized to pass through pre-heated tubes, thus becoming vaporised. The kerosene vapour continues through a jet to mix with a air and when ignited directed through a nozzle, producing a forceful flame.

Fig 1



BLOW LAMP

The flame within the housing provides the heat to maintain vaporisation of the kerosene. The free flame at the nozzle outlet is used to heat the soldering bit.

Blow lamp is a portable heating appliance used as a direct source of heat for soldering irons or other parts to be soldered. Fig 1 shows parts of blow lamp.

It has an tank made of brass, filler cap is fitted at its top to fill kerosene. A pressure relief valve is connected to the tank to switch ON/OFF and control the flame.

Priming trough is provided for filling methylated spirit for lighting the blow lamp. Set of nozzle is provided to direct the kerosene vapour to produce forceful flame. Burner housing is mounted on support brackets on which soldering iron is placed for heating as shown in figure.

Pump is provided to pressurise the kerosene in the tank.

Factors considered while soldering

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

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

Before soldering the following conditions must be met.

1 The metal must be clean.

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

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

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

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

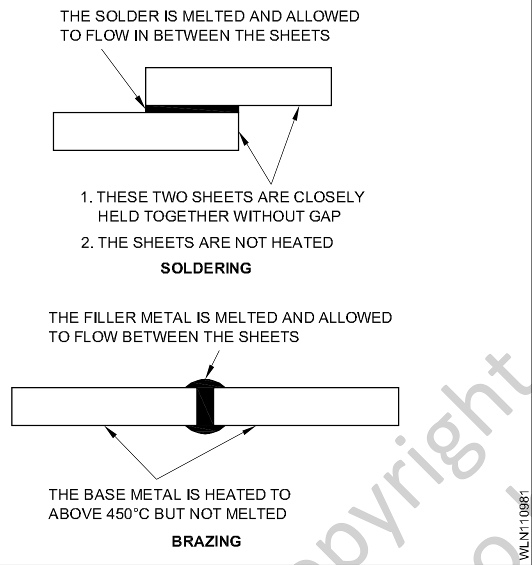
A bright metal, such as coper, can be coated with oxide even though you cannot see it. This oxide can be removed with any fine abrasive.

Soft soldering, brazing and silver brazing

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

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

Fig 1



Soft soldering: The filler metals used in soldering have a melting point below **427°C**

The alloys used for soft soldering are:

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

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

Composition of soft solder

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

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

TYPES OF FLUXES

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

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

Suitable fluxes for various materials

Steel - zinc chloride

Zinc and galvanized iron - hydrochloric acid

Tin - Zinc chloride

Lead - tallow resin

Brass, copper, brass - Zinc chloride, resin.

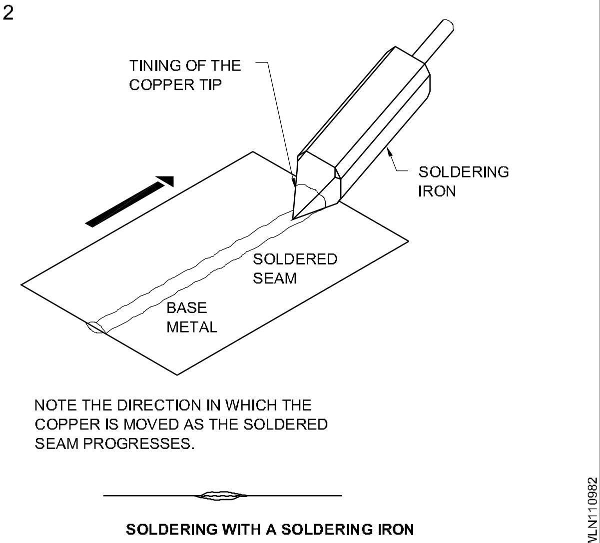
Basic operations in soldering

The parts to be soldered are fitted closely.

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

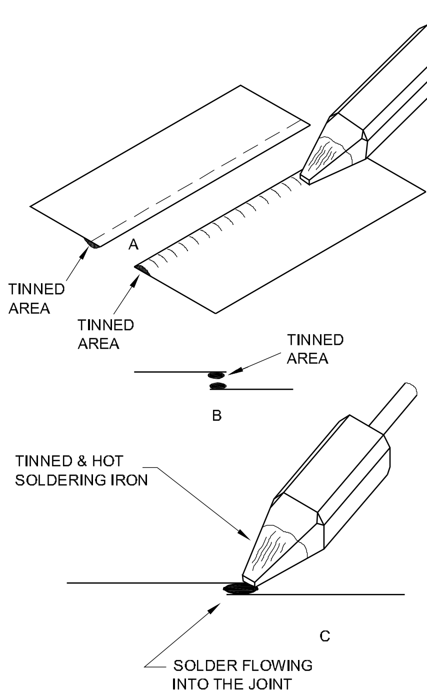
The surfaces to be soldered are coated with flux to remove the films of oxide. (Fig 2)

Fig 2



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

Fig 3



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

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

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

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

- Clean the area of the joint thoroughly by wire brushing, emerying 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.

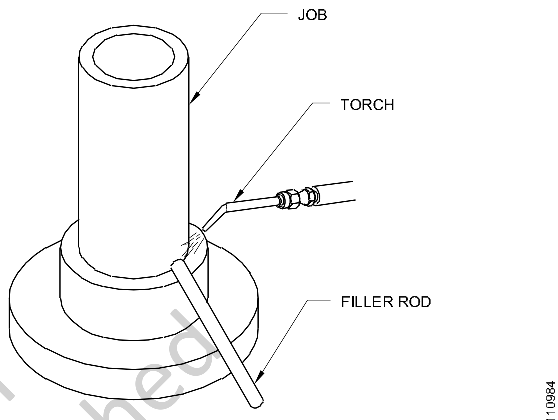
It is applied on the joint in the form of a paste made by mixing up with water.

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 berrylium.

VARIOUS METHODS OF BRAZING

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

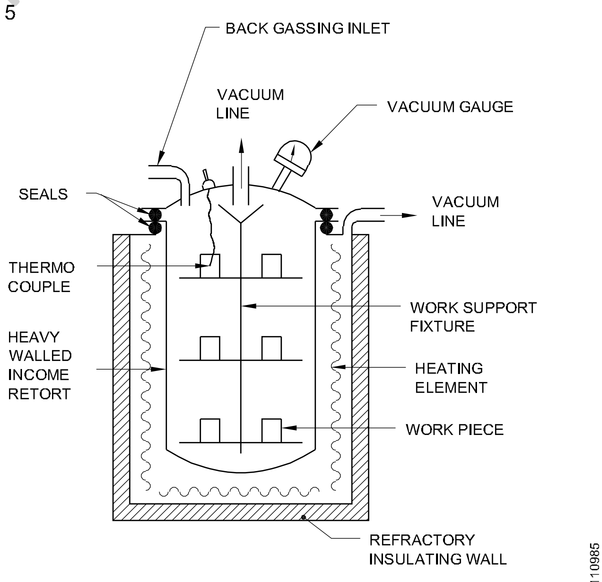
Fig 4



TORCH BRAZING

Furnace brazing: The parts to be brazed are aligned with the brazing material placed in the joint. The assembly is kept in the furnace. The temperature is controlled to provide uniform heating. (Fig 5)

Fig 5

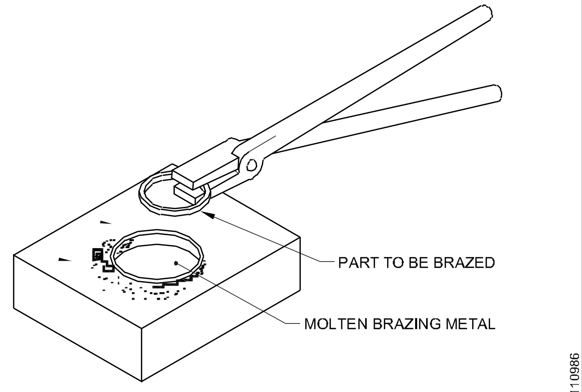


VACUUM FURNACE FOR BRAZING

Dip brazing: The parts to be brazd are submerged in a molten metal or chemical bath (Fig 6) of brazing filler metal.

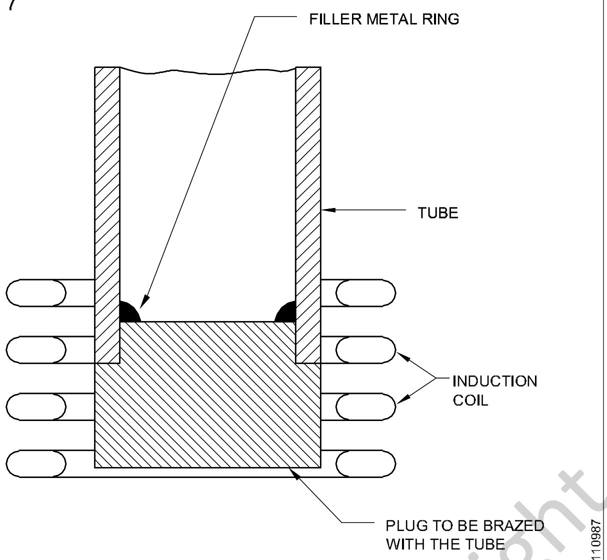
Induction brazing: The parts to be brazed are heated to the melting point of the brazing material by means of a high frequency electric current. This is done by encircling the joint with a water cooled iduction coil (Fig 7).

Fig 6



DIP BRAZING PROCESS

Fig 7



INDUCTION BRAZING

Conditions to obtain satisfactory brazed or soldered joint

Wet the base metal.

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

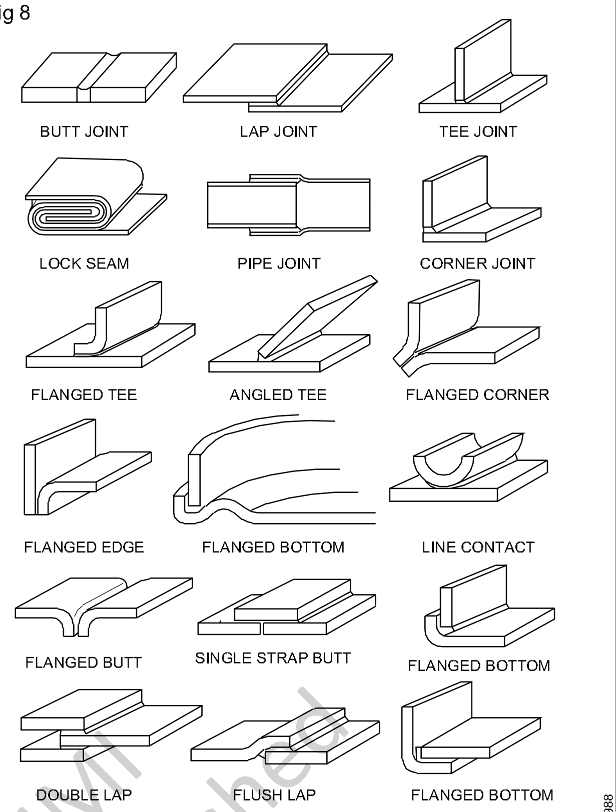
Suggested joint designs for soldering and brazing are shown in Fig 8

Advantages of brazing

The completed joint requires little or no finishing.

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

Fig 8



SUGGESTED JOINT DESIGNS FOR SOLDERED AND BRAZED JOINTS

There is no flash or weld spatter.

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

The process can be easily mechanised.

The process is economical owing to the above advantages.

Disadvantages of brazing

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

All the brazing alloys loose strength at an elevated temperature

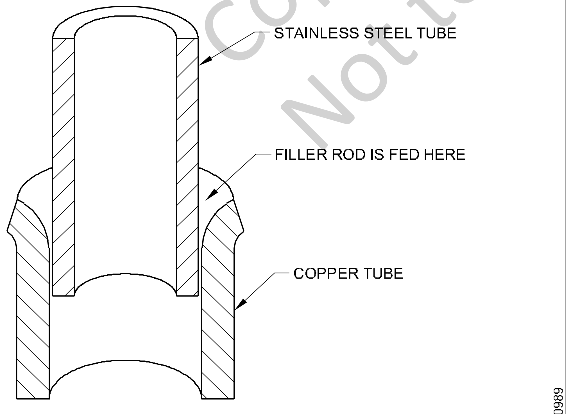
The colour of the brazing alloy which ranges from silver white to copper red may not match the base metal very closely.

Brazing: Problems and remedies

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

Silver brazing: Silver brazing is also sometimes called silver soldering. It is one of the best methods used to connect/join parts which are to be leak proof and has to give maximum strength of the joint. It is a very useful and easy process for joining copper brass, bronze parts as well as for joining dissimilar metal tubes like copper to stainless steel tubes etc. The melting point of silver brazing alloy filler rods will be around 600 to 800°C which is always less than that of the base metals joined. Fig. 1 shows silver brazing of stainless steel tube to be with a copper tube.

Fig 9



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 techique. 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 temperture.

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

Clean the joint throughly to remove all residual flux.

Fluxes used fo 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 soceity 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 liquidus 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 liquidus 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, jewellers, 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 jewellery 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 chiefy 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 leaproof joints are desired. Brazing and braze welding are superior to welding in some applications, since they do not affect the heat treatment of the original metals as much as welding.

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

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

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

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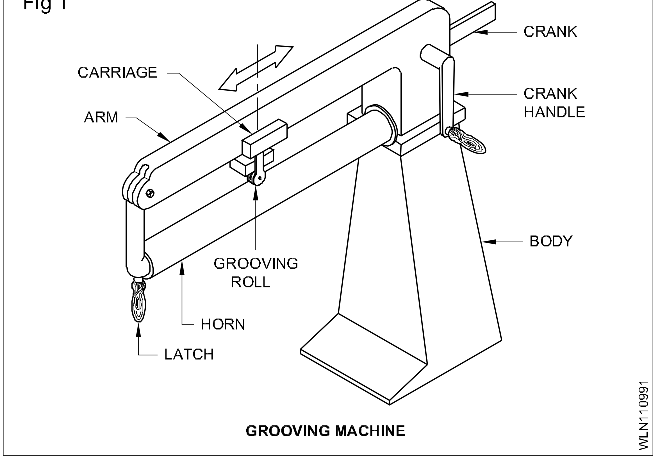
Seaming and Machine

Objectives: At the end of this lesson you shall be able to
- **explain the construction of the seam closing machine**
- **identify the parts of the seam closing machine**
- **state the uses of the seam closing machine.**

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

Parts shown in fig 1 are Body, Arm, Hom, Pressure roller, carriage, Crank handle, Latch and Crank rack.

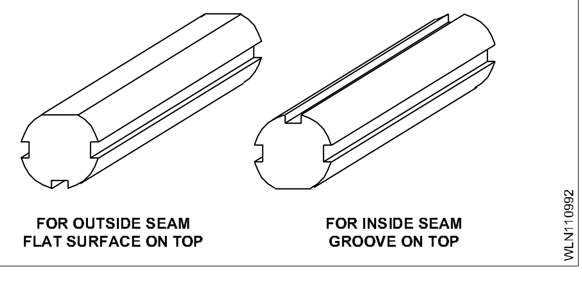
Fig 1



GROOVING MACHINE

Horn: It contains grooves of various widths on throughout the length as shown in Fig 2.

Fig 2



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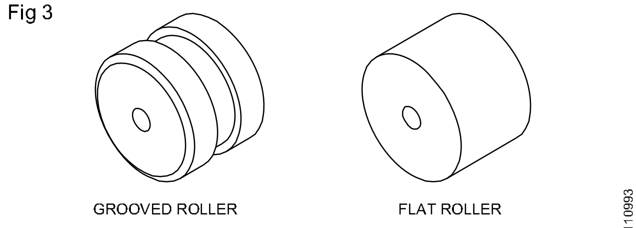
Pressure roller: Two types of pressure rollers are available alongwith the machine. One is flat roller and the other is grooved one, Grooved roller is having grooves of 3 mm, 4 mm, 5 mm and 6 mm widths as shown in Fig 3.

Fig 3

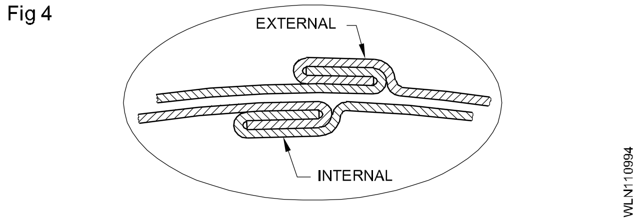


PRESSURE ROLLERS

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

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

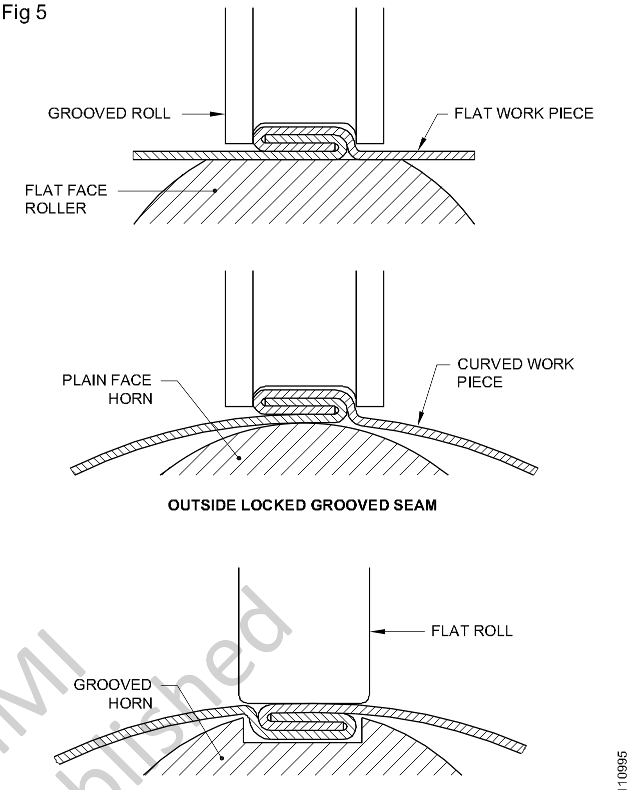
Fig 4



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

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

Fig 5



Basic Welding Joints and Nomenclature of butt and fillet weld

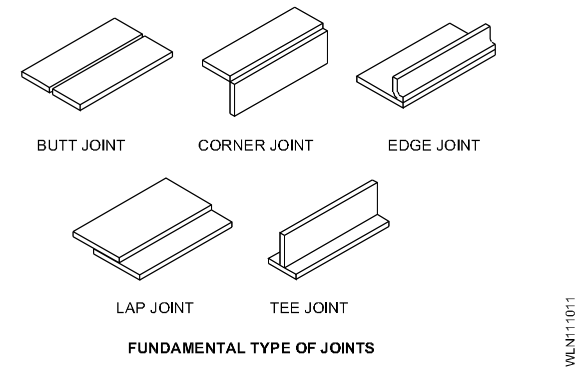
Objectives: At the end of this lesson you shall be able to
- **illustrate and name the basic welding joints.**
- **explain the nomenclature of butt and fillet welds.**

Basic welding joints (Fig. 1)

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

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

Fig 1

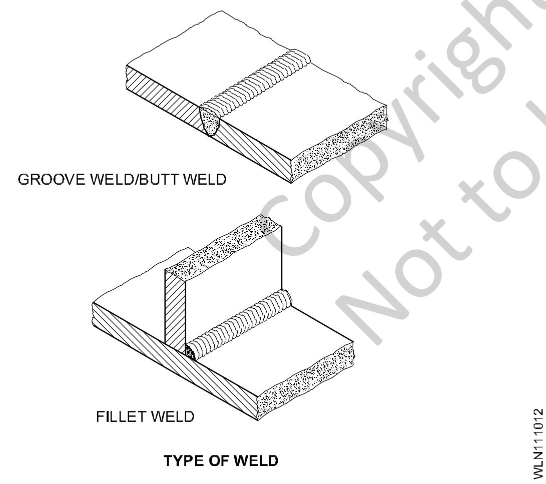


FUNDAMENTAL TYPE OF JOINTS

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

- Groove weld/butt weld
- Fillet weld

Fig 2



TYPE OF WELD

- Application of welding joints to the included

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

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

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

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

Fig 3

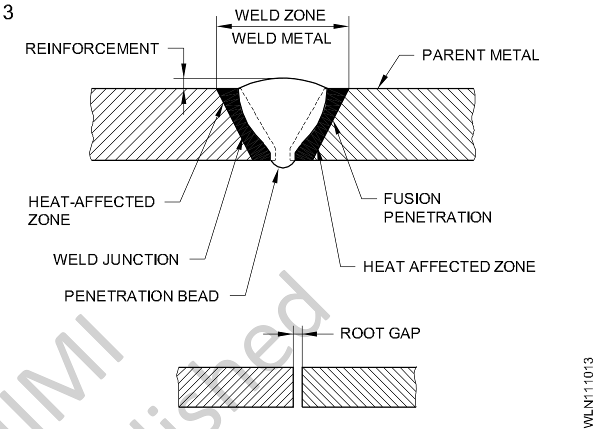
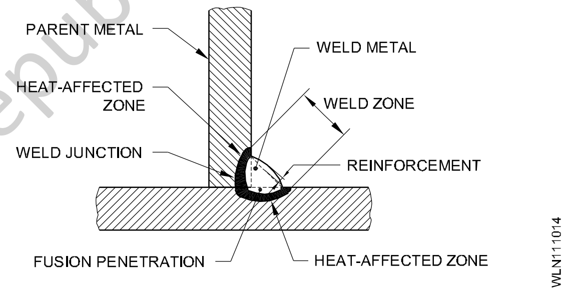


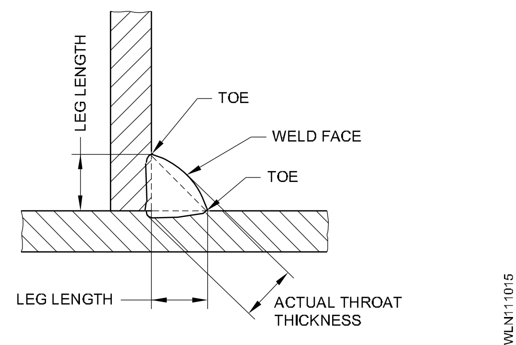
Fig 4



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

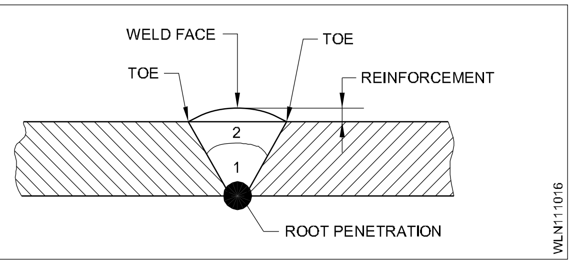
Fusion penetration: The depth of fusion Zone in the parent metal. (Fig.3 and 4)

Fig 5



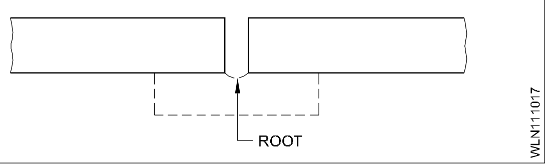
Reinforcement: Metal deposited on the surface of the parent metal of the excess metal over the line joining the two toes. (Fig6)

Fig 6



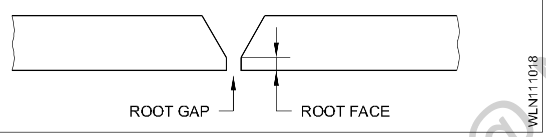
Root: The parts to be joined that are nearest together. (Fig 7)

Fig 7



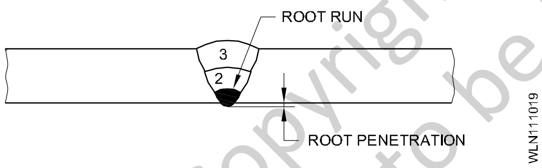
Root face: The surface formed by squaring off the root edge of the fusion face to avoid a sharp edge at the root. (Fig 8)

Fig 8



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

Fig 9



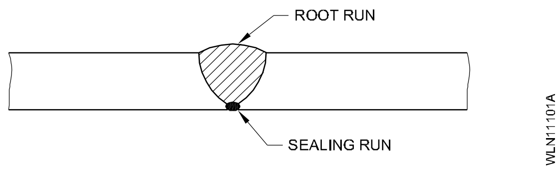
Root penetration: It is the projection of the root run at the bottom of the joint (Fig. 6 and 9)

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

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

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

Fig 10



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

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

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

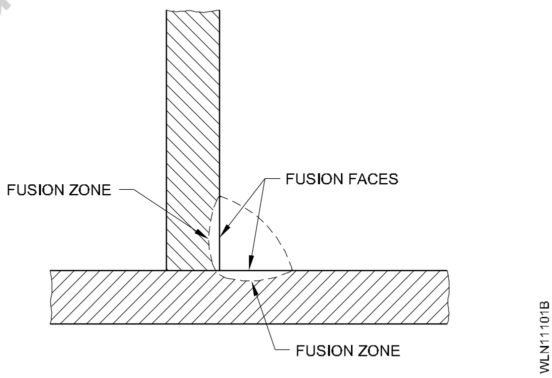
weld face: The surface of a weld seen from the side from which the weld was made. (Fig 5&6.)

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

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

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

Fig 11



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Material preparation method

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

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

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

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

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

Different methods used to cut metals

1 By chiseling the sheets

2 By hacksawing

3 By shearing using hand lever shear

4 By using guillotine shear

5 By gas cutting

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

Tools and equipments used to cut metals

1 Cold chisel

2 Hacksaw with frame

3 Hand lever shear

4 Guillotine shear

5 Oxy-acetylene cutting torch

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

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Edge preparation

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

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

- The welding process like SMAW, oxy-acetylene welds, Co_2, eletro-slag etc.
- The type of metal to be joined, (i.e) mild steel, stainless steel, aluminium, cast iron etc.
- The thickness of metal to be joined.
- The type of weld (groove and fillet weld)
- Economic factors

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

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

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

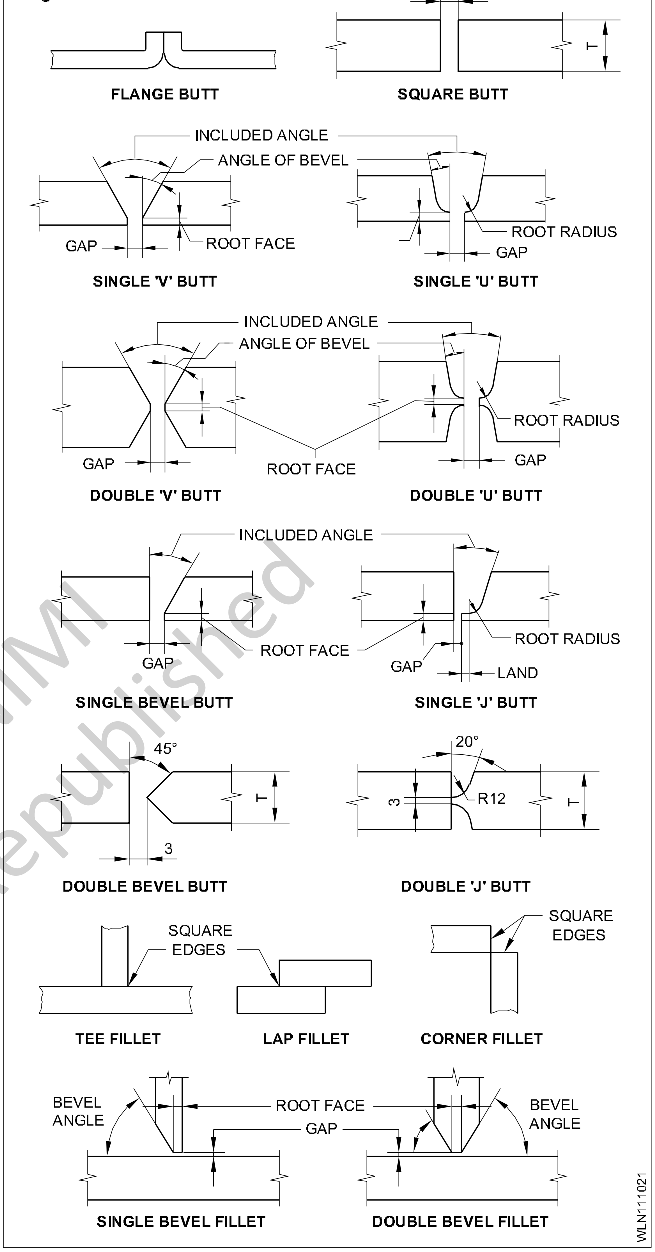
Method of edge preparation: The joining edges may be prepared for welding by any one of the methods mentioned below.

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

TYPES OF EDGE PREPARATION AND SETUP

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

Fig 1



Methods of cleaning the base metals before welding

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

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

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

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

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

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

Fig 1

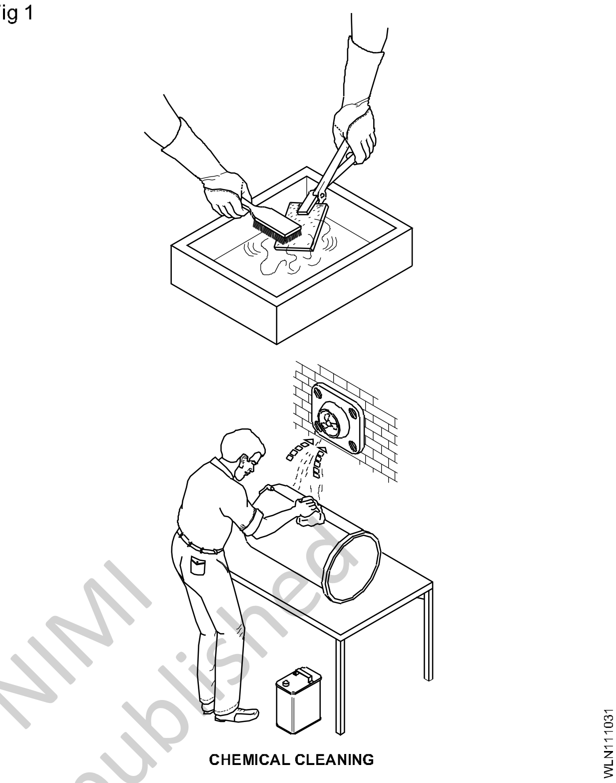
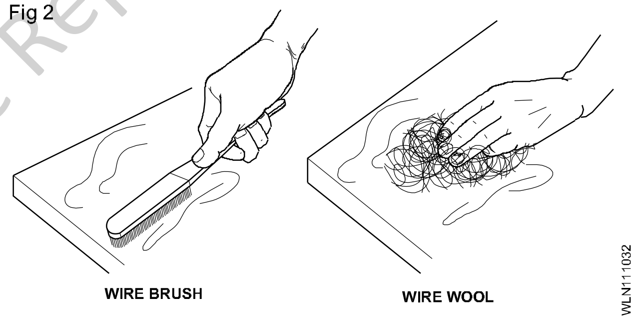


Fig 2



Basic electricity as applied to welding

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

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

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

It is dangerous to play with electricity.

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

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

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

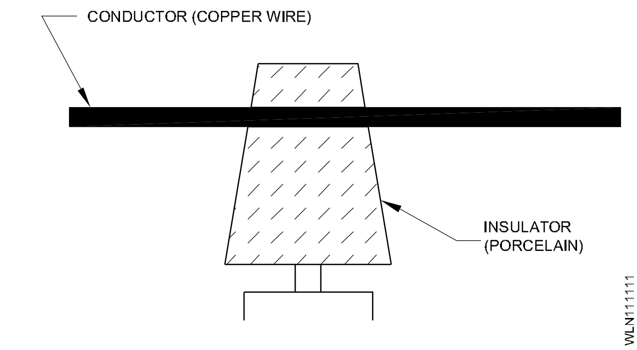
Electric resistance; It is the property of a substance to oppose the flow of electric current passing through it.

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

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

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

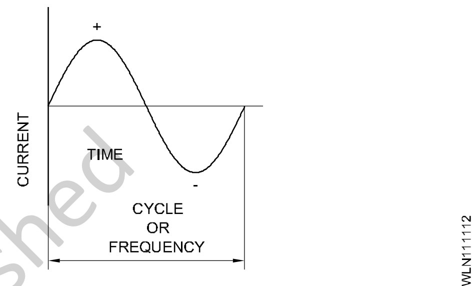
Fig 1



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

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

Fig 2



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

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

The fundamental types of cricuit are:

- series circuit
- parallel circuit.

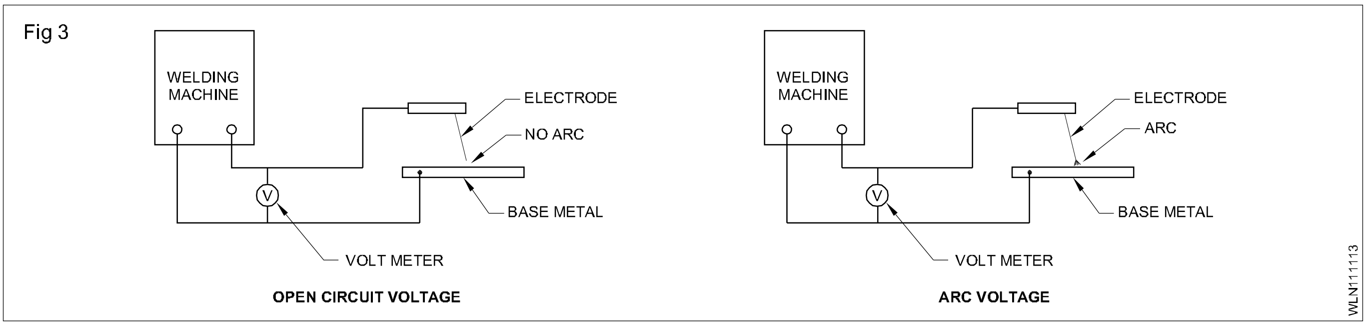
Series circuit: The resistances of a circuit are cnnected in a series end-to-end making only one path in which the current flows.

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

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

Direct current (DC) (Fig. 4): Electric current which always flows in a particular direction is known as direct current.

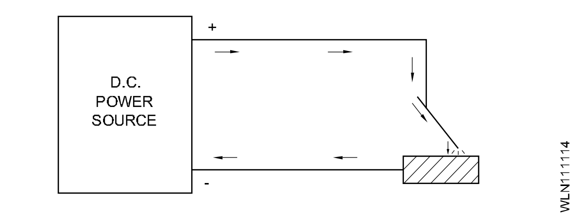
Fig 3



(I.e) Negative to positive (electronic direction). Positive to negative (conventional dirction).

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

Fig 4



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

The law states:

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

V=IR

Where V = Voltage

I = Current

R = Resistance

Current decreases when resistance increases.

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

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

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

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

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

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

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

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

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

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

- creating a high temperature (4500°C) arc between the electrode and the work using electric voltage and high current. (All types of arc welding)

- heating the work to red hot condition by using the resistance property of the metal and passig a very high current for a fraction of a second and then applying a very heavy pressure. (All types of resistance welding)

- using highly concentrated electron beam on the joint of the workpiece (Electron beam welding)

- Using the resistance of the slag and the current to flow through the molten slag (Electroslag welding)

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

Heat and temperature

Objectives : At the end of this lesson you shall be able to
- **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 and vice versa, using tables.**

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

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

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

- Centigrade scale
- Fahrenheit scale

In both systems there are two fixed points which indicate:

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

Temperature is measured by a unit called 'degree'.

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

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

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

Conversion of temperature from °C to °F

The formula used for temperature conversion is

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

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

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

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

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

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

Heat and temperature should not be confused with each other.

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

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

Example

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

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

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

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

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

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

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

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

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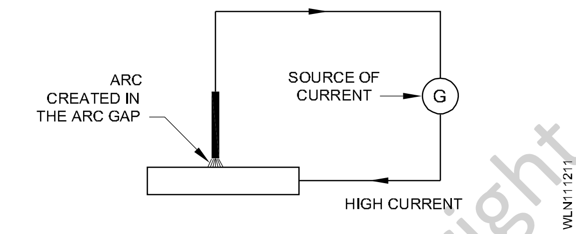
Principle of arc welding

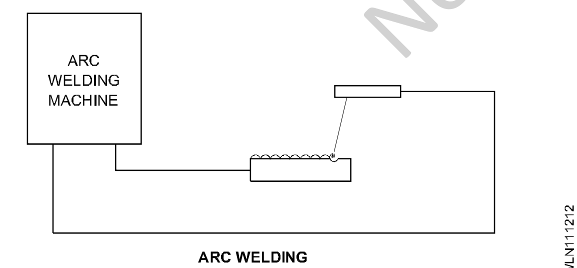
When high current passes through an air gap from one conductor to another, it produces very intense and concentrated heat in the form of a spark. The temperature of this spark (or arc) is app. 3600°C, which can melt and fuse the metal very quickly to produce a homogeneous weld. (Fig 1)

Fig 1



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

Fig 2

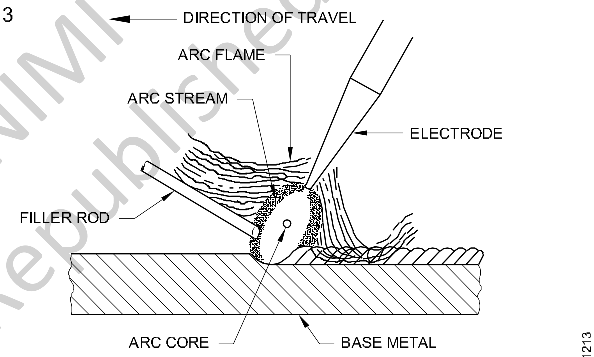


ARC WELDING

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

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

Fig 3



CARBON ARC WELDING

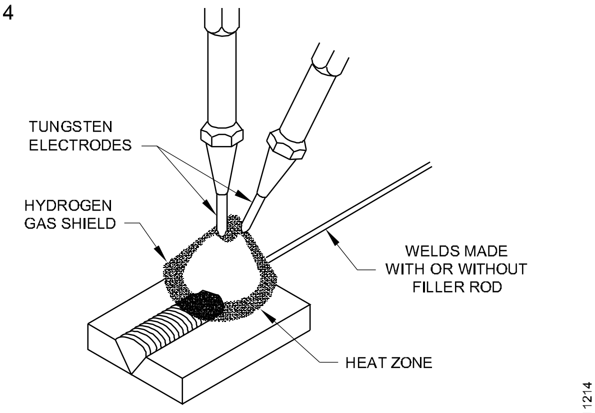
A separate filler rod is usd since the carbon electrode is a non-metal and will not melt.

Atomic hydrogen arc welding (Fig 4): In this process the arc is formed between two tungsten electrodes in an atmosphere of hydrogen gas.

the welding job remains out of the welding circuit.

A separate filler rod is used to add the filler metal.

Fig 4



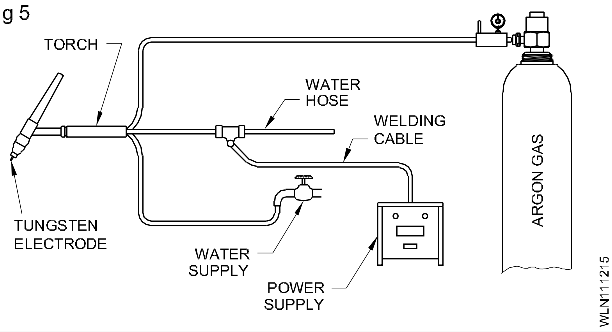
ATOMIC HYDROGEN WELDING PROCESS

Tungsten inert gas arc welding (TIG) (Fig 5): In this case the arc is formed between the tugsten electrodes (nonconsumable) and the welding job in an atmosphere of an inert gas (argon or helium).

A separate filler rod is used to add the filler metal.

This process is also called gas tungsten arc welding (GTAW) process.

Fig 5



Gas metal arc welding (GMAW) or Metal inert gas arc welding (MIG) (Fig 6): 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 is replaced by carbon dioxide then it is called CO_2 arc welding or metal active gas (MAG) arc welding.

The common name for this process is gas metal arc welding (GMAW).

Submerged arc welding (Fig 7): Here the 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 submerged in the flux (invisible).

Fig 6

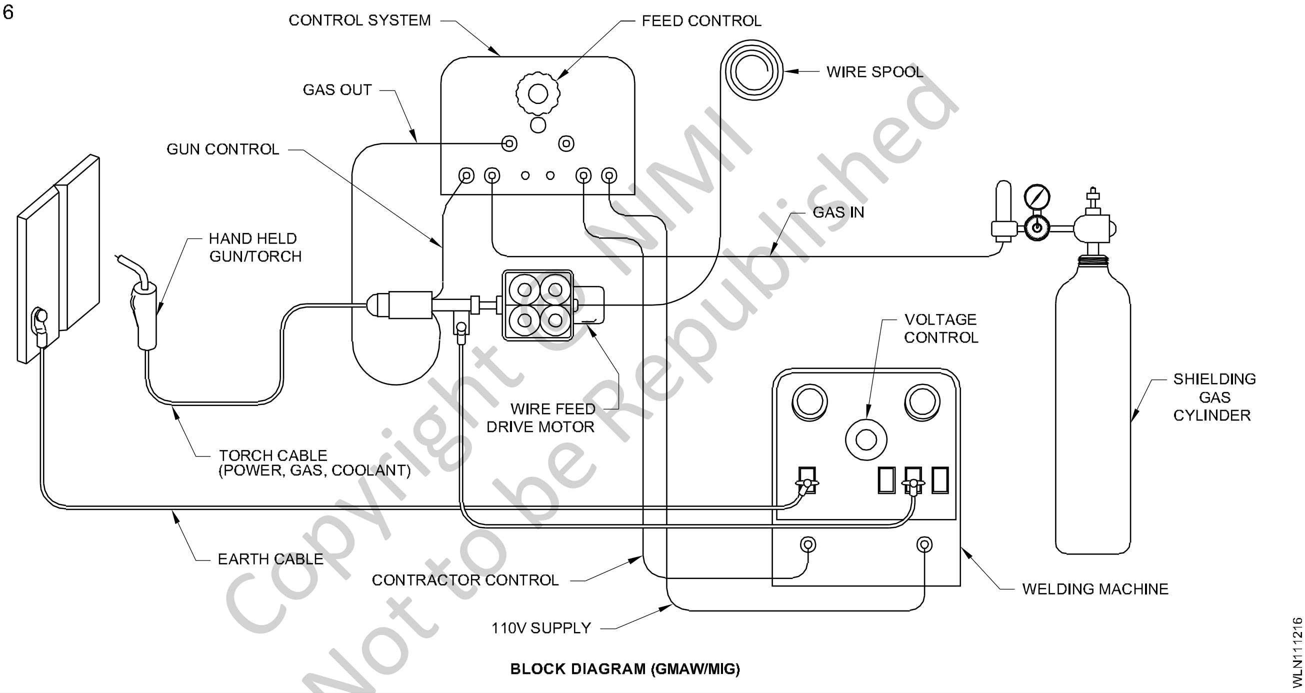
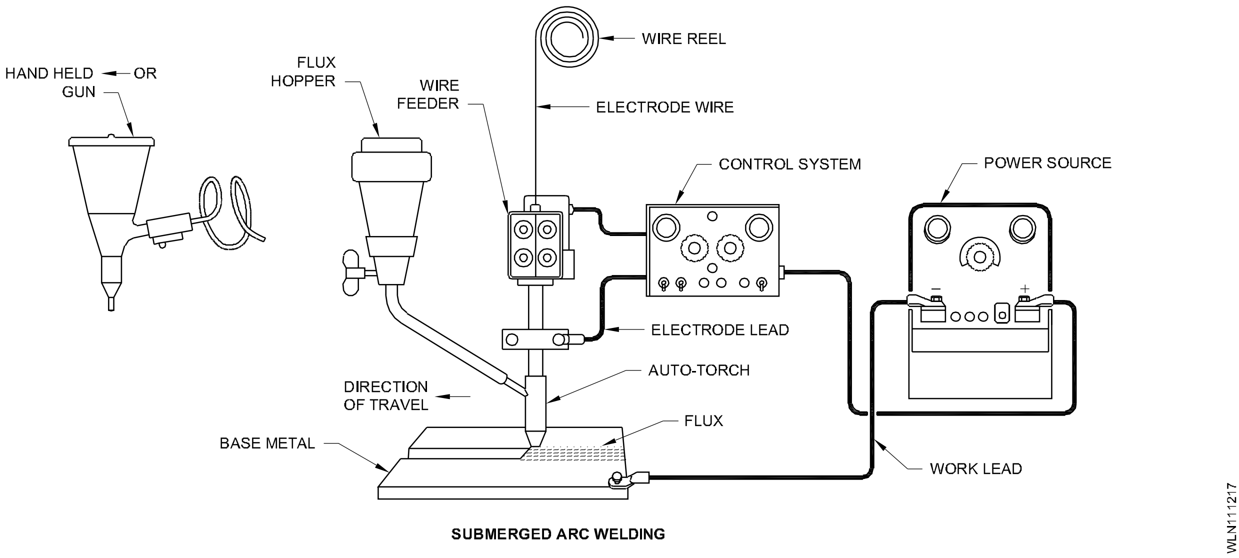


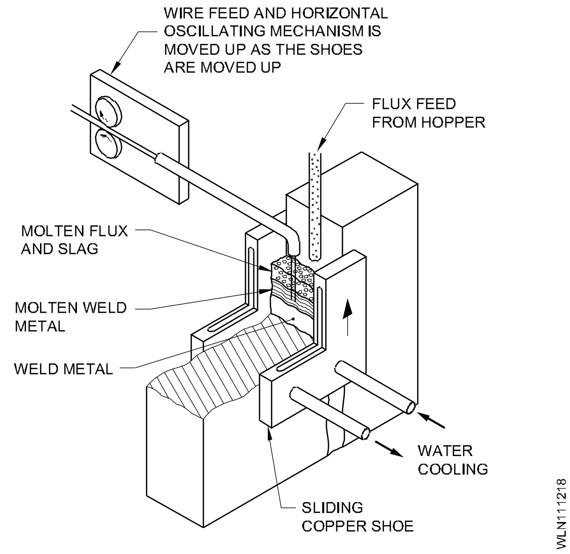
Fig 7



Electro-slag welding (Fig 8): The arc is fomed between a continuous, automatically fed, metalic consumable electrode and the welding job under a thick pool of molten flux (slag).

This automatic process requires special equipment and is used only in vertical position for the welding of heavy thick plates.

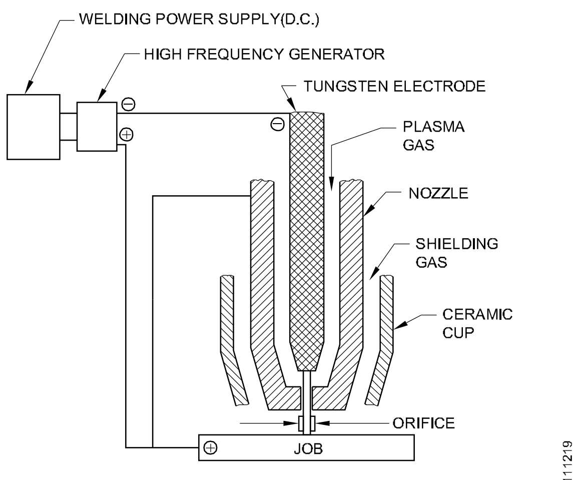
Fig 8



Plasma arc welding (Fig 9): In this process the arc is formed between a tungsten electrode and the welding job in an atmosphere of plasma-forming gas- nitrogen, hydrogen and argon.

A separate filler rod is used to add the filler metal in the joint, if necessary. But normally no filler rod is used.

Fig 9



PLASMA ARC WELDING SYSTEM

The process is similar to TIG welding.

Plasma cutting is used to cut non-ferrous metals and alloys successfully and quickly.

Gases used for welding and gas flame combinations

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

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

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

Comparison of different gas flame combinations and their uses

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

Chemistry of oxy-acetylene flame

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.**

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.

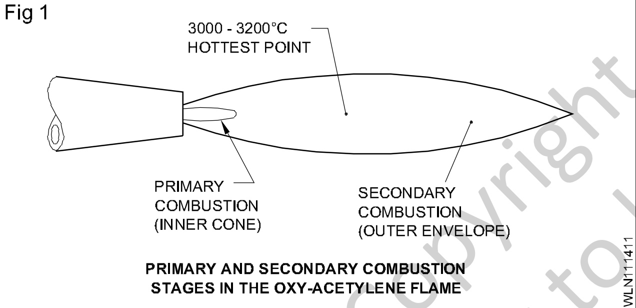
To know the characteristics and effects of oxy-acetylene flame a welder must know the chemistry of the flame.

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

- Inner cone
- inner reducing zone
- Outer zone or envelope (Fig 1)

Different zones and temperature: To know and make the best use of oxy-acetylene flame, the temperature in different zones is shown in Fig 1.

Fig 1



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 in flame

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

Acetyene	:	Oxygen + O
1 litre	:	2.5 litres

Equal volumes of acetylene and oxgen are supplied from the blowpipe to produce a neutral flame. (Fig 1)

Acetylene	:	Oxygen
1 litre	:	1 litre

(primary combustion)

So another 1.5 litres of oxgen is required for complete burning of acetylene.

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 carbon di-oxide and 1 volume of water vapour 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 H_2 have reducing effect (no oxides are forming) Maximum heat (Hottest point) is just in front of the inner cone.

One volume of oxgen 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

$2CO + O_2 \uparrow 2CO_2 +$ Heat

$2H_2\ + O2 \uparrow 2H\ _0O +$ 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 dioxde and 1 volume of water vapour.

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

The region surrounding the inner cone and its tip is called reducing zone

The reducing zone protects the molten metal from atmospheric effects as it uses the atmospheric oxygen for secondary combustion.

Types of oxy - acetylene flames

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

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

- it has a well controlled flame with high temperature

- the flame can be easily manipulated for proper melting of the base metal

- it does not change the chemical composition of the base metal /weld.

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

- Neutral flame

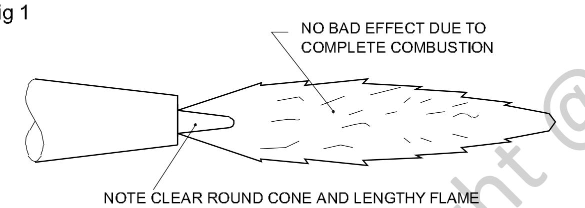
- Oxidising flame

- Carburising flame.

CHARACTERISTICS AND USES

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

Fig 1



NEUTRAL FLAME (EQUAL QUANTITIES OF OXYGEN AND ACETYLENE)

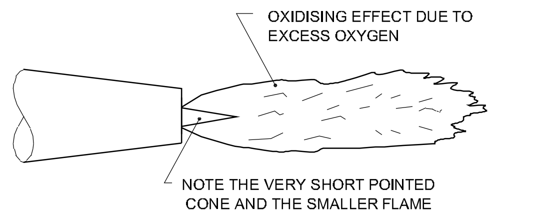
Complete combustion takes place in this flame.

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

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

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

Fig 2



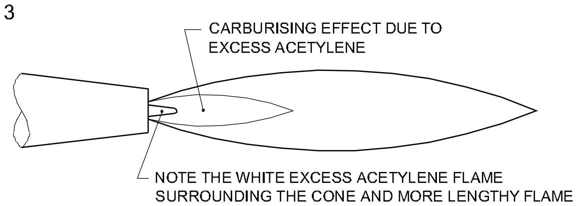
OXIDISING FLAME (EXCESS OXYGEN)

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

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

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

Fig 3



CARBURISING FLAME (EXCESS ACETYLENE)

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

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

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

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

Principle of gas cutting and application

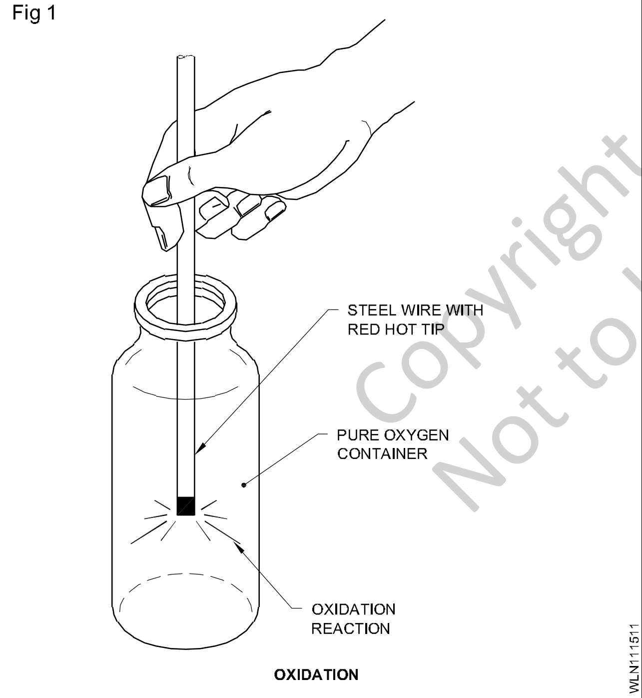
Objectives : At the end of this lesson you shall be able to
- **explain the principle of gas cutting**
- **describe the cutting operation and its application.**

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

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

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

Fig 1



When a piece of wire with a red hot tip is placed in a container of pure oxygen, it bursts in to flame immediately and is completely consumed. Fig 1 illustrates this reaction. Similarly in oxy-acetylene cutting the combination of red hot metal and pure oxygen causes rapid burning and iron is changed into iron oxide (oxidation).

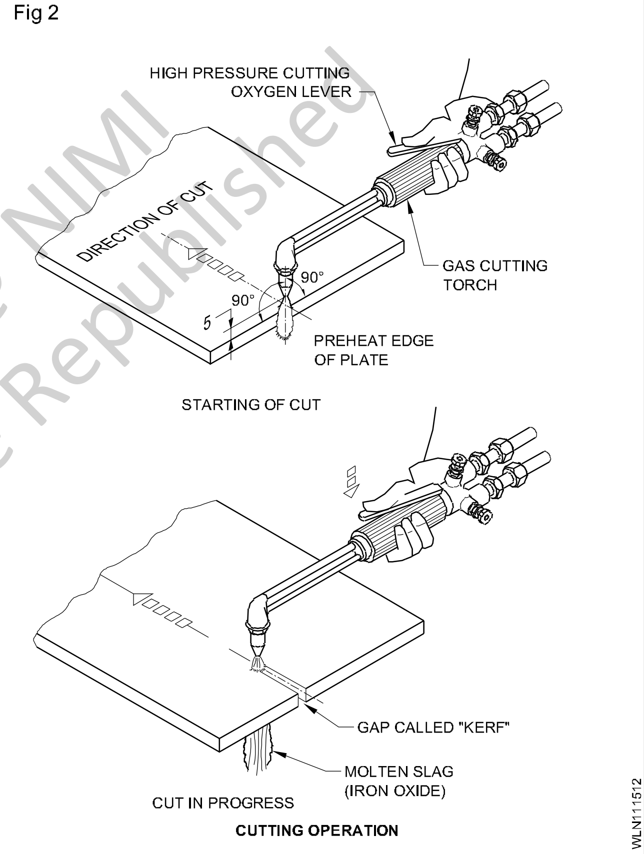
BY this continuous process of oxidation the metal can be cut through very rapidly.

The iron oxide is less in weight than base metal.

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

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

Fig 2



The two operations are done simultaneously with a single torch.

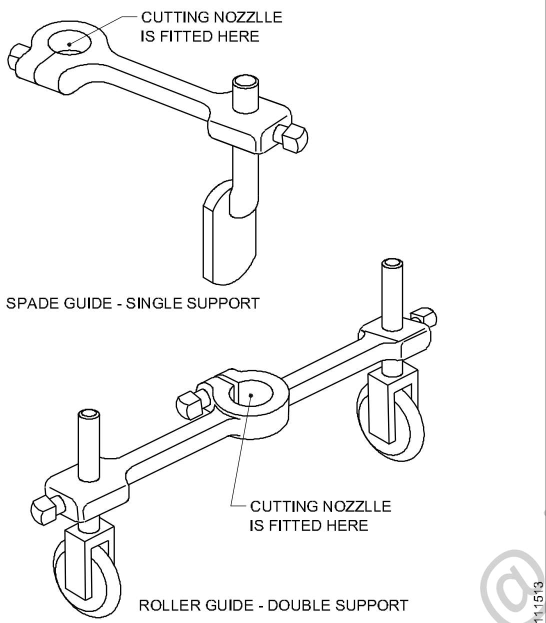
The torch is moved at a proper travel speed to produce a smooth cut. The removal of oxide particles from the line of cut is automatic by means of the force of oxygen jet during the progress of cut.

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

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

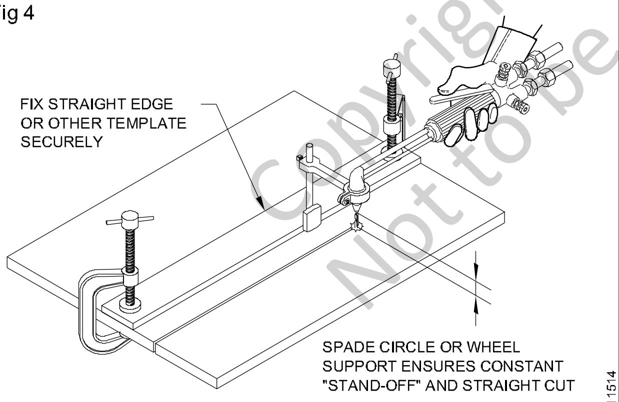
Fig.3 to Fig.7 Shows the guides used to cut straight lines, bevel and small circles.

Fig 3



GUIDES

Fig 4

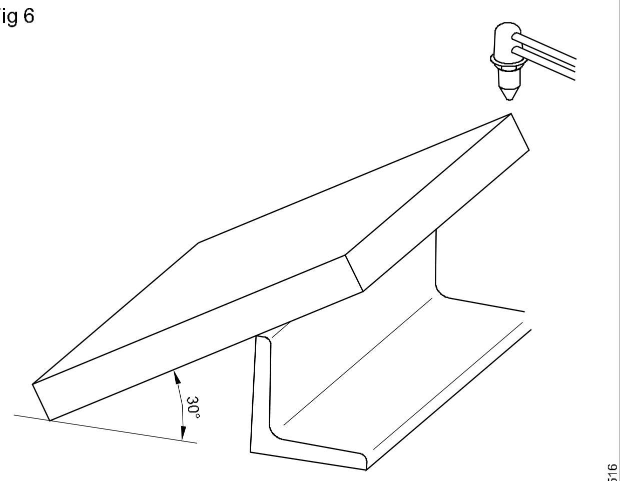


CUTTING WITH STRAIGHT EDGE AND SINGLE SUPPORT

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

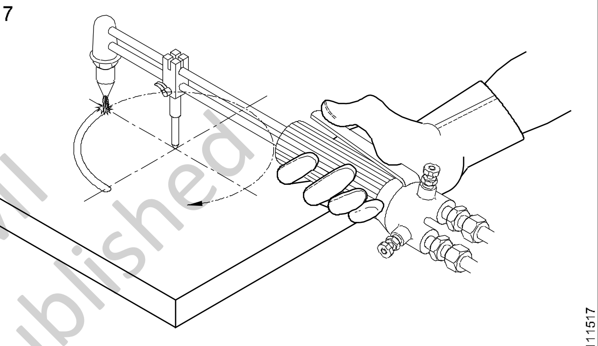
They can be either a roller guide, double support or spade guide with single support.

Fig 6



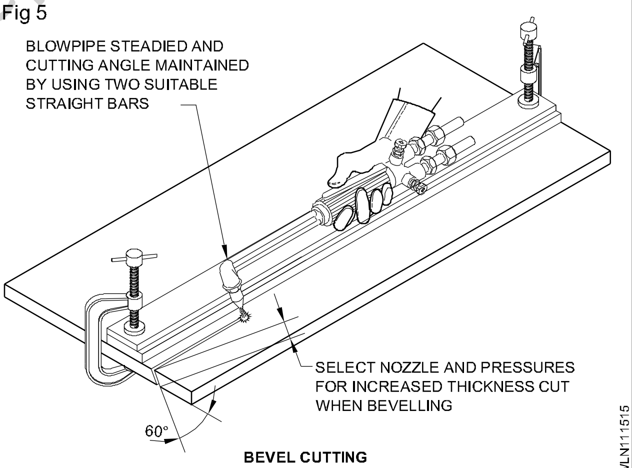
ALTERNATIVE METHOD OF CUTTING
BEVELLED EDGE ON INCLINE

Fig 7



SMALL CIRCLE CUTTING

Fig 5



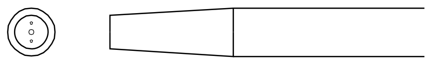
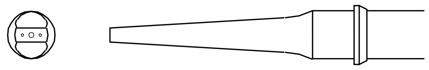
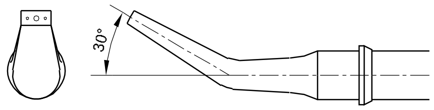
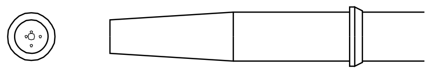
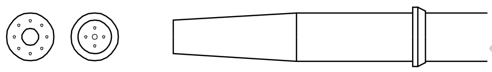
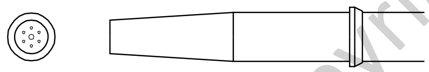
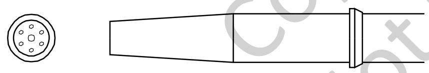
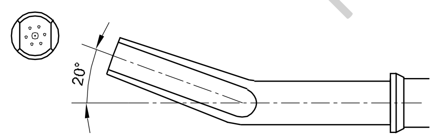
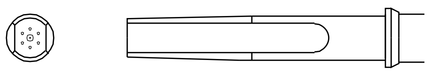
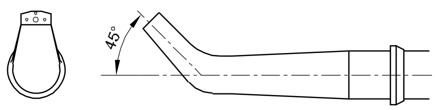
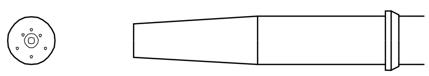
BEVEL CUTTING

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

Oxy-acetylene hand cutting - piercing hole and profile cutting

Objectives : At the end of this lesson you shall be able to
- **explain the special types of nozzles for gas cutting and their application**
- **describe the parts of a cutting equipment and their functions**
- **explain trouble shooting and the remedy of the faults in oxygen cutting.**

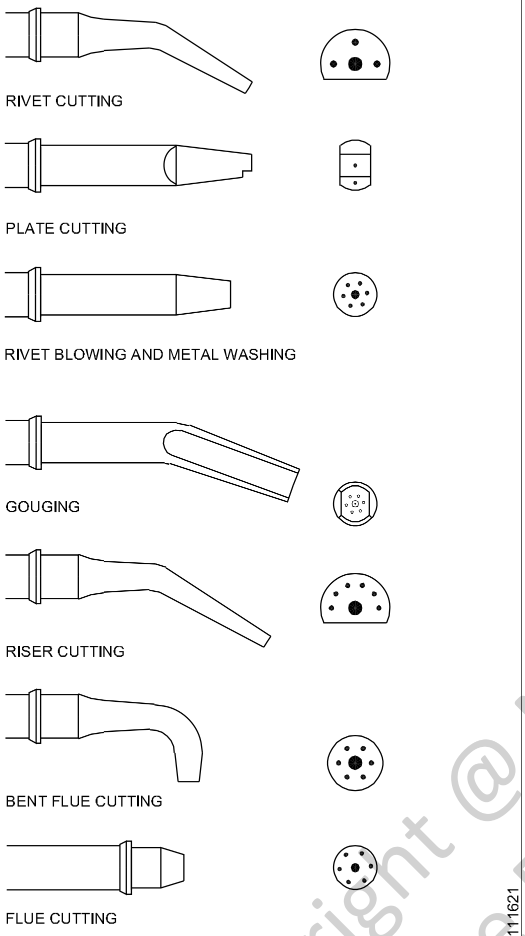
Table of some common cutting torch tips and their uses

Number of preheat orfices in cutting torch tips	Degree of preheating	Aplication
 2	Medium	For straight line or circular cutting of clean plates.
 2	Light	For splitting angle iron, trimming plates and sheet metal cutting.
 30° 2	Light	For hand cutting rivet heads and machine cutting 30 deg. bevels.
 4	Light	For Straight line and shape cutting clean plate.
 4,6,8	Medium	For rusty or painted surfaces.
 6	Heavy	For cast iron cutting and preparing vee for cast iron welding.
 6	Very heavy	For general cutting; also for cutting and stainless steel.
 20° 6	Medium	For grooving,flame machining, gouging and removing imperfect welds.
 6	Medium	For grooving,gouging or removing imperfect welds.
 45° 3	Medium	For machine cutting 45° deg. bevel or hand cutting rivet heads.
 6 WLN111611	Heavy	Flared cutting orifices provide a large oxygen stream of low velocity for rivet head removal (Washing).

Special purpose nozzle: For profile cutting. different types of nozzles are used for cutting metals in different shapes.

Nozzles used for cutting profiles are shown in fig 1.

Fig 1



SPECIAL TYPES OF NOZZLES USED FOR GAS CUTTING

Cutting torch: Fig.2 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 piecred.

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 2

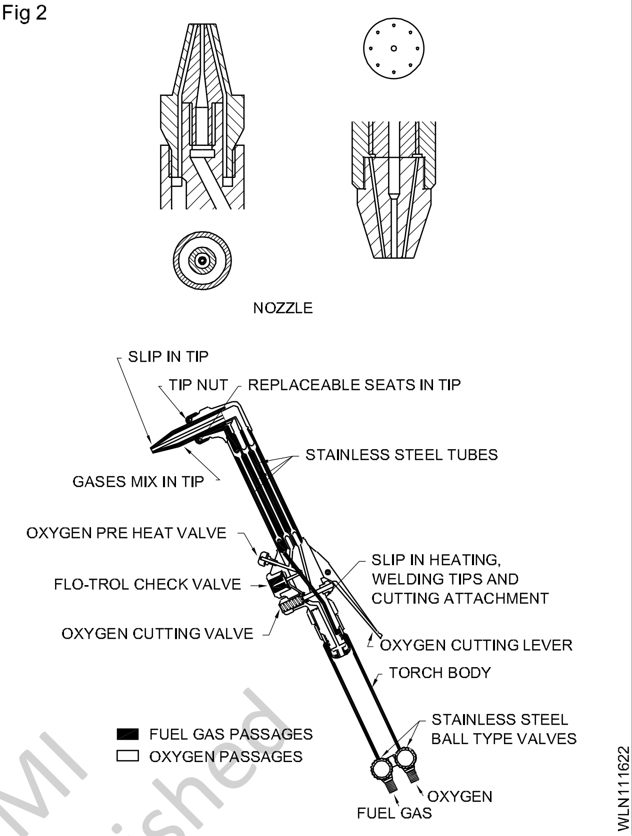
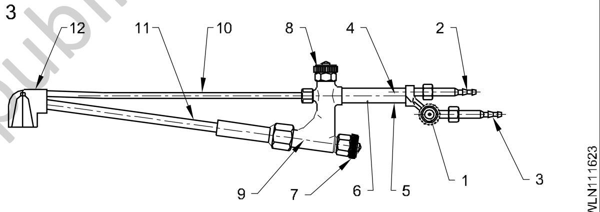


Fig 3



Names and function of the parts of a cutting torch (Fig 3 and Table 1)

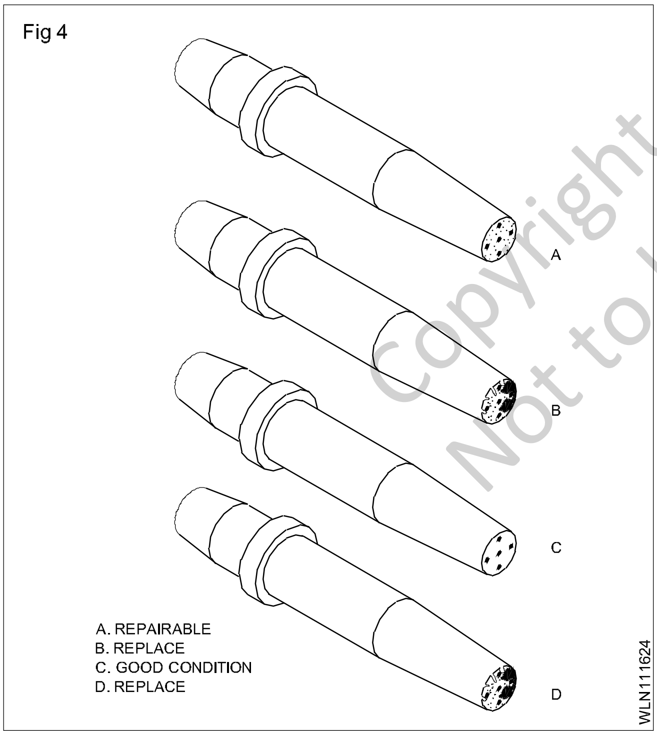
Table 1

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

Troubleshooting

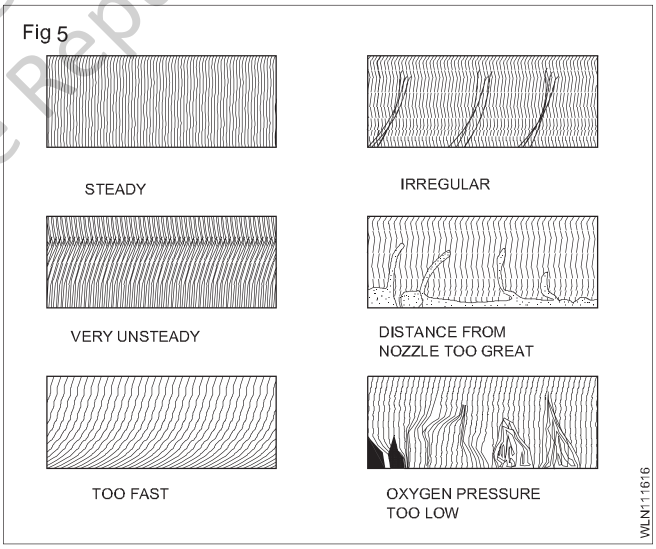
Object	Trouble	part to be	Method	Remedy	
		Hose joint	soap water or water	Tighten further or replace.	At the beginning of the work.
	Gas leakage	Valve & regulator	Soap water or water	Replace the torch.	At the beginning of the work.
Torch		Cutting tip attching part	soap water or water	Tighten further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

Care and maintenance: The cutting oxygen orifice should be cleaned at regular intervals by using different size wire of nozzle cleaner. (Fig 4)



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

This can be analysed as shown in the figure . (Fig 5)



Oxy-acetylene cutting equipment

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

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

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

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

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

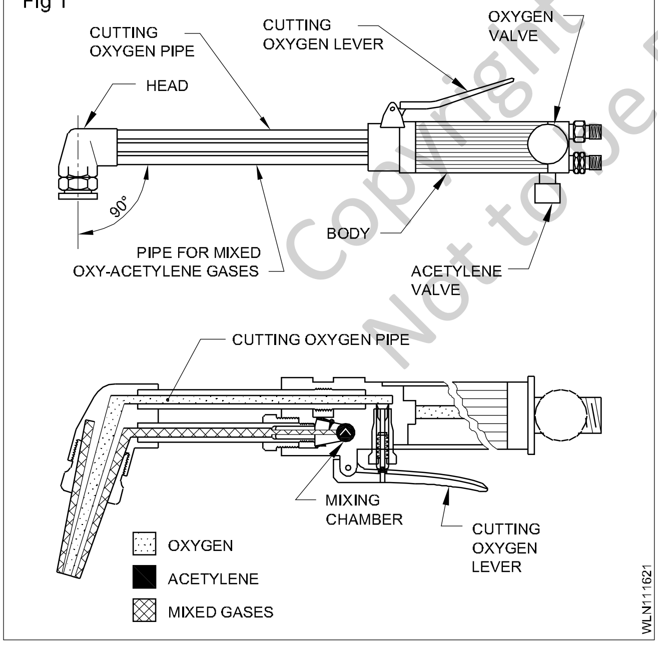


Fig 1

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

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

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

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

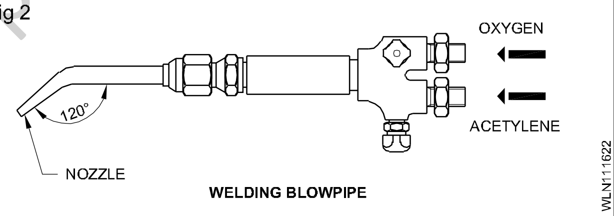


Fig 2

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

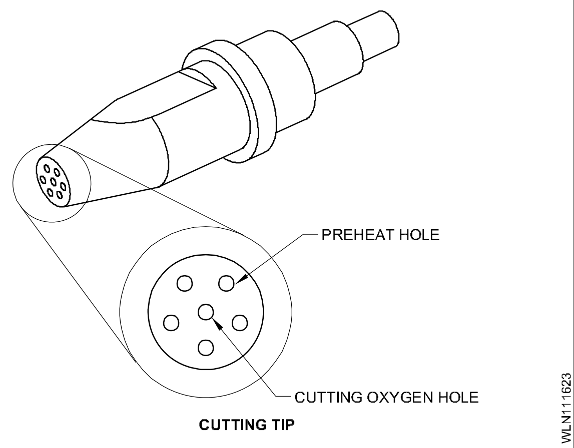
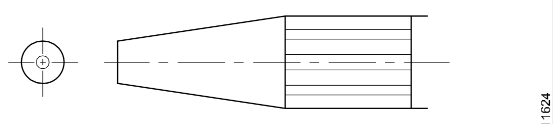


Fig 3

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

Fig 4



WELDING NOZZLE

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

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

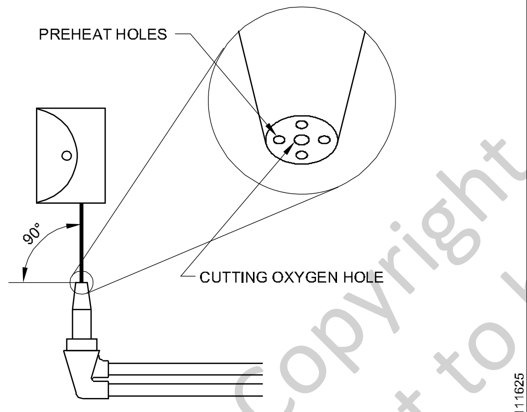
The cutting nozzle size is given by the diameter of the cutting oxygen orifice in mm.

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

Operating data for cutting mild steel

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

Fig 5



CLEANING THE HOLES OF CUTTING NOZZLE

However, the oxidation of metals has also certain useful effects, i.e a stream of pure oxygen if applied (used) on a red hot mild steel plate through a nozzle, the plate will get cut into 2 pieces. Hence the principle of oxidation is effectively used in gas cutting and gouging of mild steel.

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

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

To remove any slag particles of dirt from the nozzle orifice use the correct size nozzle cleaner Fig.5. Use an emery paper if the nozzle tip is damaged to make it sharp and to be at 90° with the nozzle axis.

Oxy-acetylene machine cutting

Objectives : At the end of this lesson you shall be able to
- **explain different types of gas cutting machines**
- **explain profile cutting using templates**
- **state gas cutting defects, their causes and remedies..**

There are two types of cutting machines.

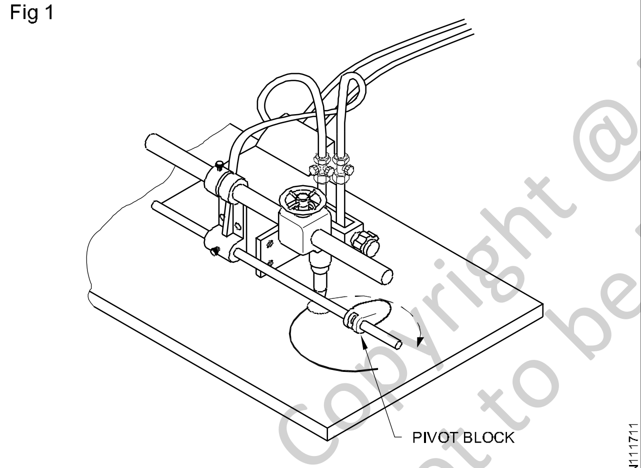
- Manually driven cutting machines
- Electrically driven cutting machines

Manually operated cutting machines

A manually driven cutting machine normally consists of:

- a crank or wheel to drive the cutter via a screw thread and this machine can be used for straight line cutting and bevel cutting
- a system of links or rods which are used with the machines and by which simple circles, ellipses, squares, etc. can also be cut. (Fig. 1)

Fig 1



SMALL CIRCLE CUTTING

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

Electrically driven cutting machines

There are two types of machines available.

Portable machines

Static machines

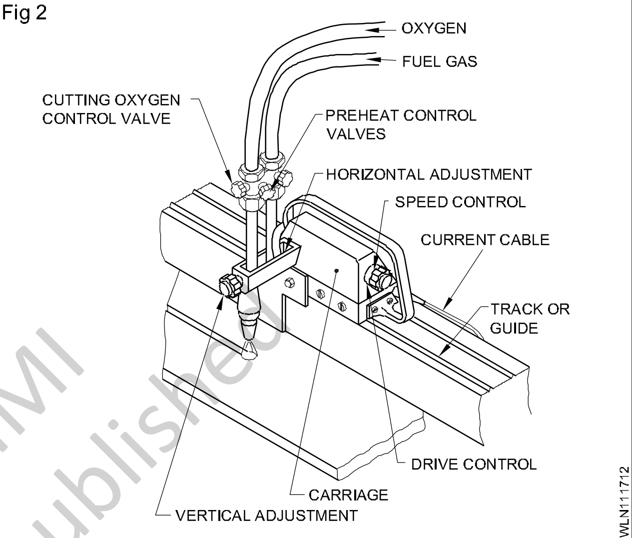
PORTABLE MACHINES

An electrically driven portable cutting machine generally consists of:

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

This machine can be used for straight line cutting, bevel cutting, circular cutting and profile cutting. (Fig 2)

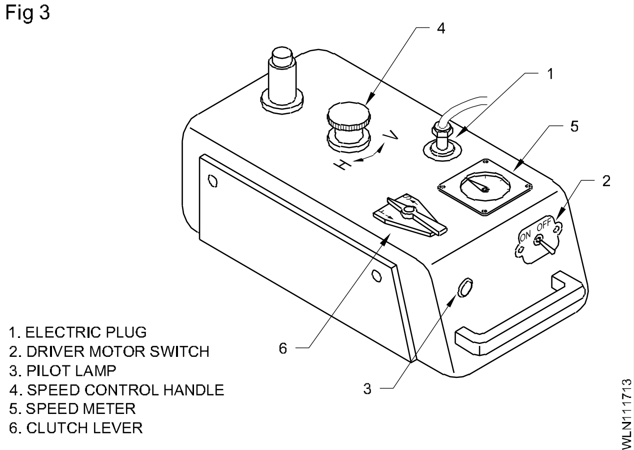
Fig 2



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

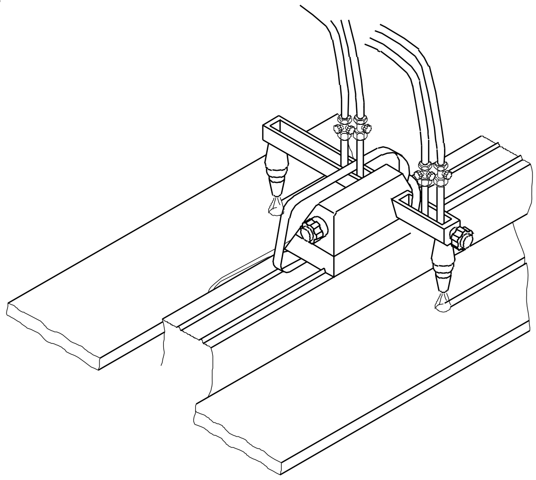
The electrical control unit fitted to the carriage is shown in Fig.3.

Fig 3



The speed of an electrically driven machine, when it, is constant, and normally it is able to produce better cuts than a manually driven machine. The speed range of an electrically driven machine is greater than that of the manual type and the adjustment of speed helps to control more accurately. Multiple cutting heads can be mounted to increase the volume of cutting, these cutting heads may be mounted on an adjustable bar extending to either side of the track at 90° to the direction of travel. (Fig 4)

Fig 4



PORTABLE MACHINE WITH MULTIPLE CUTTING HEADS

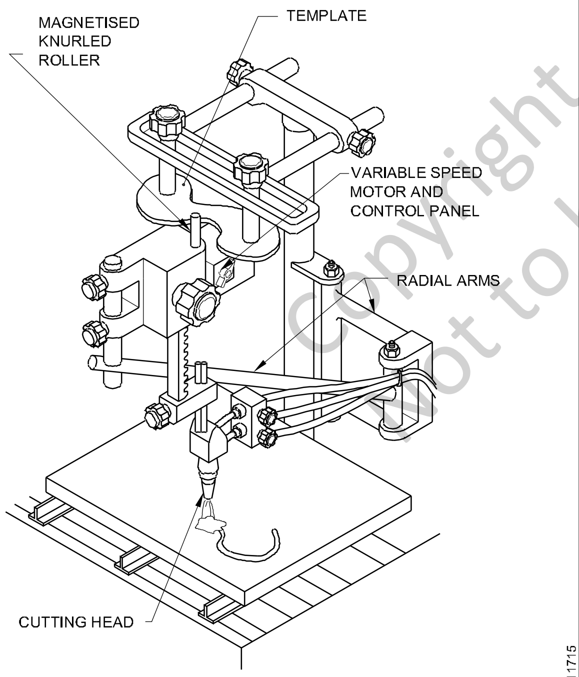
WLN111714

STATIC MACHINES

These machines are generally used to produce more accurate work than what is possible with manually operated or portable cutters.

These machines can be used with radial arm and cross-carriage arrangements. In general the work is required to be brought to the machine. With this machine straight line cutting, circle and profile cutting can be done. (Fig 5)

Fig 5



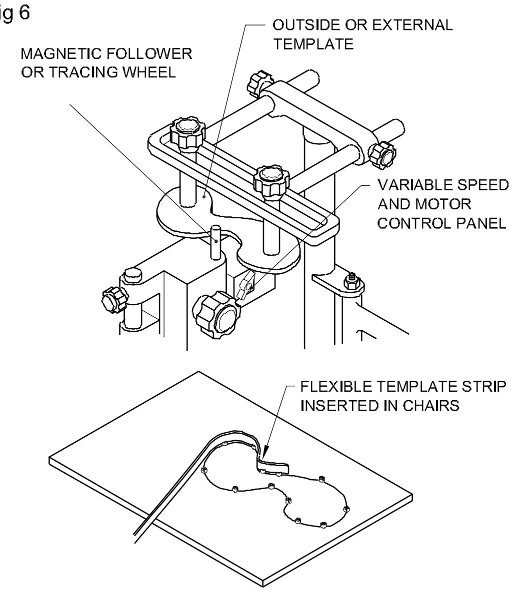
STATIC MACHINE WITH RADIAL ARM CUTTING MACHANISM

WLN111715

Profile cutting by using templates

Profile cutting can be done by static cutting machines as per the shape of the templates. (Fig 6) The templates are mainly used for reproducing the same shapes into a no. of pieces. The templates are made from wood, hardboard, aluminium or steel.

Fig 6



STATIC CUTTING MACHINE AS PER SHAPE OF THE TEMPLATES

WLN111716

Two types of templates are in use depending on their size.

- Outside template
- Inside template

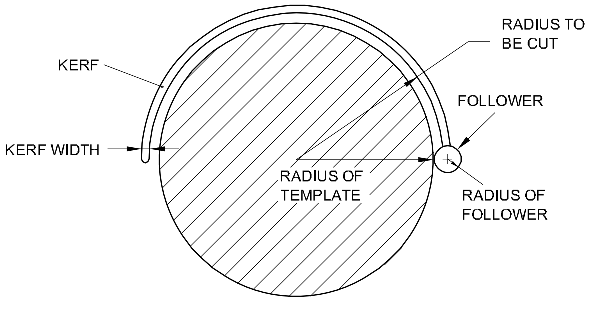
Outside template

The outline of the template will be the shape to be cut, reduced in size by the radius of the follower wheel or roller which is (Knurled) attached with the motor af the machine.

The size of the template is excluding the radius of the tracing wheel (knurled wheel) - half of the kerf width. (Fig 7)

Example

Fig 7



RADIUS OF TEMPLATE = RADIUS OF CIRCLE – (RADIUS OF FOLLOWER + $\frac{\text{KERF WIDTH}}{2}$)

EXTERNAL TEMPLATE

WLN111718

To cut a circle using an extermal template

Radius of circle		100 mm
Radius tracing wheel	6.5 mm (a)	
Half the kerf width		0.8 mm (b)
Difference [(a) - (b)]		5.7 mm
So pre-radius of external template		100-5.7 mm
	=	94.3 mm

NOTE:

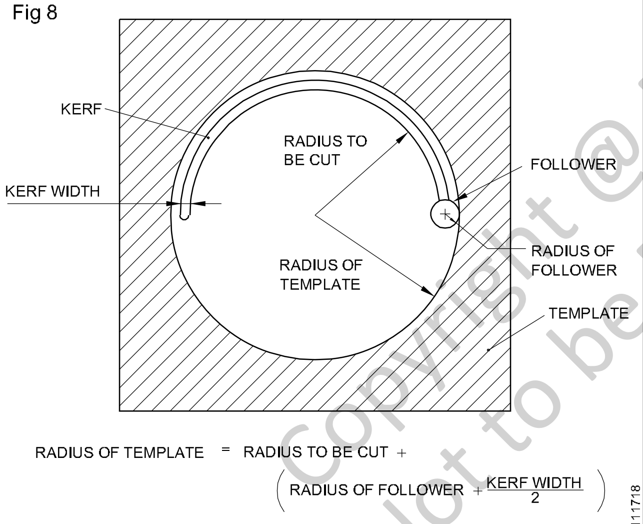
Kerf width is variable according to the:

- nozzle size, type and condition
- plate thickness
- cutting speed
- pressure of cutting oxygen
- preheat flame size.

Internal template or inside template

The shape of the template will be the shape to be cut increased by the radius of the following roller (knurled wheel) + half the kerf width. (Fig 8)

Fig 8



INTERNAL TEMPLATE

Example

To cut a circle using an internal template:

Radius of circle	-	100mm
Radius of tracing wheel (knurled)	-	6.5 mm (a)
Half the kerf width	-	0.8 mm (b)
Sum of (a) + (b)	=	6.5 + 0.8 mm
	=	7.3 mm
The radius of the external template	=	100 + 7.3 mm
	=	107.3 mm

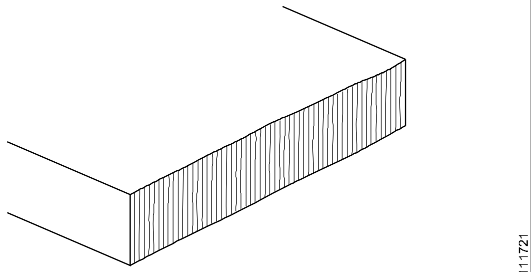
GAS CUTTING DEFECTS

Recognition of cutting and gouging defects, their causes, prevention and permissible methods of rectification

- In a correct cut the top of the cut is both sharp and clean, the drag lines are almost invisible, producing a smooth side. Oxide is easily removed, the cut is sharp and bottom edge is clearly and sharply defined.

Drag lines should be vertical for profiles. A small amount of drag is allowed on straight cuts.

Fig 1

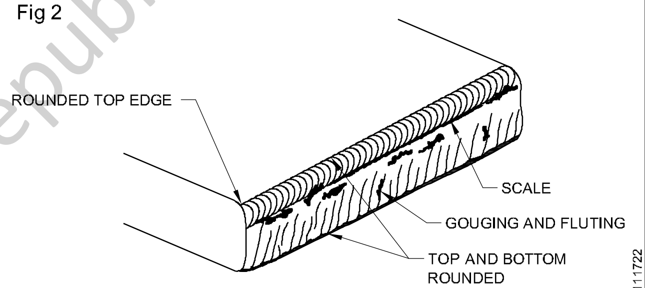


CORRECT CUTTING

- Due to melting, the top edge has become rounded. Gouging is pronounced at the bottom edge, which is also rough. Scale on the cut face is difficult to remove.

To rectify: Traverse at recommended speed. Increase the oxygen pressure.

Fig 2

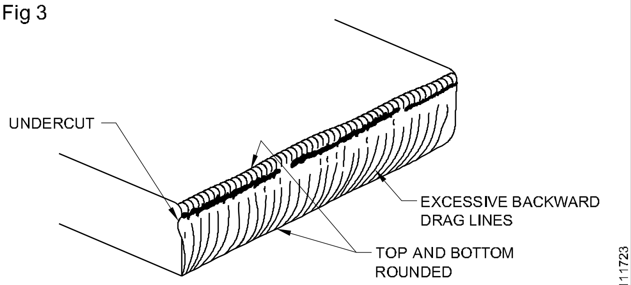


SPEED TOO LOW

- The top edge may not be sharp; there is a possibility of beading.

To rectify: slow down the traverse to the recommended speed. Leave the oxygen pressure as set.

Fig 3



SPEED TOO FAST

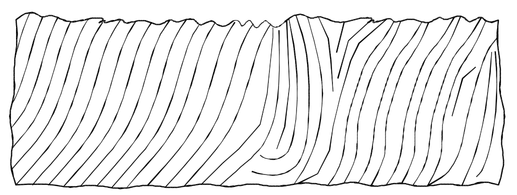
Common defects in gas cutting

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

Common faults in cutting

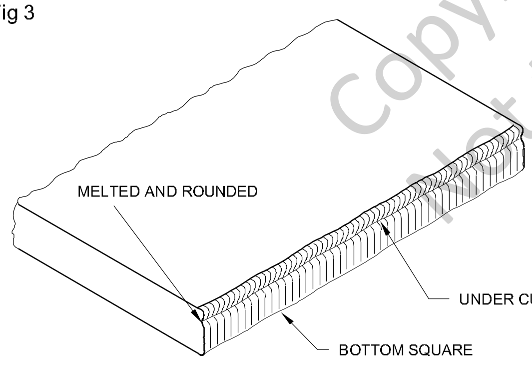
(Fig 1) The tip is too high off the steel. The top edge is heated or rounded, the cut face is not smooth, and often the face is slightly bevelled where preheat effectiveness is partially lost due to the tip being held so high. The cutting speed must be reduced because of the danger of losing the cut.

Fig 1



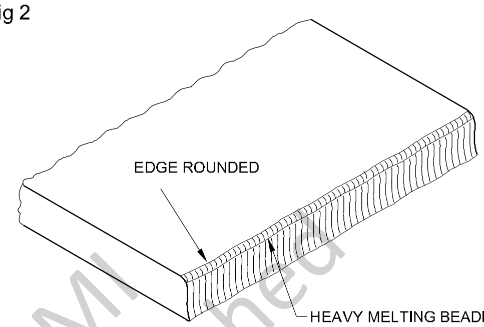
(Fig 2) Extemely slow cutting speed. Pressure marks on the cut face indicate too much oxygen for the cutting conditions. Either the tip is too big, the cutting oxygen pressure is too high, or the speed is too slow as shown by the rounded or beaded top edge. On reducing the cutting oxygen volume to the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

Fig 3



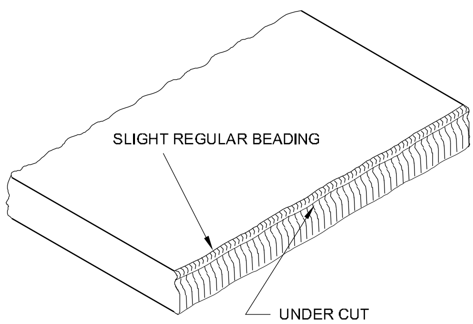
(Fig 3) Tip too close to the steel. The cut shows grooves and deep drag lines, caused an unstable cutting action. Part of the preheat cones burned inside the kerf, where normal gas expansion affected the oxygen cutting stream.

Fig 2



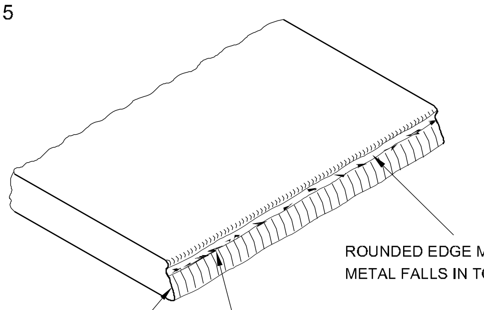
(Fig 4) Too much cutting oxygen. The cut shows pressure marks caused by too much cutting oxygen. When more oxygen is supplied than can be consumed in oxidation, the remainder flow around the slags, creating gouges or pressure marks.

Fig 4



(Fig 5) 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.

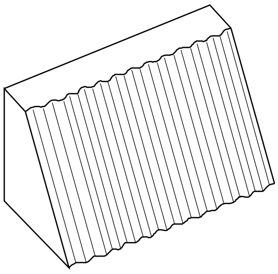
Fig 5



TOO MUCH PREHEATING

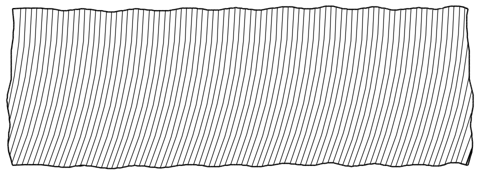
(Fig 6) Poor quality bevel cut. The most common fault is gouging, caused by either excessive speed or inadequate perheat flames. Another fault is a rounded top edge caused by too much preheat, indicating excessive gas consumption.

Fig 6



(FIg 7) 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.

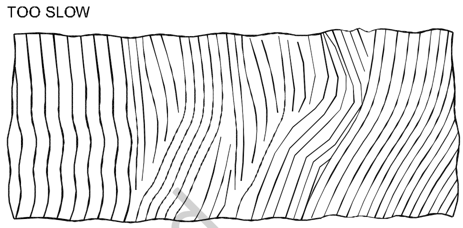
Fig 7



SLIGHTLY TOO FAST CUT

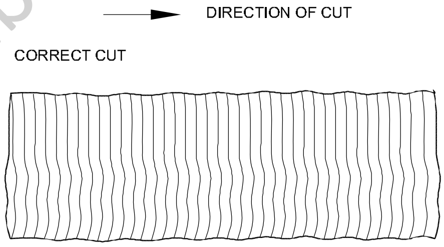
(Fig 8) Slightly too slow a cutting speed. The cut is of high quality although there is some surface roughness caused by the vertical drag line. The top edge is usually slightly beaded. This quality is generally acceptable, but faster speeds are more desirable because the labour cost for this cut is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

Fig 8



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

Fig 9



Power source selection criteria

Some General Terms to Understand

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

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

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

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

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

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

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

Power Source Selection Criteria General:

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

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

Power source selection criteria SMAW:

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

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

Power source selection criteria MIG/MAG:

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

Inverter its concept and application

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

Why inverters: Traditional power sources have the following disadvantages:

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

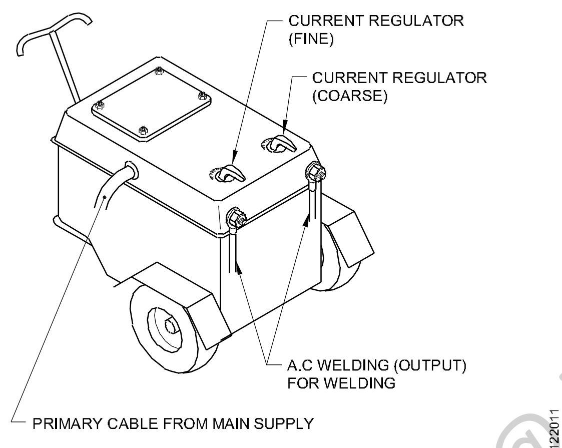
- Very light and compact-portable.
- Power consumption reduced by 40-50%
- Can quickly modify static, and dynamic output characteristics for multi-process capability.
- Excellent arc stability.
- TIG welding can be done at 1ampere.
- Hot start and adjustable arc force for SMAW,GMAW-pulse and synergic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

A.C welding transformer and its construction

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

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

Fig 1



AC WELDING TRANSFORMER

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

It is a step down transformer, which:

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

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

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

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

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

Two welding cables are attached with the output terminals.

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

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

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

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

This action is called the principle of mutual induction.

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

Voltage at secondary coil =

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

Advantages

Less initial cost

Less maintenance cost

Freedom from arc blow

NO noise

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

Disadvantages

Not suitable for:

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

AC cannot be used without special precautions of safety.

care and maintenance

Transformer body must be properly earthed.

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

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

Do not run the machine continuously on its maximum capacity.

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

Do not change the current when welding is going on.

Always keep and install the machine on dry floor.

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

D.C welding generator

Necessity of DC welding generator

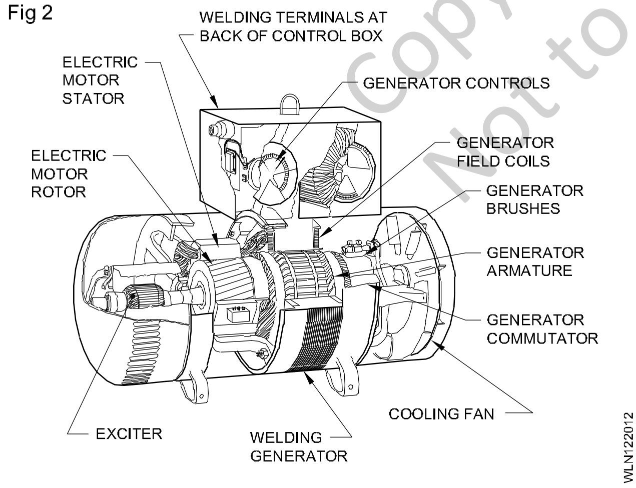
DC welding generators are used to:

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

Constructional features of DC welding generator (Fig.2)

A DC welding generator (Fig.2) consists of the following parts.

Fig 2



Main poles: These are connected to the body or yoke to produce magnetic lines of force, also called FIELD COILS.

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

Armature: It is a laminated steel drum with longitudinal stole which accommodate copper conductors.

It is mounted on a shaft which rotates in suitable bearing arranged at its ends.

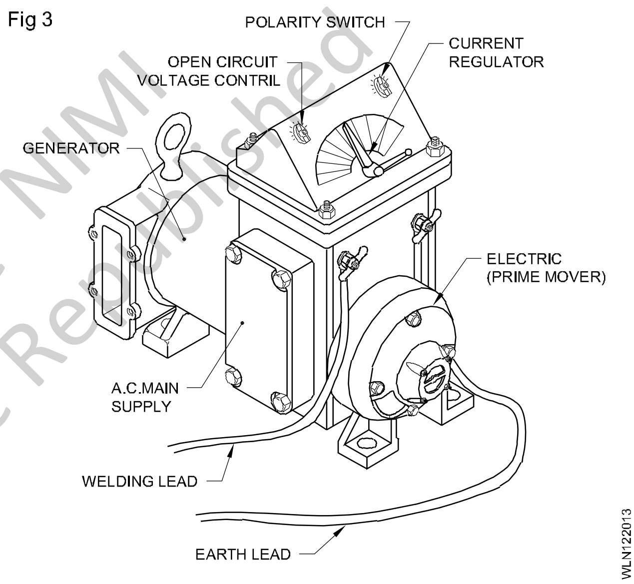
It is also mounted on the shaft along with the armature and is connected to the armature conductors.

Carbon brushes: These are mounted on the body to have contact with the rotating commutator and are connected to the output terminals.

Fan: It is meant for cooling the generator.

Prime mover: It is the driving source as motor or engine used to rotate the armature in the generator. (Fig 3)

Fig 3



Working principle of DC welding genertor: The armature is made to rotate with the help of a prime mover between the main poles, where a strong magnetic field exists

The armture cuts the magnetic lines of force, generating emf in its conductors. The commutator, being connected to the armature conductors, changes the generated alternating current into DC. The generated DC is then taken to the generator terminals through the carbon brushes. Where the main supply electricity is availble; a motor is used as a prime mover. For field work or where main supply is not available, petrol or diesel engine may be used as a prime mover.

care and maintenance of arc welding generators

To make the best use of the arc welding generator and to ensure its longer life the following checkpoints are to be observed.

Checkpoints for engine of an engine driven generator.

Check the water level in the radiator and the oil level in the engine daily.

Change the engine oil after running for 250 hrs.

Lubricate the fan bearing once in a week.

Check fan belts daily for their proper tightness.

Check petrol or diesel pipe unions leakage daily.

Checkpoints for motor driven generator

Blow out the dust from the inside of the generator with dry compressed air at 1.5 to 2.0 kg/cm^2 pressure after every three months.

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

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

Guard the rotaing parts with suitable covers.

Do not cover the air ventilation ducts.

Do not operate the polarity switch during arcing.

Ensure a proper working of the cooling fan.

Check the electrical connections and avoid loose connections.

Never run the motor on a weak phase.

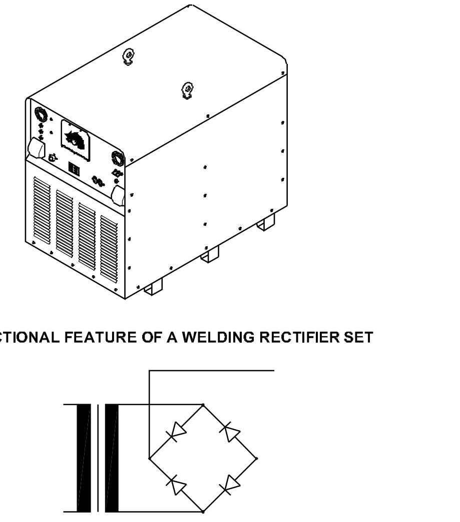
Ensure the electric motor is properlay earthed.

AC/DC welding rectifier its construction

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

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

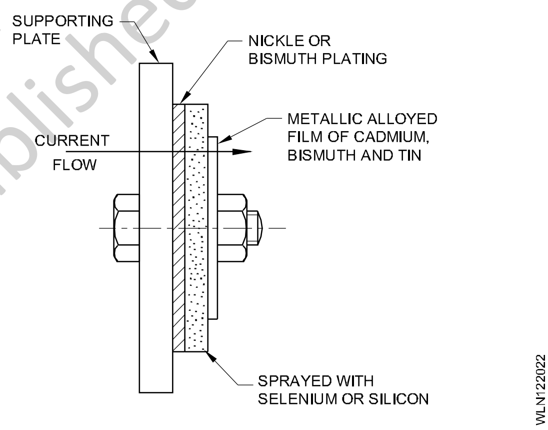
Fig 1



CONSTRUCTIONAL FEATURE OF A WELDING RECTIFIER SET

SYMBOLIC REPRESENTATION

Fig 2



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

Care and maintenance of rectifier welding set

Keep all the connections in tight condition.

Lubricate the fan shaft once in 3 months.

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

Keep the rectifier plates clean.

Check and clean the set atleast once in a month.

Keep the air ventilation system in good order.

Never run the machine without the fan.

Inverters

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

Inverters

Basic principle:

inverter basically converts DC to AC

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

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

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

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

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

Working principle

1 Main voltage is rectified to DC

2 The inverter converts the Dc to high frequency AC

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

4 The AC is rectified

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

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

7 A DC voltage is available for welding purpose

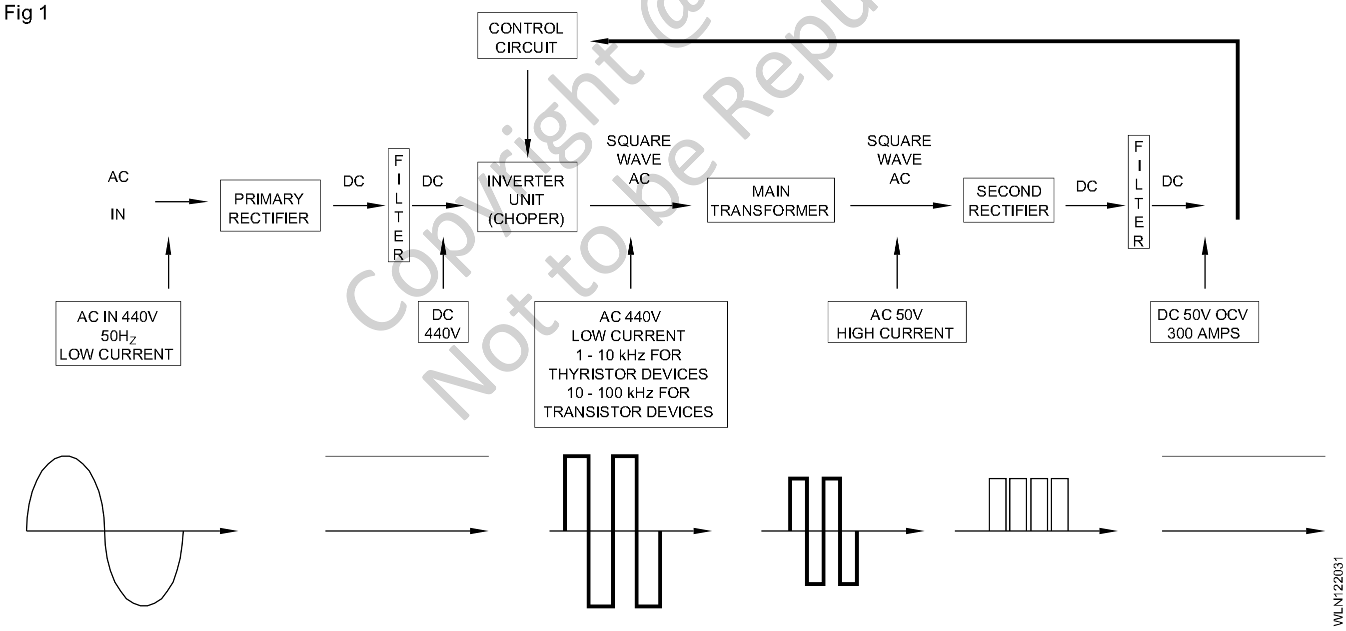
Advantage:

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

Disadvantage:

- expensive
- difficult to repair
- sensitive to high currents

Fig 1



Advantages and disadvantages of AC and DC welding

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

Advantages of AC welding

A welding transformer has:

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

Disadvantages of AC welding

It is not suitable for bare and light coated electrodes.

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

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

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

Advantages of DC welding

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

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

Bare wires and light coated electrodes can be easily used.

Positional welding is easy due to polarity advantage.

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

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

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

It is easy to strike and maintain a stable arc.

Remote control of current adjustment is possible.

Disadvantages of DC welding

DC welding power source has:

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

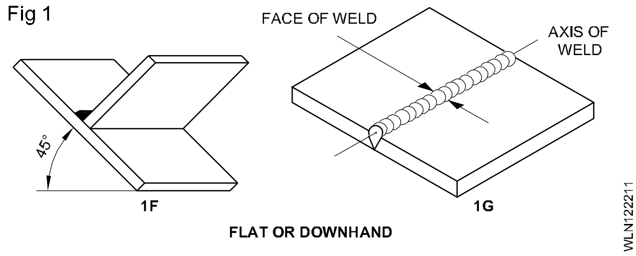
Basic welding positions

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

Basic welding positions

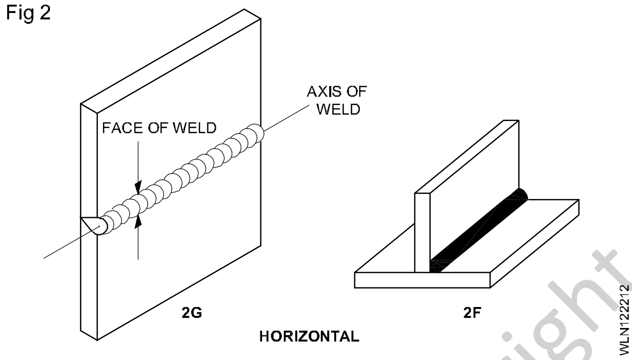
- Flat or downhand position (Fig 1)

Fig 1



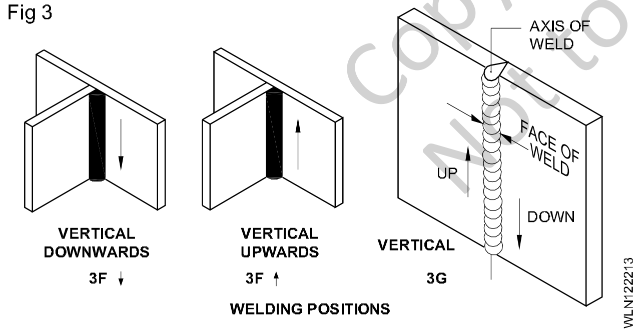
- Horizontal position (Fig 2)

Fig 2



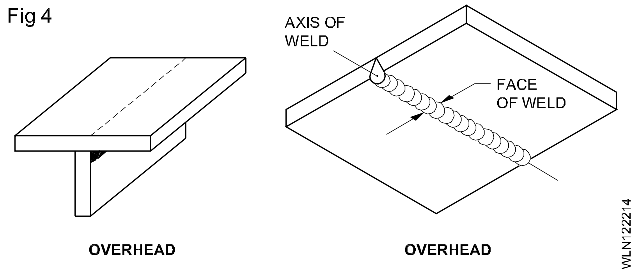
- Vertical position (Vertical up and down) (Fig 3)

Fig 3



- Overhead position (Fig 4)

Fig 4



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

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

All joints may be welded in all positions.

Plate welding position:

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

Pipe welding position:

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

Weld slope and rotation

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

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

1 Flat or downhand

2 Horizontal

3 Vertical

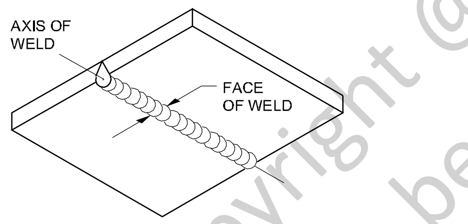
4 Overhead

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

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

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

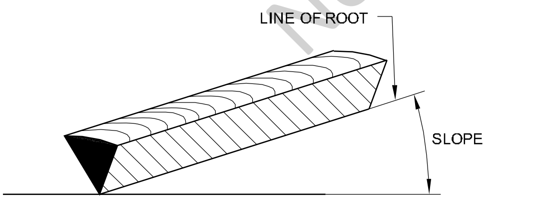
Fig 1



OVERHEAD

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

Fig 2



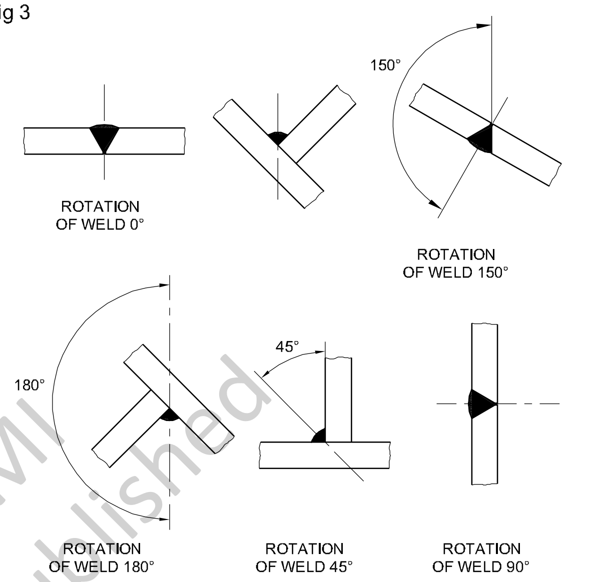
WELD SLOPE

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

Slope and rotation (Fig 4)

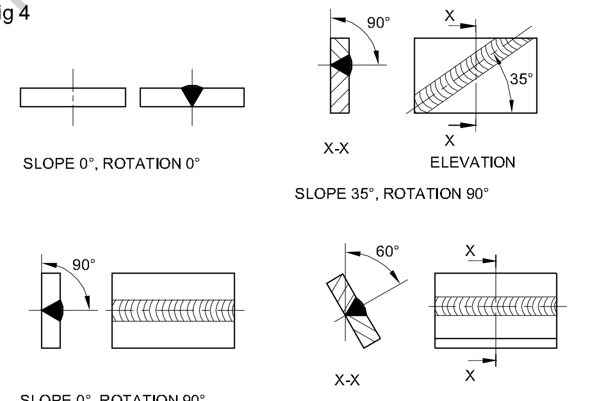
weld in flat position. (Fig 5)

Fig 3



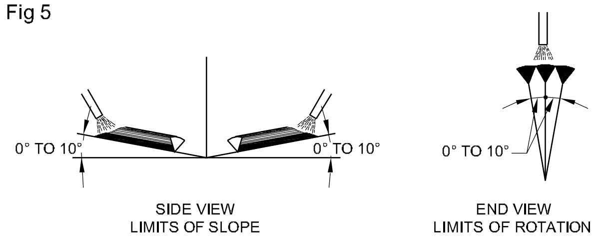
WELD ROTATION

Fig 4



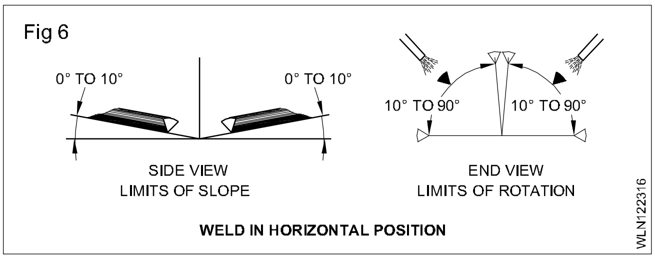
SLOPE AND ROTATION

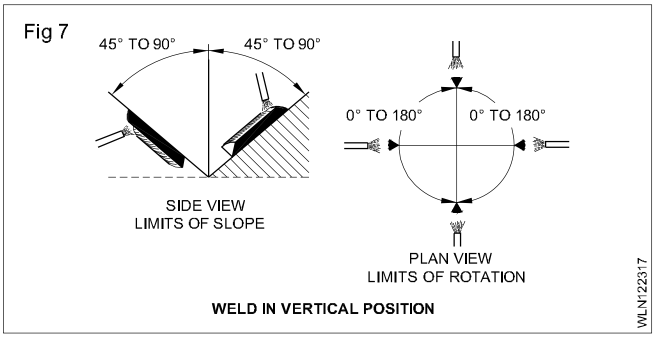
Fig 5



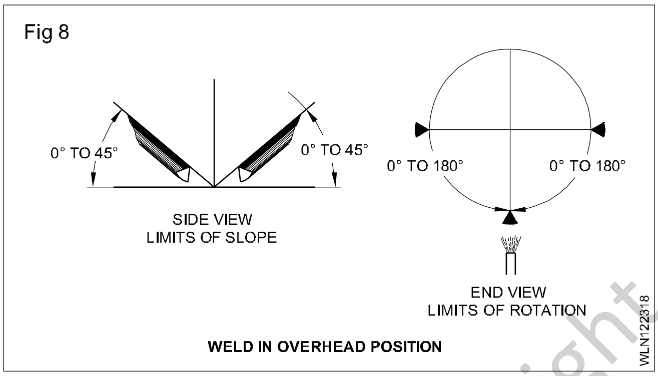
WELD IN FLAT POSITION

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





Weld in overhead position. (Fig 8)



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

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

DEFINITIONS OF WELDING POSITIONS

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

Weld symbol and welding symbol - Description and uses

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

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

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

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

TABLE 1

Elementary symbols

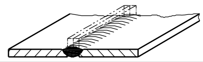
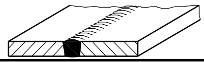
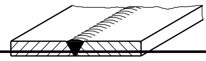
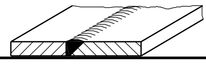
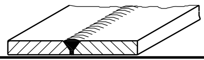
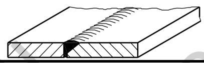
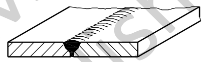
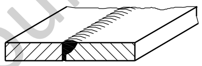
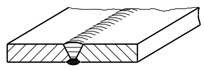
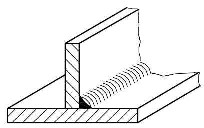
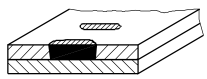
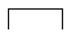
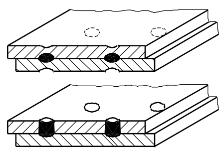
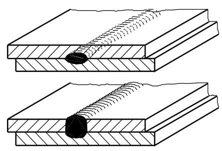
Sl. No.	Designation	Illustration	Symbol
1	Butt weld between plates with raised edges (the raised edges being melted down completely)	Fig 1 	
2	Square butt weld		
3	Single V butt weld		
4	Single bevel butt weld		
5	Single V butt weld with broad root face		
6	Single bevel butt weld with broad root face		
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		

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TABLE 2

Supplementary symbols

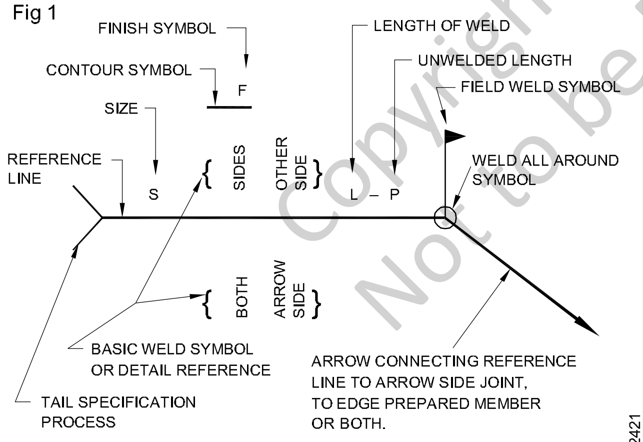
Shape of weld surface	Symbol
a) Flat (Usually finished flush)	
b) Convex	
c) Concave	

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 proces 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 4)

1 Reference line
2 Arrow
3 Welding elementary symbols
4 Dimensions and other details
5 Supplementary symbols
6 Finish symbols
7 Tail (Specification, process)

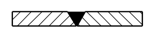
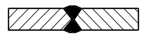
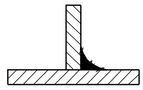
Fig 1



STANDARD LOCATION OF ELEMENTS OF A WELDING SYMBOL

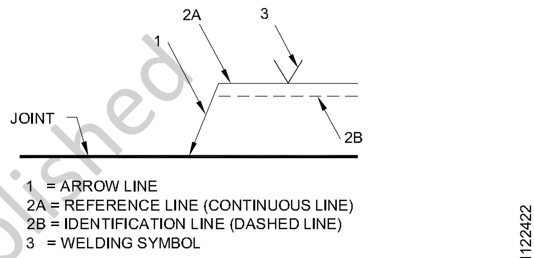
TABLE 3

Examples of application of supplementary symbols

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

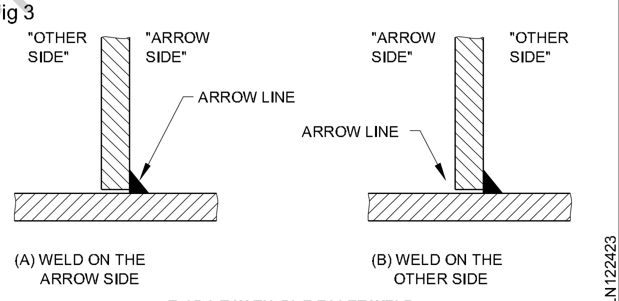
Methods of representation (Fig 2 and 3)

Fig 2



METHOD OF REPRESENTATION

Fig 3



T-JOINT WITH ONE FILLET WELD

The reference line, arrow-head and tail

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

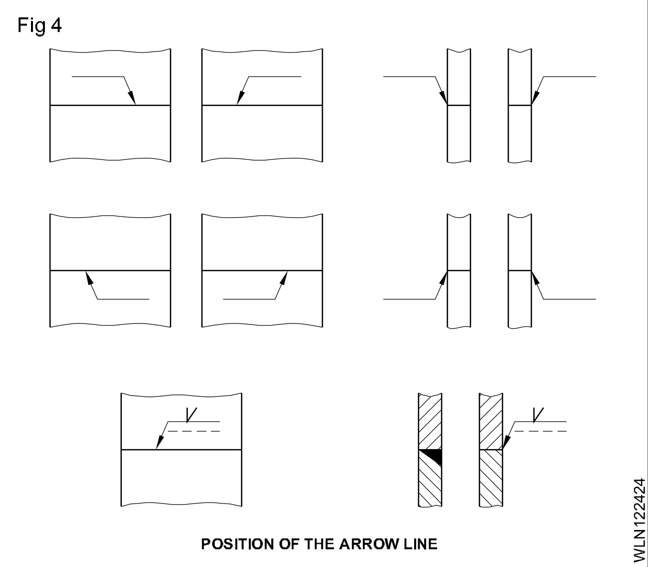


Fig 4

POSITION OF THE ARROW LINE

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

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

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

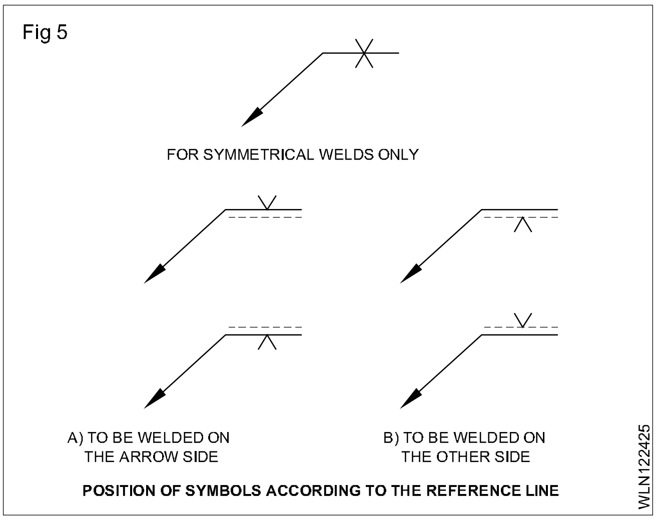
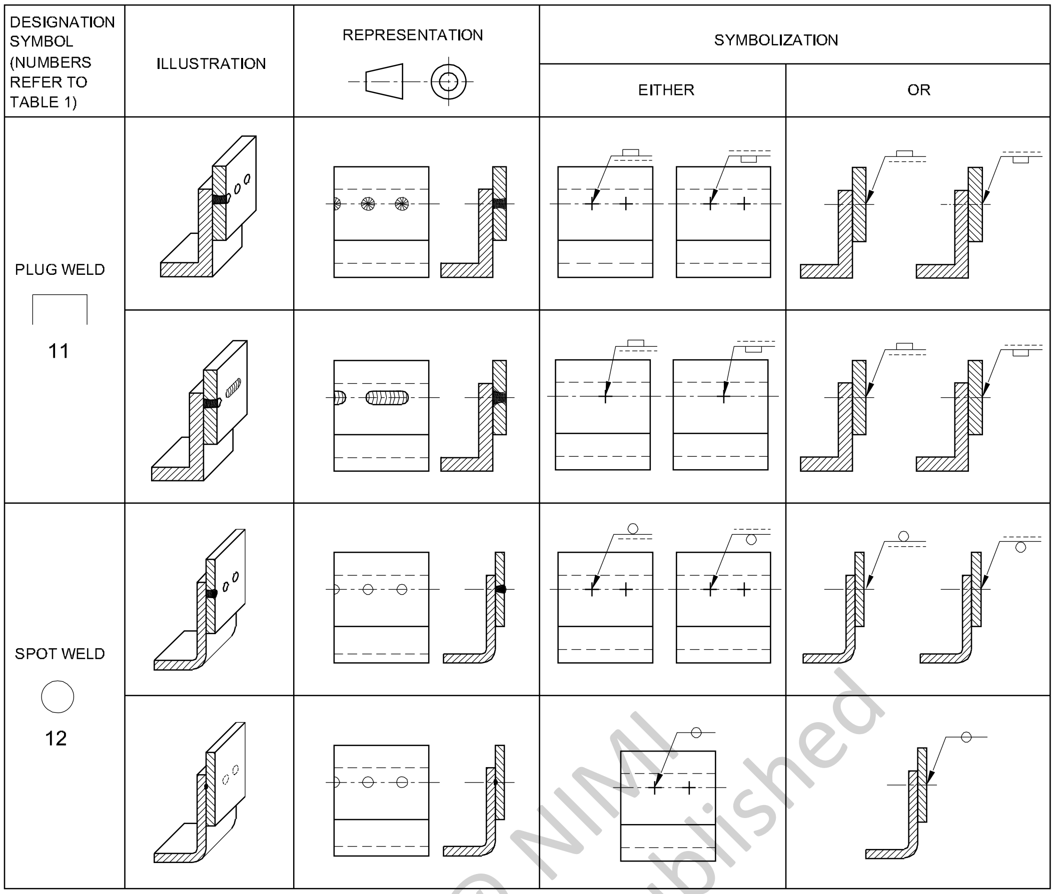


Fig 5

POSITION OF SYMBOLS ACCORDING TO THE REFERENCE LINE

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

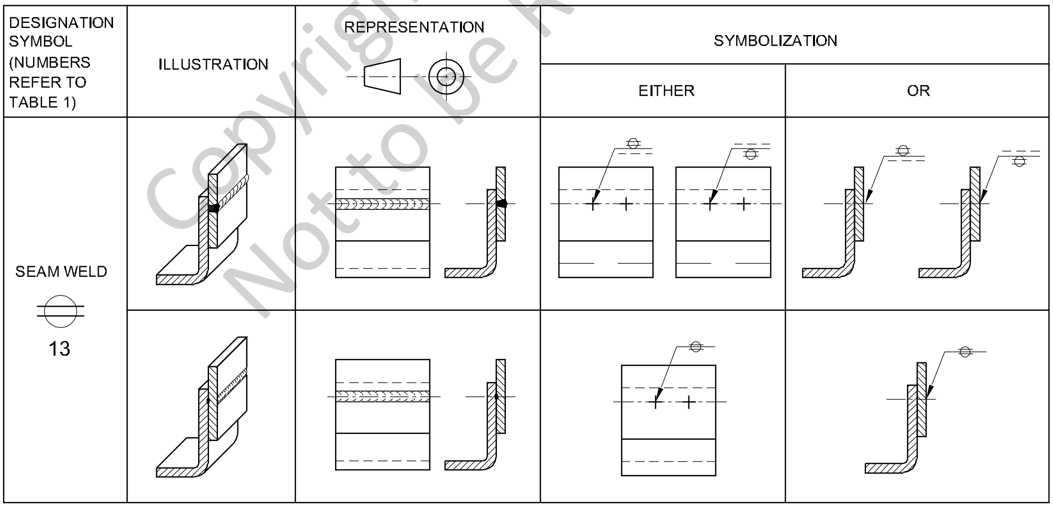
Fig 6



EXAMPLES OF USE OF ELEMENTRY SYMBOLS

WLN122426

Fig 7



EXAMPLES OF USE OF ELEMENTRY SYMBILS

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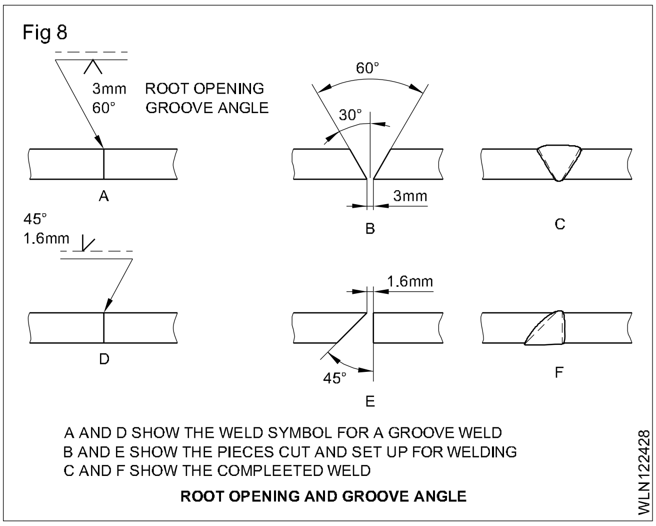
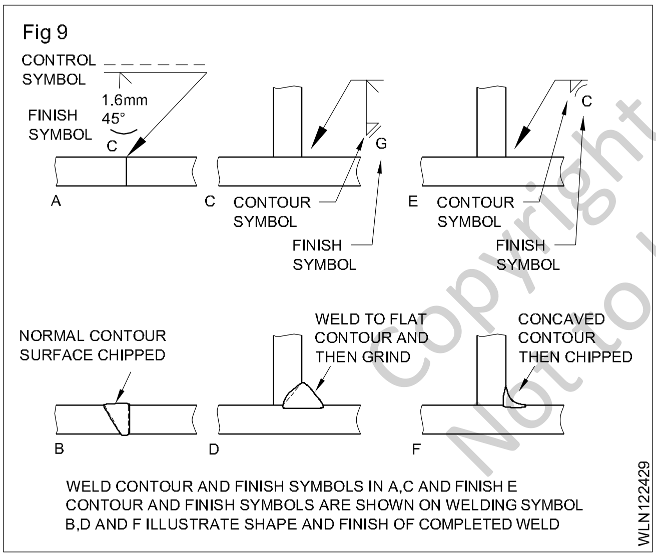
Root opening and groove angle: The root opening size appears inside the basic weld symbol on the complete welding symbol. The included angle or total angle of a groove weld is shown above the basic weld symbol. (Fig 8)

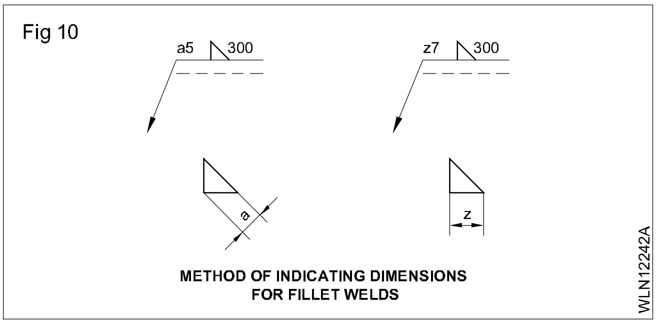


Contour and finish symbols: The shape or contour of the completed weld bead is shown on the welding symbol as a straight or curved line between the basic weld symbol and the finish symbol. The curved contour line indicates a normal convex or concave weld bead. (Fig 9)



Dimensions and other details: The size of a weld is important. The term 'size of weld' means different things for the fillet weld and butt weld. The dimensions of a fillet weld are shown to the left of the basic weld symbol. (Fig 10) The number 300 indicates the length of the weld is 300mm; a5 indicates that the throat thickness is 5mm; z7 indicates the leg length is 7mm.

As per AWS (American Welding Society), basic weld symbols and their location on welding symbols is given as per following charter.



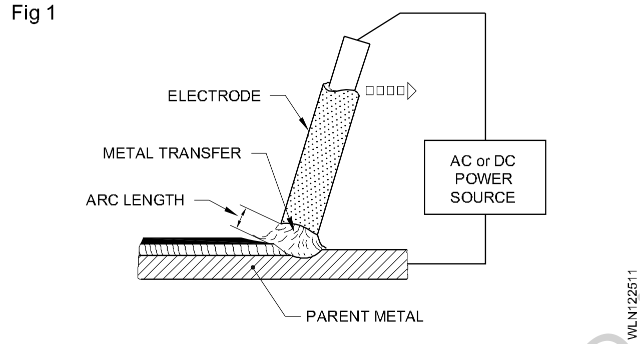
Arc length and its effects

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

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

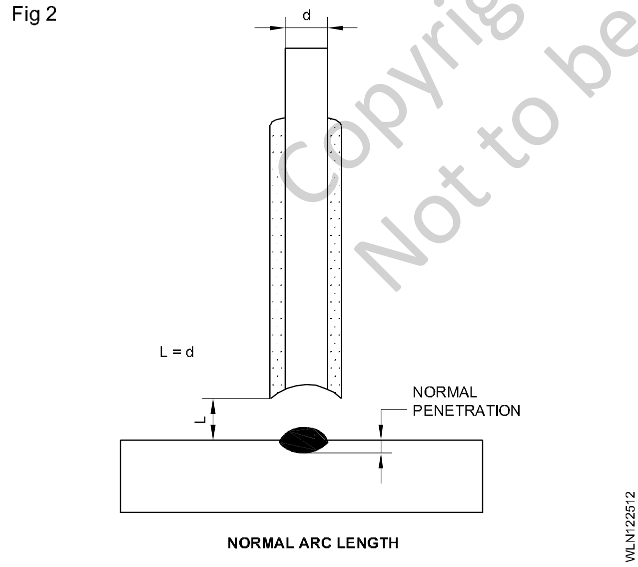
- Medium or normal
- Long
- Short

Fig 1



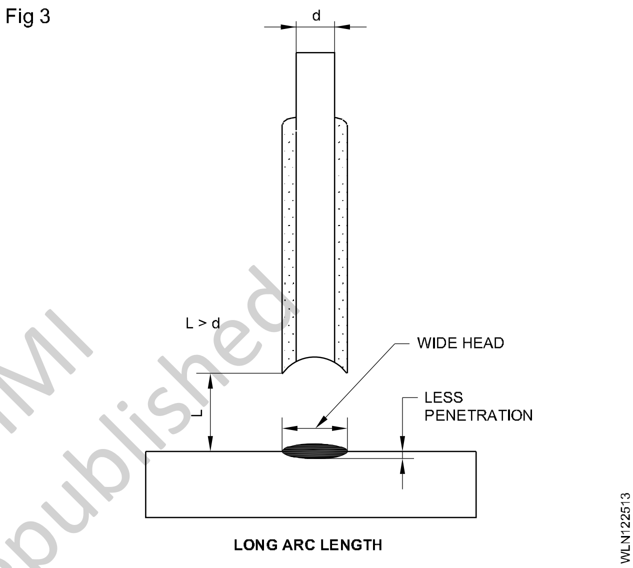
Medium, normal arc (Fig 2): The correct arc length or normal arc length is approximately equal to the diameter of the core wire of the electrode.

Fig 2



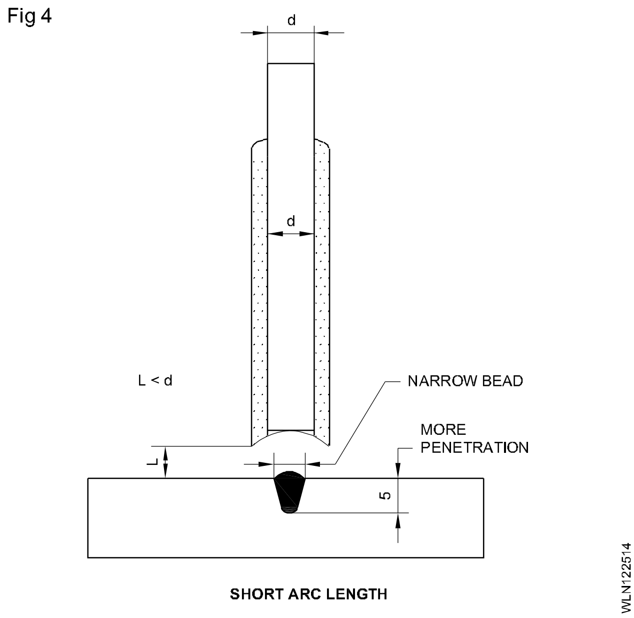
Long arc (Fig 3): If the distance between the tip of the electrode and the base metal is more than the diameter of the core wire it is called a long arc.

Fig 3



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

Fig 4



Effects of different arc length

Long arc

It makes a humming sound causing:

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

Short arc: It makes a popping sound causing:

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

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

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

Uses of different arc lengths

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

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

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

— — — — — — — —

Metal transfer across the arc (Characteristics of arc)

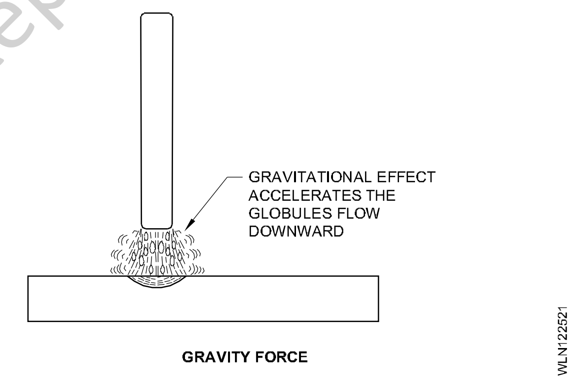
Objectives: At the end of this lesson you shall be able to

- **explain the factors involved in the transfer of metal across the arc due to arc characteristics.**

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

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

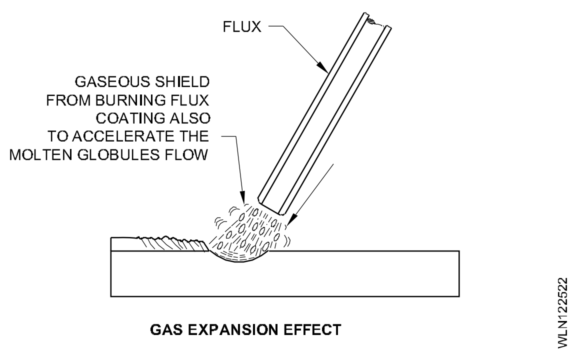
Fig 1



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

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

Fig 2



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

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

— — — — — — — —

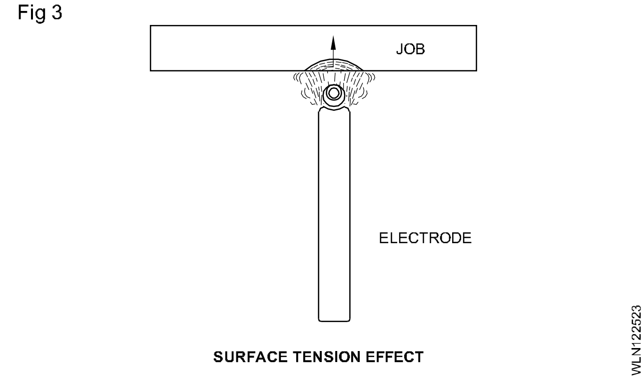
These gases expand and gain velocity. The flux sleeve direct these gases to flow in the direction of the molten metal. The gases flowing from the tip of the electrode have a pushing effect. Thus the metal globules are carried deep into the weld pool and influence penetration.

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

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

The short arc promotes more surface tension effect.

Fig 3

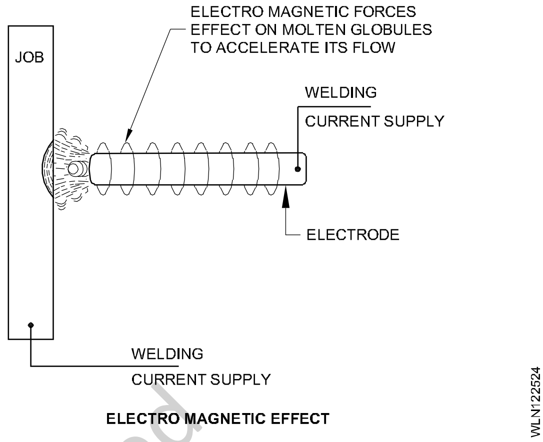


SURFACE TENSION EFFECT

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

This effect is more useful in positional welding.

Fig 4



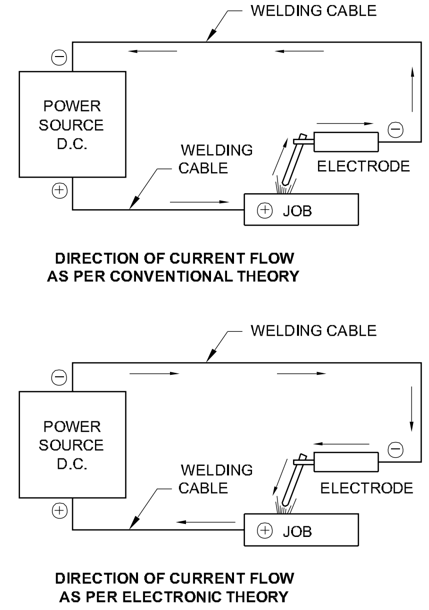
ELECTRO MAGNETIC EFFECT

Polarity in DC arc welding

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

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

Fig 1



Direct current (DC) Always flows from:

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

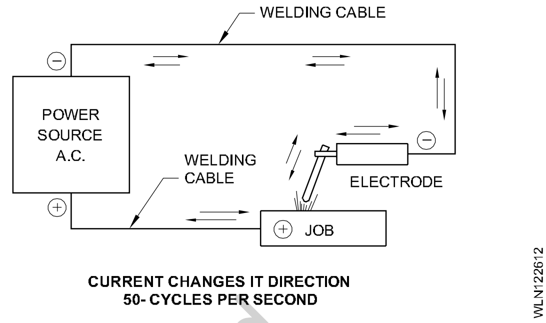
In older machines the electrode and earth cables are interchanged whenever the polarity has to be changed.

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

Flow of electrons is always from negative to the positive.

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

Fig 2



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

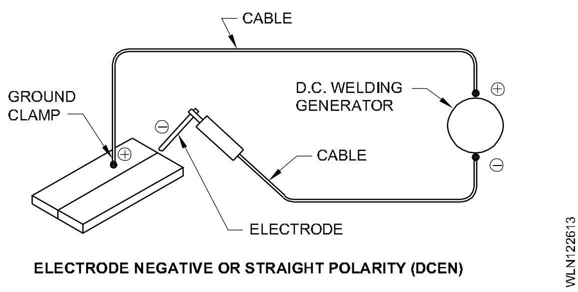
To have this advantage of unequal heat distribution in the electrode and base metal, the polarity is an important factor for successful welding.

Kinds of polarity

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

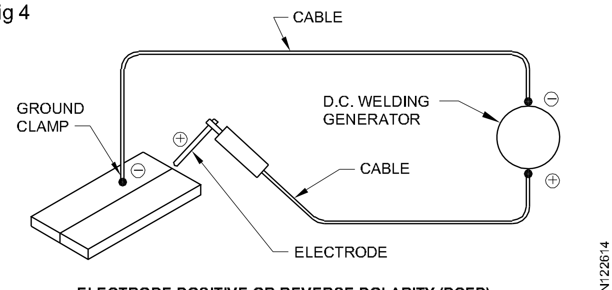
Straight polarity: In straight polarity the electrode is connected to the negative and the work to the positive terminal of the power source. (Fig 3)

Fig 3



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

Fig 4



ELECTRODE POSITIVE OR REVERSE POLARITY (DCEP)

Straight polarity is used for:

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

Reverse polarity is used for:

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

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

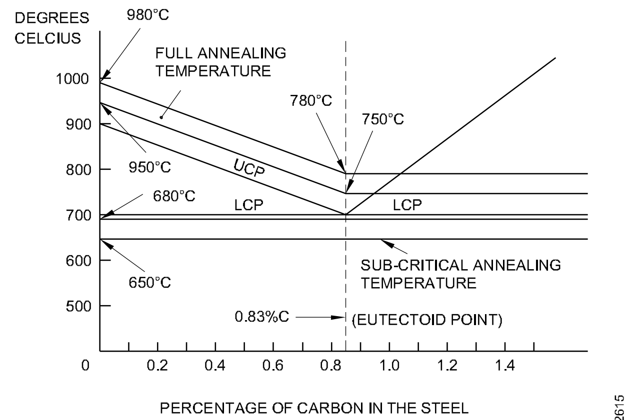
Choice of the polarity also depends on the instruction of the electrode manufacturers.

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

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

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

Fig 5

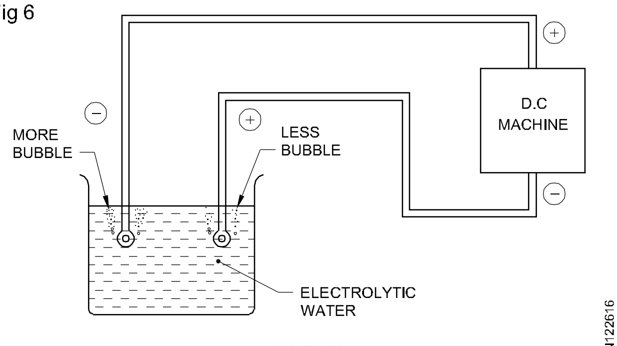


ANNEALING TEMPERATURES FOR PLAIN CARBON STEELS

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

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

Fig 6



WATER TEST

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

Indication of wrong polarity

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

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

Weld qualify and inspection visual inspections

Objectives : At the end of this lesson you shall be able to
- **state the necessity of weld qualify and inspection**
- **explain the quailfy inspection- conducted to overcome the common welding trainers.**
- **describe the appearance of good and defective welds.**

Introduction

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

Welding qulify and inspection:

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

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

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

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

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

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

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

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

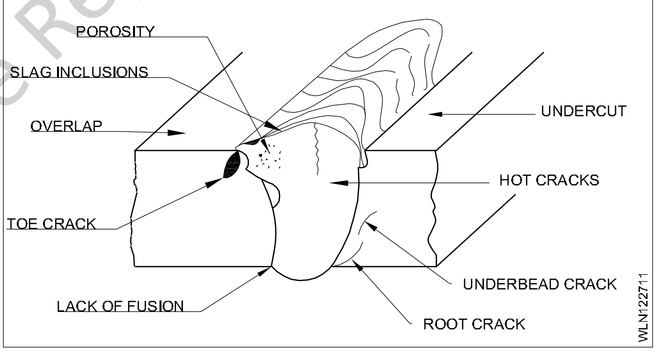
6 **Root crack:** The crack occurs at the root of a used joint

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

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

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

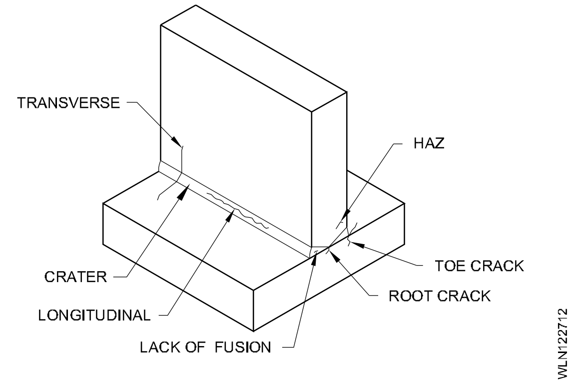
Fig 1



Common welding mistakes (Defects)

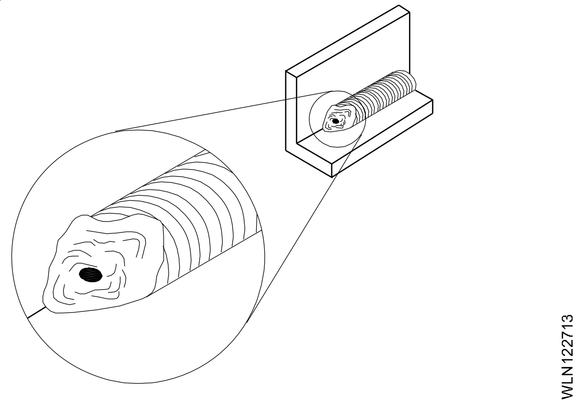
10 **Transverse crack:** The crack occurs at the location of the weld joint of base metal and weld ,method accross weld bead.

Fig 2



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

Fig 3



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

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

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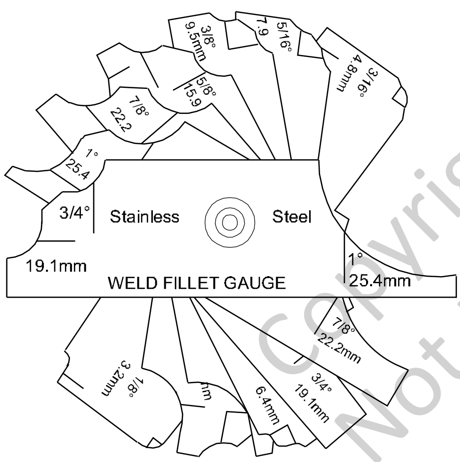
Weld gauger and its uses

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

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

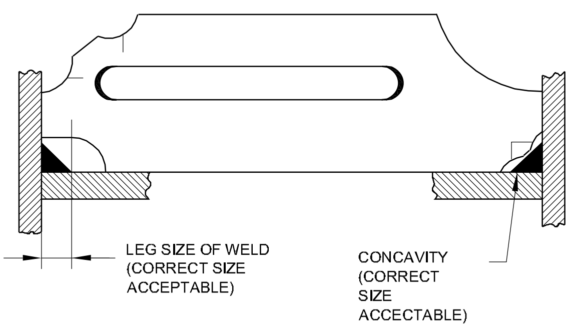
- weld fillet gauge (Fig 1)
- AWS type weld measurement gauge (Fig 2)

Fig 1



WLN122811

Fig 2



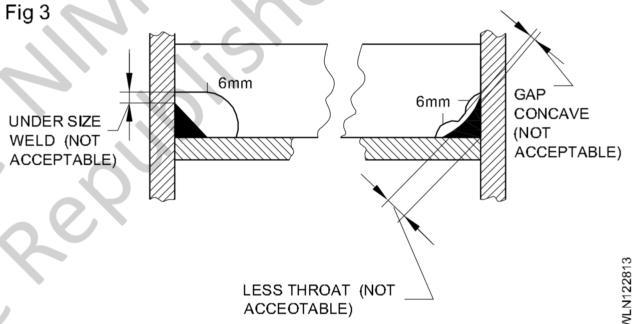
WLN122812

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

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

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

Fig 3



WLN122813

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

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

All weld measurement gauge:

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

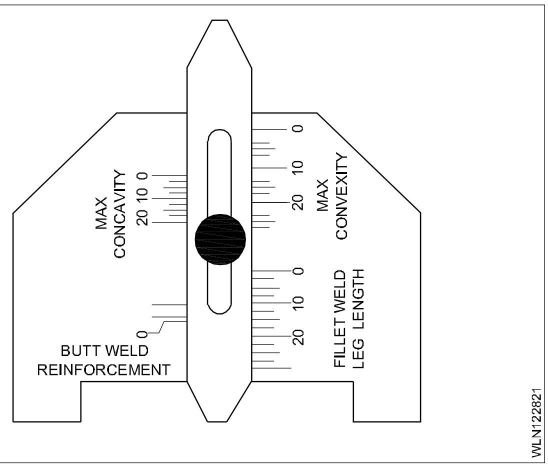
1 Leg size of fillet used.
2 Acceptable size of convexity.
3 Acceptable size of concavity.
4 Acceptable reinforcement height on butt weld

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

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

According to the type of measurement the blade after positioning over the weld bead the locking screw as shown in (Fig 1) Is tightened suitably to determine the measurement .

Fig 1

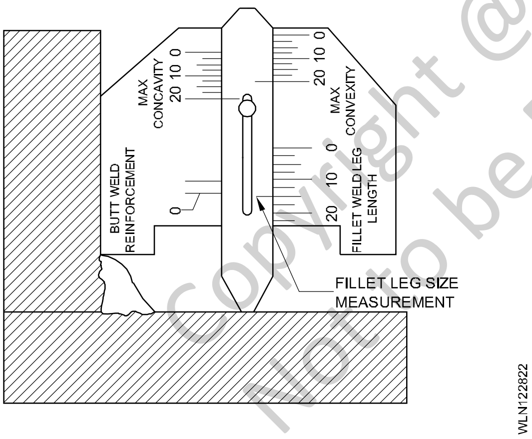


1 Leg size of fillet weld: To determine the fillet weld leg size the slot is placed against the toe of the weld as shown in (Fig 2)

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

The co-incidence of the graduation scale defines the fillet issued leg measurement.

Fig 2

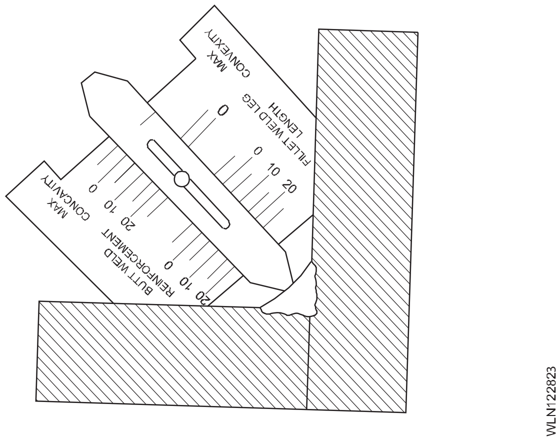


2 Acceptable size of convexity: To determaine the acceptable size of convexity, the stock portion of the gauge having 45° angle sides to which both the members of the joints is placed as shown in (fig 3)

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

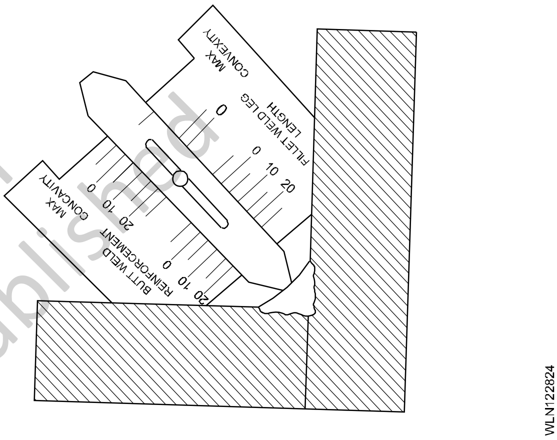
3 Aceeptable size of convexity: To determine the acceptable size of convexity the stock portion of the gauge having 45° angle sides touching both the members of the joints is placed as shown in Fig 4.

Fig 3



On sliding the pointer blade to touch the face of the weld determines the concavity, formed due to under fill of the weld bead as shown in Fig 4.

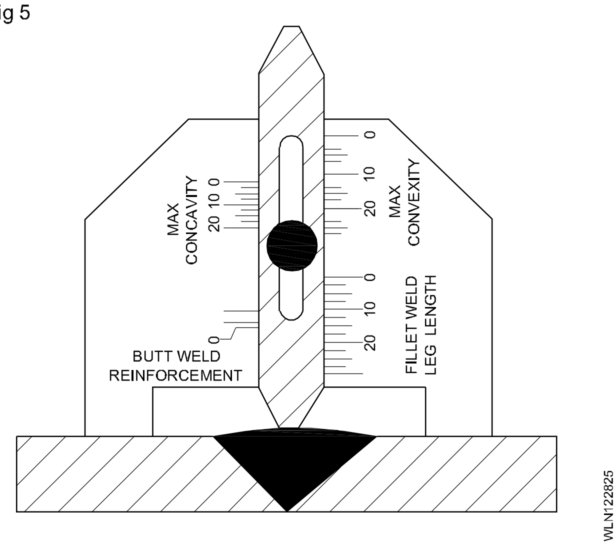
Fig 4



4 Acceptable reinforcement height on butt weld: To determine the acceptable size of reinforcement height on butt weld, the spode portion of the gauge, flat portion may be scated on either size of butt weld as shown in Fig 5, on sliding the pointer blade downwards so as to touch the reinforcement placed on the butt weld.

The co-incidence of the graduated scale determines the acceptable reinforcement height of the weld bead.

Fig 5



Calcium carbide preparation and its uses

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

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

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

- calcium = 62.5%

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

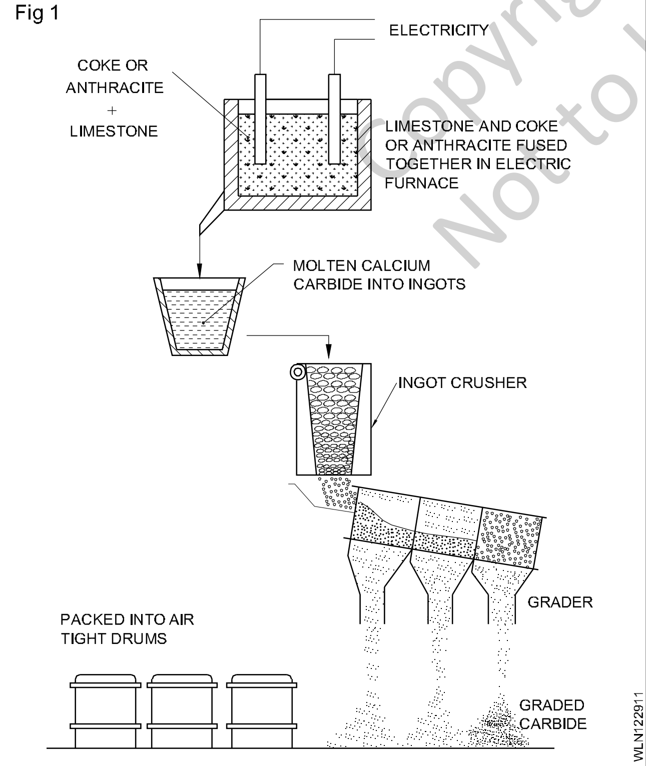
its chemical symbol is $Ca\ C_2$

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

Production of calcium carbide

Calcium carbide is produced in an electric furnace by smelting coke and lime in right proportion.(Fig 1)

Fig 1



Production of one metric ton of calcium carbide requires: (average)

- 950 to 1000 kg of lime
- 600 to 610 kg coke and anthracite
- 40 to 70 kg of carbon electrode material

It takes 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. Lime+Coke+Heat= calcium carbide+carbon monoxide.

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 sizes and packed into airtight steel drums.

Grades/sizes of calcium carbide: Different grades/sizes of calcium cardibe are available for use in different types of acetylene generators.

These are designated as:
- LUMP
- EGG
- NUT - 14 NDT.

The sizes given above indicate the range in the screening sizes. For example (LUMP) size 90*50 means that no piece is larger than 90 mm nor smaller than 50 mm.

Safety precautions for handling and storage of calcium carbide: It can be stored in approved places only, Storage building must not have either water line or high temperature. It must be stored in perfect airtight containers. Fire breakout in a carbide storage room must be extinguished with Co_2 fire extinguishers or dry sand and not with water. Do not allow the carbide to come in contact with water/mosisture outside the acetylene generator. Never put a naked light of any kind or any other source of ignition into or near the caridide container. Carbide drums should be opened with tools which will not produce sparks.

Use a brass chisel and hammer.

After taking out the carbide from a drum, it must be closed and made airtinght immedialtely. Preserve carbide in kerosene oil in case of emergencey. The person, handling calcium carbide, must wear rubber gloves. Empty carbide drums must be filled completely with water before disposing off.

Acetylene gas - Properties

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

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

Composition of acetylene gas: Acetylene is composed of:

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

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

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

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

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Acetylene gas generation

Objectives: At the end of this lesson you shall be able to
- **explain the principle and name the different methods of acetylene gas generation**
- **explain the working principle of the types of acetylene generators**
- **compare the types of acetylene generators**
- **state their care and maintenance.**

Composition of acetylene: Acetylene is a fuel gas composed of:

carbon 92.3% and Hydrogen 7.7%

Its chemical symbol is C_2H_2

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 (slaked lime).

Calcium caribide 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 genertor (low pressure)
- Carbide-to-water type acetylene genertor (medium pressure)

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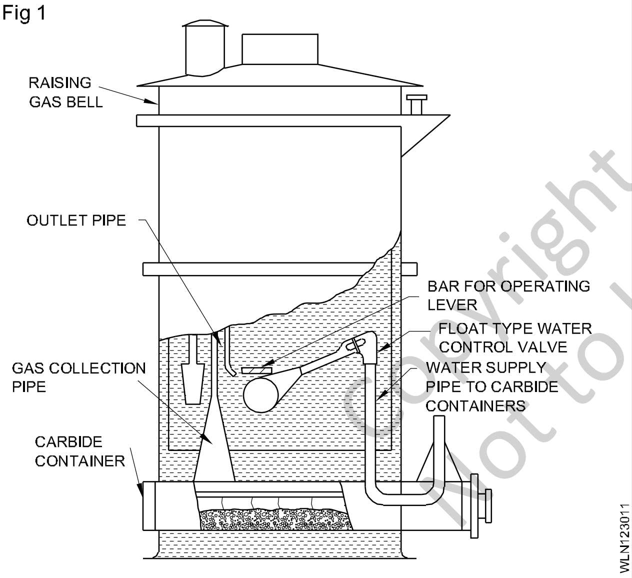
Water to carbide acetylene gas generator

Features of water-to-carbide acetylene generator: In this low pressure acetylene gas generator, water falls on the carbide to generate acetylene gas. Acetylene pressure up to 0.17 kg / cm^2 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.

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 sfficient water.

Calcium carblde 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 cross-bar 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 cross-bar presses the float ball down to open the water alve. 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.

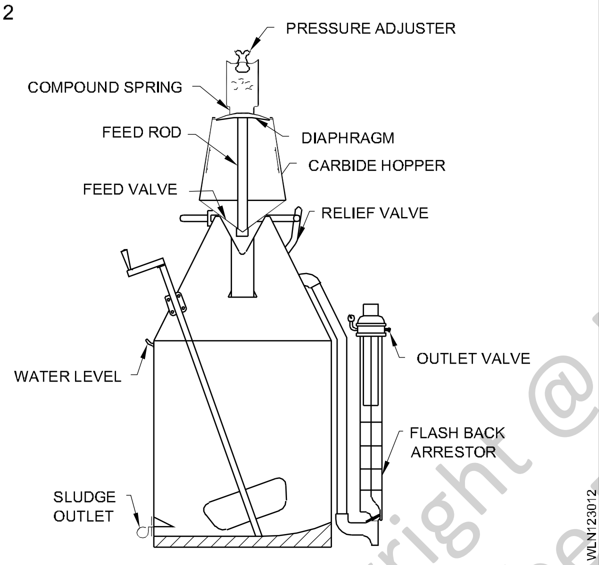
Non-automatic type generators are also available, in which the welder himself pours water on the carbide, by a hand operated valve, as per his requirements of acetylene gas.

Features of carbide-to-water type acetylene generator: In this generator carbide falls on water automatically to generate the acetylene gas. Acetylene pressure up to 1 kg/cm^2 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. At a 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 Fig2.

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 cardide hopper door. (The hopper door is closed.) The carbide hopper is attached at the top of the water tank tightly.

After starting the genertor, 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 diaphram 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 diaphagm 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 incresses 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 prssure 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.

Flashback arrestor: The purpose of the flashback arrestor cum purifier is to save the generator from the danger of backfire or flashback and also to purify the generated acetylene gas before it is used for welding.

Comparison of acetylene gas generators

Water-to-carbide type

Consumption of water is less.

Recharging is not a problem.

Sludge disposal is not easy.

Pressure of the gas is low.

Has lower gas generation.

The gas is slightly hot as there is no proper cooling system.

Any grade of calcium carbide can be used.

May be automatic or non-automatic.

Care and maintenance is not easy.

Control on working pressure difficult.

Cost of generator less.

Only injector type blowpipe can be used.

Suitable for one operation and no need of the manifold system.

Carbide-to-water type

Consumption of water is very high.

Recharging takes more time.

Sludge disposal is easy but takes more time.

Pressure of the gas is medium and high.

Has higher gas generation.

Gas is cool as the gas is produced at the bottom level of water tank and travels the full height of the water.

Only a particular grade (14 NDT) of calcium carbide can be used.

Operation is always automatic.

Care and maintenance easy.

Control on working pressure easy.

Cost of generator more.

Both injectors and non-injector type 'blowpipes' can be used.

Many operations can be done at a time and a manifold system is essential.

Care and maintenance of acetylene generators: Display 'no smoking' boards near generators. Generators must be fitted with safety devices, (Hydraulic back pressure valve). Avoid overcharging of calcuim carbide in the generator's chamber or carbide hopper, before recharging from the carbide chamber or generator. Avoid the creation of sparks inside the carbide chamber generator during cleaning. Acetylene generators should be cleaned,checked and painted periodically by competent persons, clean and recharge the acetylene generator in a well ventilated place, away from naked flame of fire. Leakages in valves, connection joints or any other fitting of acetylene generator must be checked daily (before use) using soap solution. Maintain the required water level in the generator daily. Keep and operate the generator away from sparks/fire or combustible materials. Disposal of slaked lime (Sludge) should be made in sludge pits (Away from fire or sparks) in open space. The recommended grade/size of calcium carbide should be used in each generator (type). Joints of carbide container and carbide hopper must be pressure-tight joints with generators.

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Acetylene gas purifier

Objectives : At the end of this lesson you shall be able to
- **explain the necessity and the features of the acetylene gas purifier**
- **explain the working principles of a purifier.**

Acetylene purifier: It is a cylindrical device which is used to purify the generated acetylene gas. It is fitted between the acetylene generator and blowpipe of a low pressure system of oxy-acetylene welding.

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

- Sulphurated hydrogen
- Phosphorated hydrogen
- Ammonia
- Lime dust
- Water vpour

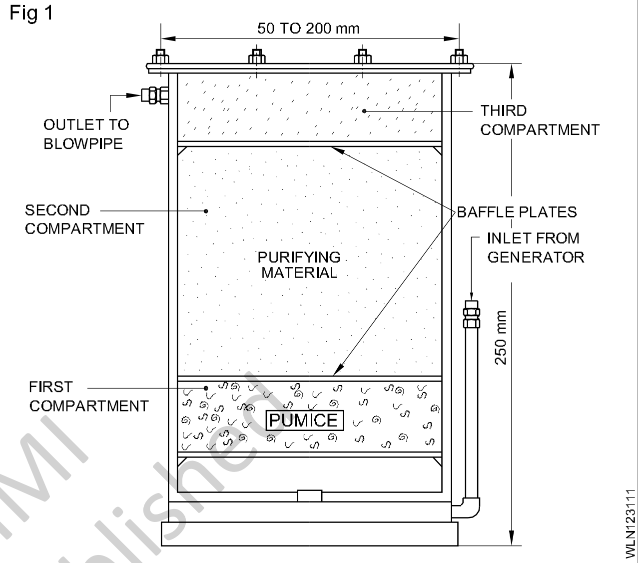
These impurities, if not removed, may have the following harmful effects.

- Reduction in flame temperature.
- Reaction with metal and influencing welding defects like blow holes, porosity etc.

Acetylene gas used for gas welding and cutting must be free from impurities. To remove these impurities, a suitable gas purifier must be used.

Gas purifier-working principle: The acetylene gas from the generator enters the purifier at the bottom chamber through the gas inlet pipe and passes through three compartments and comes out at the top through the outlet pipe. (Fig 1)

Fig 1



The first compartment contains pumice stone which absorbs moisture from the acetylene. The second compartment contains purifying chemicals, which remove sulphurated and posphorated hydrogen. The third compartment contains filter wool, which filters the lime dust and other foreign materials. Ammonia is removed within the generator when the gas passes through the water.

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Hydraulic back pressure valve

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.**

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 backfire 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 backfire to the generator, a hydraulic safety valve must be fitted in the acetylene pipe line between the blowpipe and the generator or purifier.

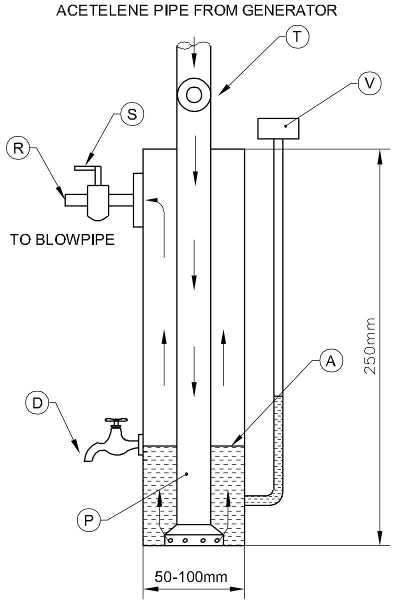
Constructional features of hydraulic back pressure valve: It is a cylindericl shaped device having 250mm depth and 50 to 100mm dia, as per the generator's capacity. (Fig 1)

Working principle

The cylindrical device is filled with water through the VENT PIPE (v) up to the level of water level (D). (Fig 1)

Gas enters from the generator through the inlet pipe valve (T) and comes down the centre pipe (P), bubbles through the outlet pipe (R) and valve (S).

Fig 1



CONSTRUCTION AND NORMAL WORKING
OF A HYDRAULIC SAFETY VALVE

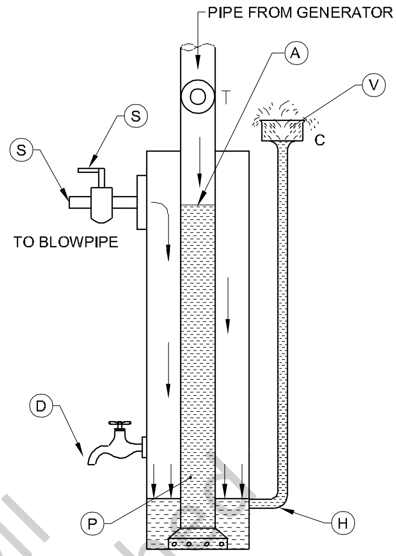
The pipe (P) has a baffle plate fixed at its lower end.

In the event of BACKFIRE or FLASHBACK (BACK PRESSURE) from the blowpipe side, the water level (A) is pushed down and water is forced up into the vent pipe until the hole (H) is exposed.

The burnt gases in case of a backire, or the back pressure gases, pass up the vent pipe into the atmosphere and are prevented from getting into the generator. (Fig 2)

Each blowpipe must have a separate hydraulic safety valve.

Fig 2



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

Flash back arrestor (Fig 1)

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

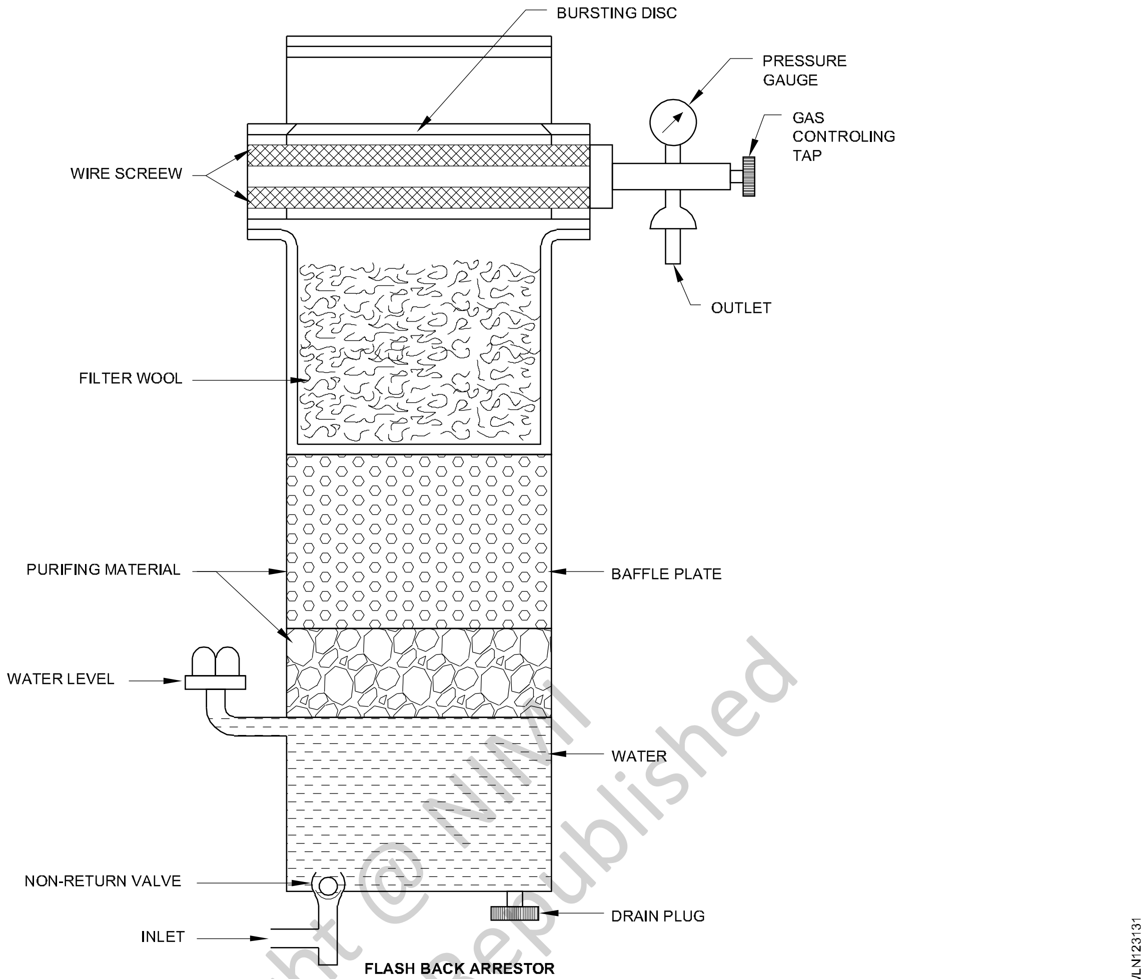
Parts: Flash back arrestor has the following parts

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 screen
10. Bursting disc
11. Pressure gauge
12. Gas controlling tap

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, returm space valve and baffle plate, filter wool. Baffle plate reduces the velocity of acetylene gas whereas the purifying materials purify the generated acetylene gas that goes to outlet through the regulator and gas controlling tap.

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

Fig 1



FLASH BACK ARRESTOR

Oxygen gas - properties and production

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

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

Properties of oxygen gas

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

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

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

Liquid oxygen has a pale blue colour.

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

Iron + oxygen = Iron oxide

Copper + oxygen = Cuprous oxide

Aluminium + oxygen = Aluminium oxide

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

Production of oxygen gas

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

This process is done in three stages.

- purification
- liquification
- Distillation

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

TABLE 1

Composition of air

Name of component	Quantity by volume %	Boiling point °C
NITROGEN	78.0300	-195.80
OXYGEN	20.9300	-182.96
ARGON	00.9325	-185.70
NEON	00.0018	
HELIUM	00.0005	
KRYPTON	00.0001	
XENON	00.000009	
HYDROGEN	00.00005	
CARBON DIOXIDE	00.030000	

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

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

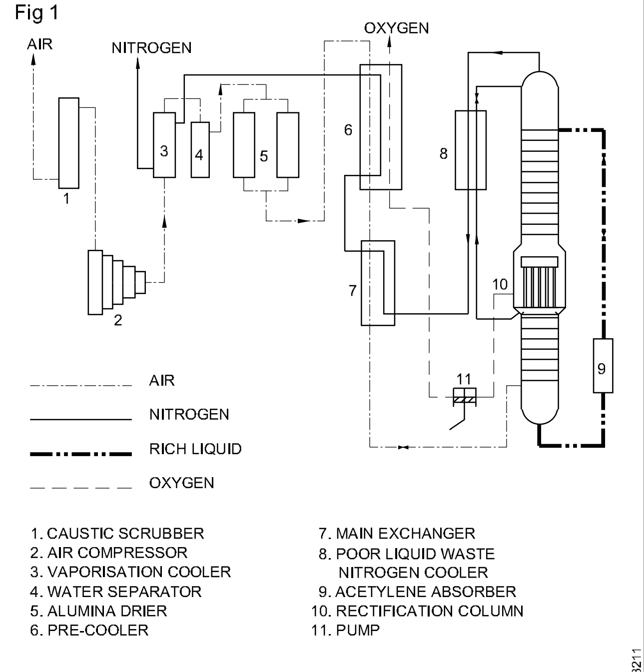
Between nitrogen and oxygen - 13°C

Between nitrogen and argon - 10°C

Between oxygen and argon - 3°C

Steps for separating oxygen (Fig 1)

Fig 1



PRODUCTION OF OXYGEN BY AIR LIQUEFACTION METHOD

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 liquification 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)evapo rates first.

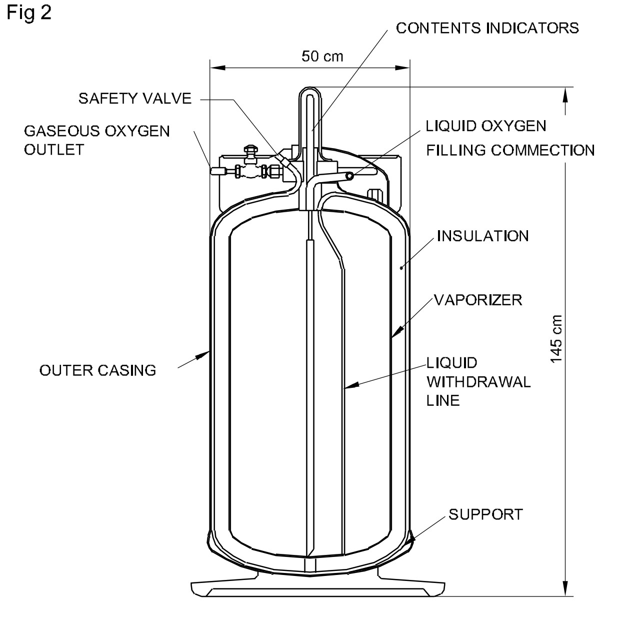
Argon having a boiling point (-185.70°C) evaporates second leaving liquid oxygen in the bottom of the condenser.

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 oxyen gas cylinders.

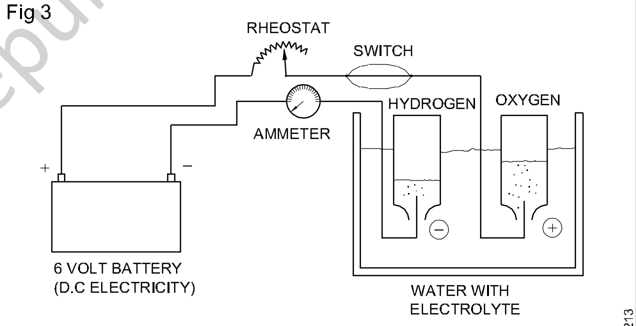
Fig 2



SECTIONAL VIEW OF THE LIQUID OXYGEN VESSEL OR CONTAINER (FLASK TYPE)

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.

Fig 3



PRINCIPLE OF PRODUCING OXYGEN BY ELECTROLYSIS OF WATER METHOD

Caustic soda is added to the water to make it a good electrolyte since pure water will not allow the current to pass.

This method produces two volumes of hydrogen and one volume of oxygen.

The cost of producing oxygen by this method is more the oxygen contains more moisture and it is difficult to obtain 99% purity and the process requires enormous quantity of water and electricity. So the air liquefaction method is more commonly used to produce commercial oxygen with a purity of 99.99%.

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Oxygen gas cylinder

Objectives : At the end of this lesson you shall be able to
- **identify different gas cylinders**
- **explain the constructional features of oxygen gas cylinder and the method of charging.**

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)

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

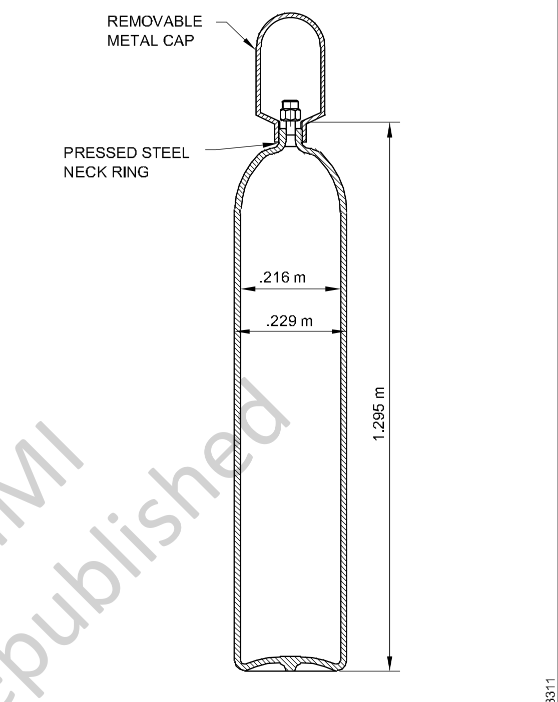
Gas cylinders are identified by their body colour marks and valve threads. (Table 1)

Oxygen gas cylinder: It is a seamless steel container used to store oxygen gas safely and in large quantity under a maximum pressure of 150 kg /cm^2, for use in gas welding and cutting.

Constructional features of oxygen gas cylinder (Fig 1)

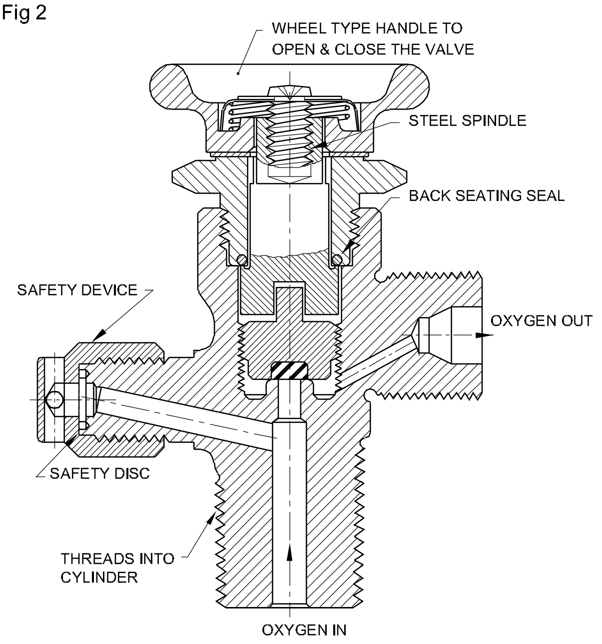
It is made from seamless solid drawn steel and tested with a water pressure of 225kg/cm^2. The cylinder top is

Fig 1



CONSTRUCTIONAL FEATURE OF OXYGEN GAS CYLINDER

Fig 2



CONSTRUCTIONAL FEATURES OF A CYLINDER VALVE 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)

The cylinder body is painted black.

The capacity of the cylinder may be 3.5m^3 - 8.5m^3.

Oxygen cylinders of 7m^3 capacity are commonly used.

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Dissolved acetylene gas cylinder

Objectives: At the end of this lesson you shall be able to
- **describe the constructional features of the DA gas cylinder and the method of charging**
- **state the safety rules for handling gas cylinders**
- **explain the safe procedure to be followed in handling an internally fired DA cylinder.**

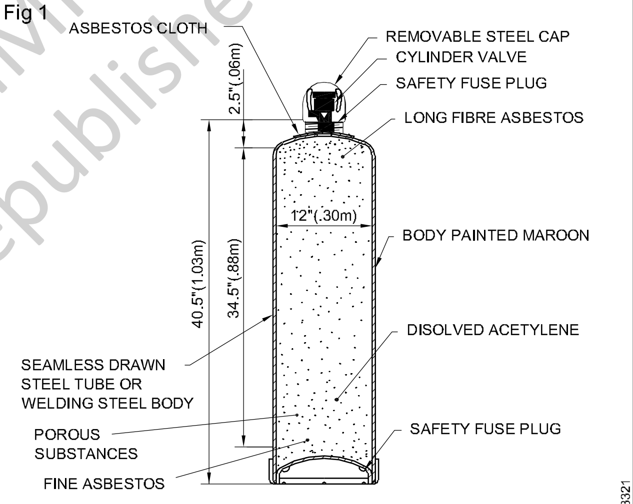
Charging of gas in oxygen cylinder: The oxygen cylinders are filled with oxygen gas under a pressure of 120-150 kg/cm^2. The cylinders are tested regularty and periodically. They are annealed to relieve stresses caused during 'on the job' handling. They are periodically cleaned using caustic solution.

Definition: It is a steel container used to store high pressure acetylene gas safely in dissolved state for gas welding or cutting purpose.

Constructional features (Fig 1): The acetylene gas cylinder is made from seamless drawn steel tube or welded steel container and tested with a water pressure of 100kg/cm^2 The cylinder top is fitted with a pressure valve made from high quality forged bronze. The cylinder valve outlet socket has standard left hand threads to which acetylene regulators of all makes may be attached. The cylinder valve is also fitted with a steel spindle to operate the valve for opening and closing. A steel cap is screwed over the valve to protect it from damage during transportation. The body of the cylinder is painted maroon. The capacity of the DA cylinder may be 3.5m^3-8.5m^3.

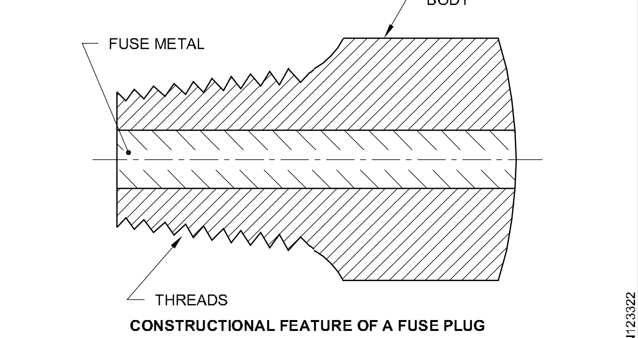
The base of the D A cylinder (Curved inside) is fitted with fuse plugs which will melt at a temperature of app. 100°C. (Fig 2) In case the cylinder is subjected to high temperature, the fuse plugs will melt and allow the gas to escape, before the pressure increases enough to harm or rupture the cylinder. Fuse plugs are also fitted on the top of the cylinder.

Fig 1



CONSTRUCTIONAL FEATURES OF A DISSOLVED ACETYLENE GAS CYLINDER

Fig 2



CONSTRUCTIONAL FEATURE OF A FUSE PLUG FITTED WITH THE CYLINDER TOP AND BOTTOM

Method of charging D A gas cylinder: The storage of acetylene gas in its gaseous form under pressure above 1kg/cm^2 is not safe. A special method is used to store acetylene safely in cylinders as given below.

The cylinders are filled with porous substances such as:

- pith from corm stalk
- fullers earth
- lime silica
- specially prepared charcoal
- Fiber asbestos.

The hydrocarbon liquid named acetone is then charged in the cylinder, which fills the porous substances (1/3rd of total volume of the cylinder).

Acetylene gas is then charged in the cylinder, under a pressure of app. 15 kg//cm^2.

The liquid acetone dissolves the acetylene gas in large quantity as safe storage medium: hence, it is called dissolved acetylene. One volume of liquid acetone can dissolve 25 volumes of acetylene gas under normal atmospheric pressure and temperature. During the gas charging operation one volume of liquid acetone dissolves 25X15=375 volumes of acetylene gas under 15kg/cm^2 pressure at normal temperature. While charging cold water will be sprayed over the cylinder so that the temperature inside the cylinder does not cross certain limit.

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Welding gas regulator

Objectives: At the end of this lesson you shall be able to
- **state the different types of regulators**
- **describe the working principle of a single and double stage regulator**
- **explain the parts of each type of regulator**
- **explain the care and maintenance of the regulators.**

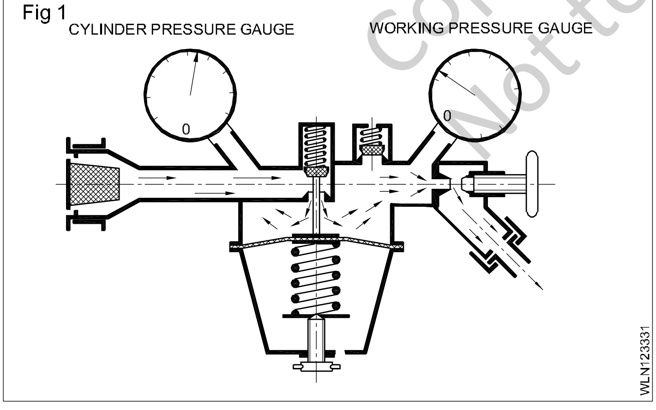
Types of regulators

- single stage regulator
- Double stage regulator

Welding regulator (Single stage)

Working principle: When the spindle of the cylinder is opened slowly, the high pressure gas from the cylinder enters into the regulator through the inlet valve. (Fig 1)

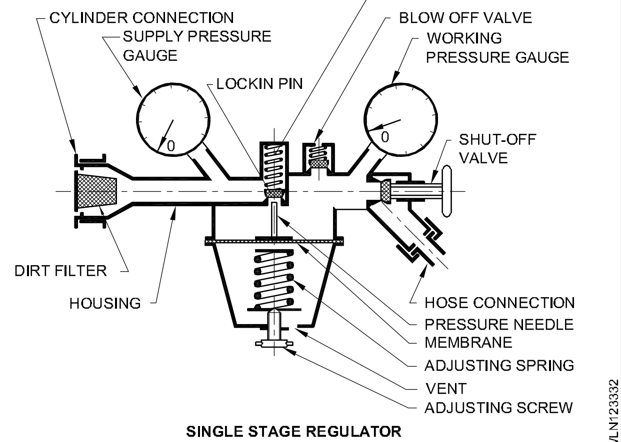
Fig 1



The gas then enters the body of the regulator which is controlled by the needle valve. The pressure inside the regulator rises which pushes the diaphragm and the valve to which it is attached, closes the valve and prevents any more gas from entering the regulator.

The outlet side is fitted with a pressure gauge which indicates the working pressure on the blowpipe. Upon the gas being drawn 'off from the outlet side, the pressure inside the regulator body falls, the diaphragm is pushed back by the spring and the valve opens, letting more gas 'in' from the cylinder. The pressure in the body, therefore, depends on the pressure of the springs and this can be adjusted by means of a regulator knob. (Fig 2)

Fig 2



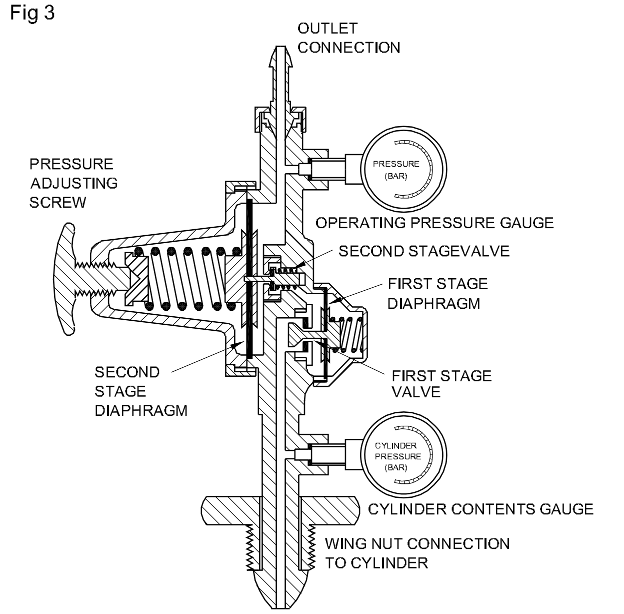
SINGLE STAGE REGULATOR

Welding regulator (double stage)

Working principle: The two-stage regulator (Fig 3) is nothing but two regulators in one which operates to reduce the pressure progressively in two stages instead of one. The first stage, which is pre-set, reduces the pressure of the cylinder to an intermediate stage (i.e,) 5kgf/mm^2 and gas at that pressure passes into the second stage, the gas now emerges at a pressure (Working pressure) set by the pressure adjusting control knob attached to the diaphragm. Two-stage regulators have two safety valves, so that if there is any excess pressure there will be no explosion. A major objection to the single stage regulator is the need for frequent torch adjustment, for as the cylinder pressure falls the regulator pressure likewise falls necessitating torch adjustment. In the two stage regulator, there is automatic compensation for any drop in the cylinder pressure.

Single stage regulators may be used with pipelines and cylinders. Two stage regulators are used with cylinders and manifolds.

Fig 3



TWO STAGE REGULATOR

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Systems of oxy-acetylene welding

Objectives : At the end of this lesson you shall be able to

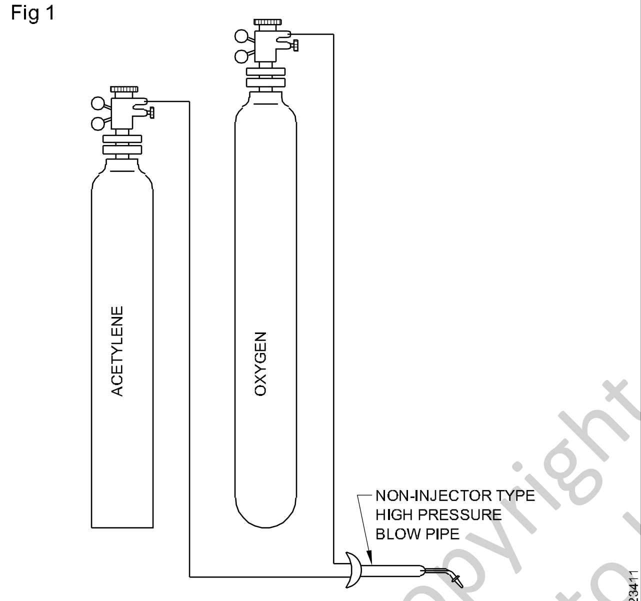
- **explain the low pressure and the high pressure systems of oxy-acetylene plants and systems**
- **distinguish between low pressure and high pressure blowpipes**
- **state the advantages and disadvantages of both systems.**

Oxy-acetylene plants: An oxy-acetylene plant can be classified into:

- high pressure plant
- low pressure plant.

A high pressure plant utilises acetylene under high pressure (15 kg/cm^2). (Fig 1)

Fig 1



HIGH PRESSURE OXY-ACETYLENE PLANT

Dissolved acetylene (acetylene in cylinder) is the commonly used source.

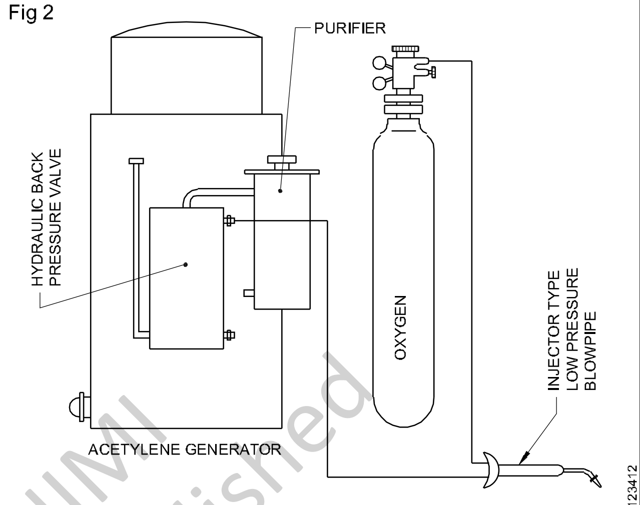
Acetylene generated from a high pressure generator is not commonly used.

A low pressure plant utilizes acetylene under low pressure (0.017 kg/cm^2) produced by the acetylene generator only. (Fig 2)

> **High pressure and low pressure plants utilize oxygen gas kept in compressed high pressure cylinders only at 120 to 150 kg/cm^2 pressure.**

Oxy acetylene systems: A high pressure oxy-acetylene plant is also called a high pressure system.

Fig 2



LOW PRESSURE OXY-ACETYLENE PLANT

A low presure acetylene plant with a low pressure acetylene generator and a high pressure oxygen cylinder is called a low pressure system.

> **The terms low pressure and high pressure systems used in oxy-acctylene welding refer only to acetylene pressure, high or low.**

Types of blowpipes: For the low pressure system, a specially designed injector types blowpipe is required, which may be used for high pressure system also.

In the high pressure system, a mixer type high pressure blowpipe is used which is not suitable for the low pressure system.

To avoid the danger of high pressure oxygen entering into the acetylene pipeline an injector is used in a low pressure blowpipe. In addition a non-return valve is also used in the blowpipe connection on the acetylene hose. As a further precaution to prevent the acetylene generator from exploding, a hydraulic back pressure valve is used between the acetylene generator and the blowpipe.

Advantanges of high pressure system: Safe working and less chances of accidents. The pressure adjustment of gases in this system is easy ang accurate, hence working efficiency is more. The gases being in cylinder are perfectiy under control. The D.A cylinder is portable and can be taken easily from one place to another place.

The D.A cylinder can be fitted with a regulator quickly and easily, thus saving time. Both injector and non-injector type blowpipes can be used. No license is required for keeping the D.A cylinder.

Sequence of steps

Slowly open the cylinder valve.

Open the shut-off valve or pressure reducing valve

Slowly screw in the adjusting screw. (The locking bolt opens.)

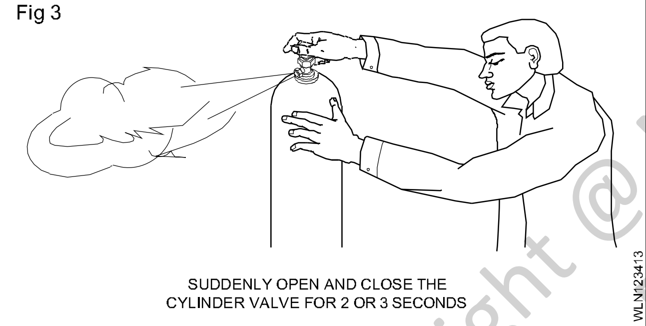
Watch the working pressure gauge.

Turn the adjusting screw until the desired pressure is reached. There is an equilibrium between the bottom adjusting spring and the pressure of the gas on the membrane, which is amplified by the spring of the locking pin.

Care and maintenance of regulators

Check the cylinder connection and crack the cylinder before fixing the regulator. (Fig 3)

Fig 3



Open the cylinder valve slowly and allow the gas to pass to the regulator (cylinder) content gauge.

Loosen the pressure screw.

Do not use oil in regulator connections. (Fig 4)

Do not fix the oxygen and acetylene regulators close together. (Fig 5)

Do not wind the hose on the regulators. (Fig 6)

Use hose-clips before connecting to the regulator.

Use soap water to check the leakage in the acetylene regulator connections and plain water on the oxygen regulator connections Fig 7

Fig 4

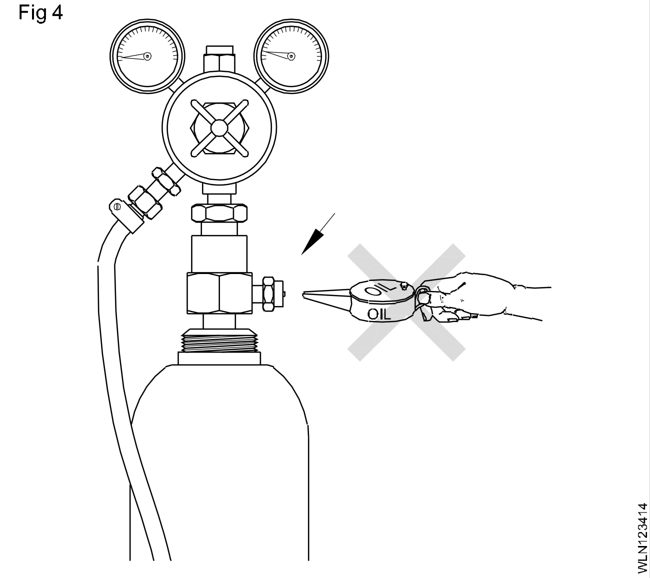


Fig 5

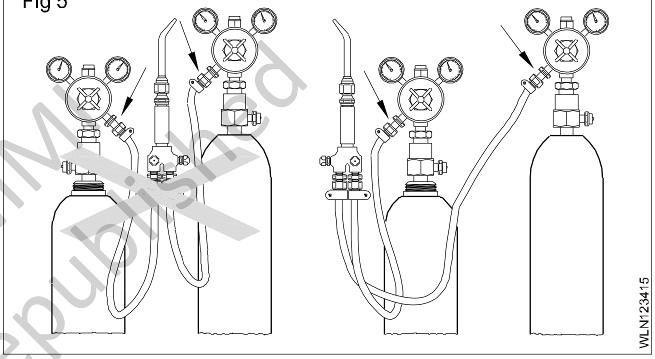


Fig 6

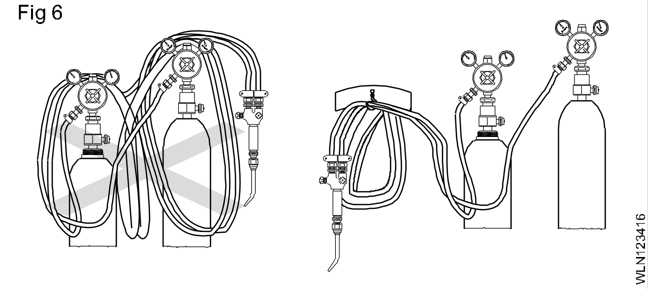
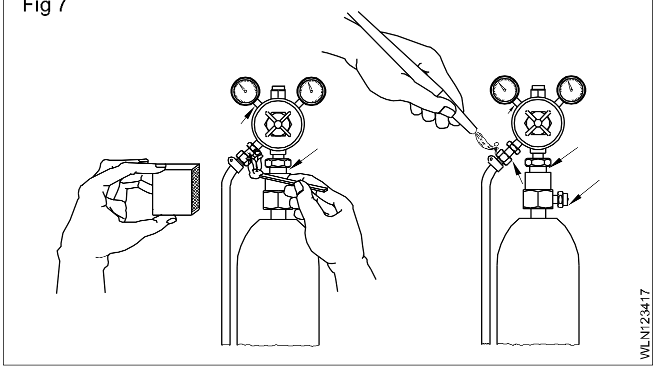


Fig 7



Gas welding torch its type and construction

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

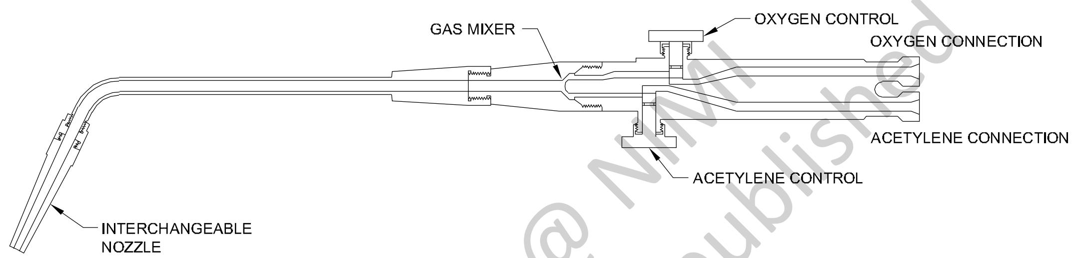
There are two types of blowpipes.

- High pressure blowpipe or non-injector types blowpipe
- Low pressure blopipe or injector type blowpipe.

Uses of blow pipes: Each type consists of a variety of designs depending on the work for which the blowpipe is required, i,e., gas welding, brazing, very thin sheet welding, heating before and after welding, gas cutting.

Equal or high pressure blowpipe (Fig 1): The H.P. blowpipe is simply a mixing device to supply approximately equal volume of oxygen and acetylene to the tip, and is fitted with valves to control the flow of the gases as required i.e, the blow pipes/gas welding torches are used for welding of ferrous and non-ferrous metals, joining thin sheets by fusing the edges, preheating and post heating of jobs, brazing, for removing the dents formed by distortion and for gas cutting using a cutting blow pipe.

Fig 1

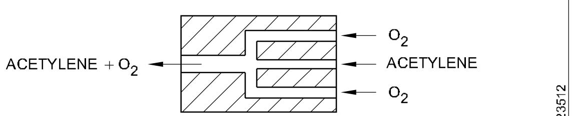


EQUAL OR HIGH PRESSURE BLOWPIPE

The equal pressure blow pipe (Fig.1) consists of two inlet connections for acetylene and oxygen gases kept in high pressure cylinders. Two control valves to control the quantity of flow of the gases and a body inside which the gases are mixed in the mixing chamber (Fig.2). The mixed gases flow through a neck pipe to the nozzle and then get ignited at the tip of the nozzle. Since the pressure of the oxygen and acetylene gases are set at the same pressure of 0.15 kg/cm^2 they mix together at the mixing chamber and flows through the blow pipe to the nozzle tip on its own. This equal pressure blow pipe/torch is also called as high pressure blow pipe/torch because this is used in the high pressure system of gas welding.

Fig 2

GAS PASSAGE IN THE GAS MIXING SECTION



EQUAL PRESSURE TYPE TORCH

A set of nozzles is supplied with each blowpipe, the nozzles having holes varying in diameters, and thus giving various sized flames. The nozzles are numbered with their consumption of gas in litres per hour.

Important caution: A high pressure blowpipe should not be used on a low pressure system.

Low pressure blowpipe (Fig 3)

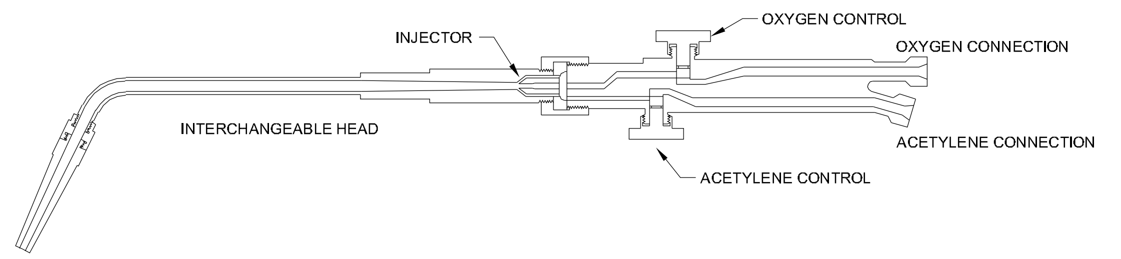
This blowpipe has an injector (Fig 3) inside its body through which the high pressure oxygen passes. This oxygen draws the low pressure acetylene from an acetylene generator into a mixing chamber and gives it the necessary helps to prevent backfiring.

The low pressure blow pipe is similar to the equal pressure blow pipe except that inside its body an injector with a very small (narrow) hole in its center through which high pressure oxygen is passed. This high pressure oxygen while coming out of the injector creates a vacuum in the mixing chamber and sucks the low pressure acetylene from the gas generator (Fig 4)

It is usual for the whole head to be interchangeable in this type, the head containing both the nozzle and injector. This is necessary, since there is a corresponding injector size for each nozzle.

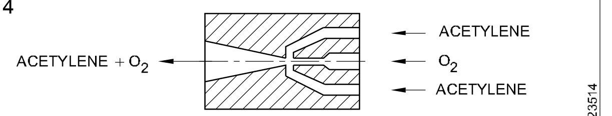
The L.P. blowpipe is more expensive than the H.P. blowpipe but it can be used on a high pressure system, if required.

Fig 3



LOW PRESSURE BLOWPIPE

Fig 4



INJECTOR TYPE TORCH

Care and maintenance

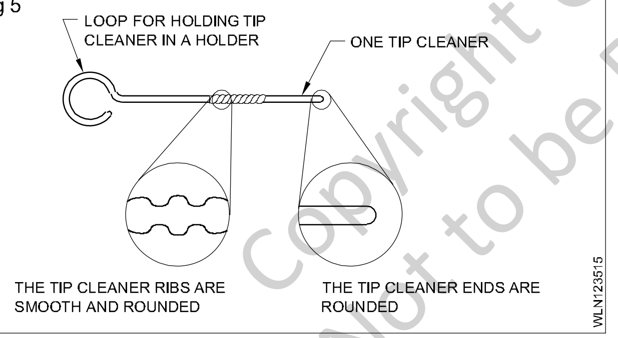
Welding tips made of copper may be damaged by careless handling.

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/scrator on the fitting surfaces when tightening on assembly.

The nozzle orifice should only be cleaned with a tip cleaner specially designed for this purpose. (Fig5,6 &7)

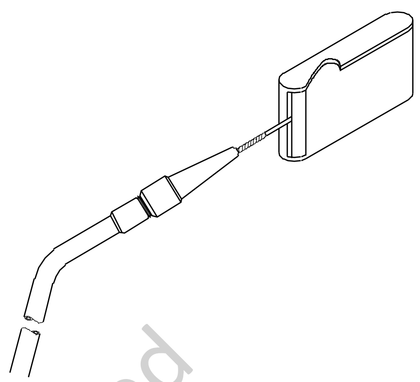
Fig 5



At frequent intervals the nozzle tip should be filed to remove any damage to the tip due to the excessive heat of the flame and the molten metal.

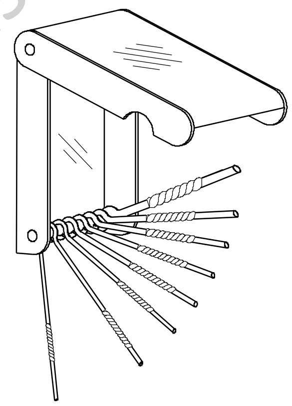
The inlet for acetylene has left hand thread and that for oxygen has right hand thread. Take care to fit the correct hose pipe with the blow pipe inlet. At frequent intervals, put off the flame and dip the blow pipe in cold water.

Fig 7



METHOD OF TIP CLEANING

Fig 6



SET OF DIFFERENT SIZE TIP CLEANERS IN A HOLDER

Welding technique of oxy-acetylene welding

Objectives: At the end of this lesson you shall be able to
- **name the different gas welding techniques and explain the leftward welding techniques**
- **describe the edge preparation and application of leftward techniques.**

There are two welding techniques on oxy-acetylene welding process. They are:

1 Leftward welding technique (Forehand technique)

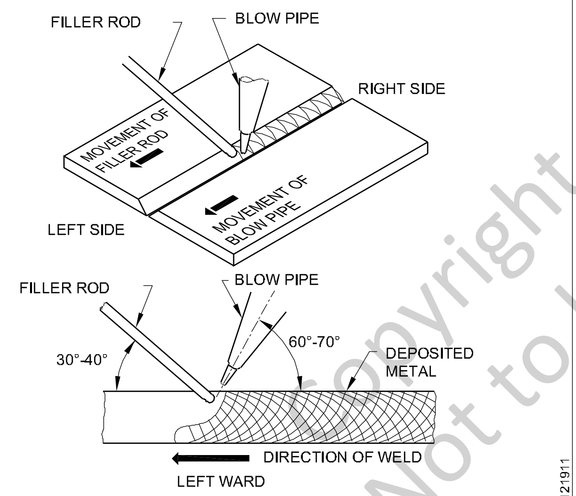
2 Righward welding technique (Backhand technique)

The leftward technique is explained below. For details of rightward technique rfer Related Theory for exercise 2..6.

Leftward welding technique: It is the most widely used oxy-acetylene gas welding technique in which the welding commences at the right hand edge of the welding job and proceeds towards the left. It is also called forwrd 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.

Fig 1



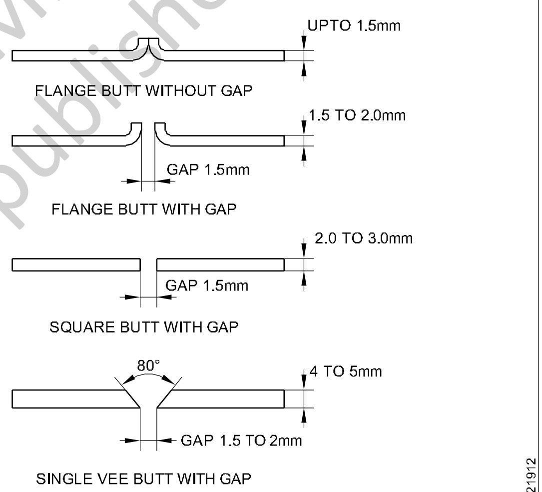
LEFT WARD WELDING TECHNIQUE

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 abtained.

Fig 2



EDGE PREPARATION FOR LEFTWARD TECHNIQUE

Edge preparation for leftward technique: For fillet joints square edge preparation is done.

For butt joints the edges are prepared as shown in fig.2. the table given below gives the details for welding mild steel by lefward technique for butt joints.

Table 1

The table given below shows the details for welding mild steel by leftward technique (For Butt joints)

Metal thiickness in mm	C.C.M.S filler rod diameter in mm	Blow pipe nozzle size	Edge preparation	Root gap in mm	Flux to be used
0.8	1.6	1	Flange	NIL	For gas welding of mild steel no flux is required to be used
1.6 to 2	1.6	3	Square	2	
2.5	2	5	Square	2	
3.15	2.5	7	Square	3	
4	3.15	7	80°Vee	3	
5	3.15	13	80°Vee	3	

For fillet joints one size larger nozzle is to be used.

Above 5.0 mm thickness,the rightward technique should be used.

Application

This technique is used for the welding of:

- mild steel up to 5mm thick
- all metals both ferrous and non-ferrous.

Rightward technique of oxy-acetylene gas welding

Objectives: At the end of this lesson you shall be able to
- **explain rightward welding technique and its advantages.**
- **describe edge preparation and the application of rightward technique.**

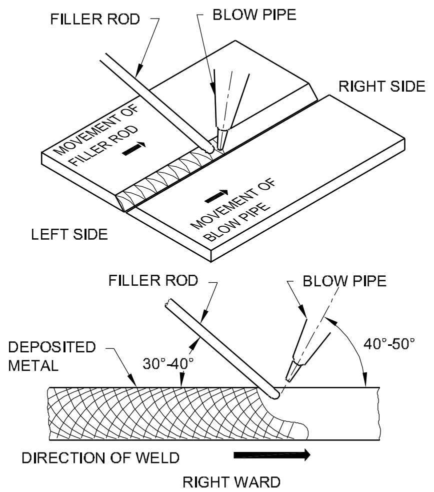
Rightward welding technique: It is an oxy-acetylene gas welding technique, in which the welding is begun at the left hand edge of the welding job and it proceeds towards the right.

This technique was developed to assist the production work on thick steel plates (Above 5mm) so as to produce economic welds of good qulity.

It is also called backward or back hand technique.

the following are its features. (Fig 1)

Fig 1



FEATURE OF RIGHTWARD WELDING TECHNIQUE

WLN123611

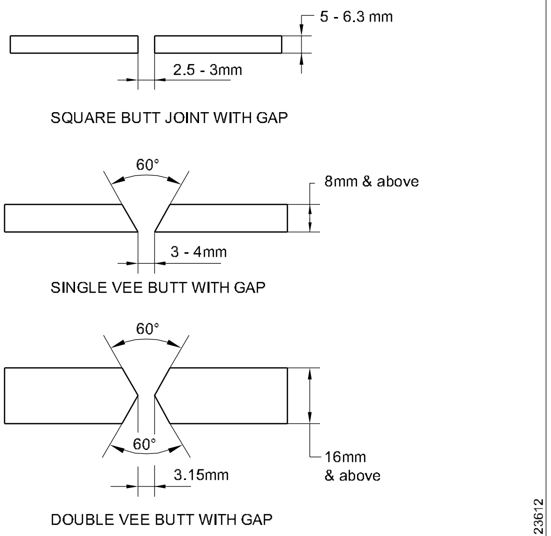
Welding is commenced at the left hand edge of the job and it proceeds to the right. The blowpipe is held at an angle of 40° - 50° with the welding line. The filler rod is held at an angle of 30° - 40° with the welding line. The filler rod follows the welding blowpipe. The welding flame is directed towards the deposited weld metal.

The filler rod is given a rotational or circular loop motion in the forward direction. The blowpipe moves back in a straight line steadily towards the right. This technique generates more heat for fusion, which makes it economical for thick steel plate welding.

Edge preparation for rightward technique (Fig 2)

For butt joints the edges are prepared as shown in fig 2.

Fig 2



EDGE PREPARATION FOR RIGHTWARD WELDING

The table given below gives the details for welding mild steel by rightward welding technique for Butt joints.

Application: This technique is used for the welding of steel above 5mm thickness and 'LINDE' WELDING PROCESS of sheet pipes.

Advantage: Less cost per length run of the weld due to less bevel angle, less filler rod being used, and increased speed. Welds are made much faster.

It is easy to control the distortion due to less expansion and contraction of a smaller volume of molten metal. The flame being directed towards the deposited metal, is allowed to cool slowly and uniformly. Greater annealing action of the flame on the weld metal as it is always directed towards the deposited metal during welding.

We can have a better view of the molten pool giving a better control of the weld which results in more penetration. The oxidation effect on the motion metal is minimized as the reducing zone of the flame provides continuous coverage.

TABLE 1 (For Butt joints)

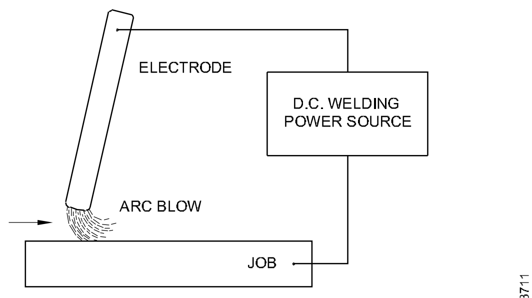
Metal thickness in mm	C.C.M.S filler rod diameter in mm	Blow pipe nozzle size	Edge preparation	Root gap in mm	Flux to be used
5	3.15	10	Square	2.5	For gas
6.3	4.0	13	Square	3.0	welding of mild
8	5.0	18	60°Vee	3.0	steel no flux
10 to 16	6.3	18	60°Vee	4.0	is required to
Above 16	6.3	25	60° double Vee	3.0	be used

Arc blow its causes and remedial measures

Objectives : At the end of this lesson you shall be able to
- **explain the arc blow in DC welding**
- **explain the effects of arc blow on welds**
- **describe the various methods used to control the arc blow.**

Arc blow in dc welding: When the arc deviates from its regular path due to the magnetic disturbances it is called 'Arc blow'. (Fig 1)

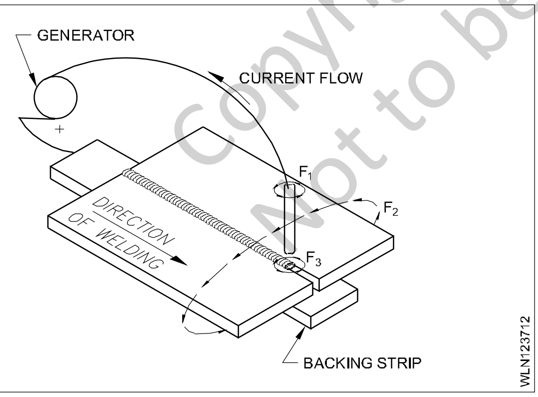
Fig 1



ARC BLOW IN DC ARC WELDING

Causes and effects of arc blow: Whenever a current flows in the electrode a magnetic field is formed around the electrode and the arc F_1 and F_3 (Fig.2). Likewise a similar magnetic field is also formed around the base metal F_2 (Fig 2). Due to the interaction of these two magnetic fields, the arc is blown to one side of the joint. At the starting of the weld there will be forward blow and at the end backward blow. Fig.3

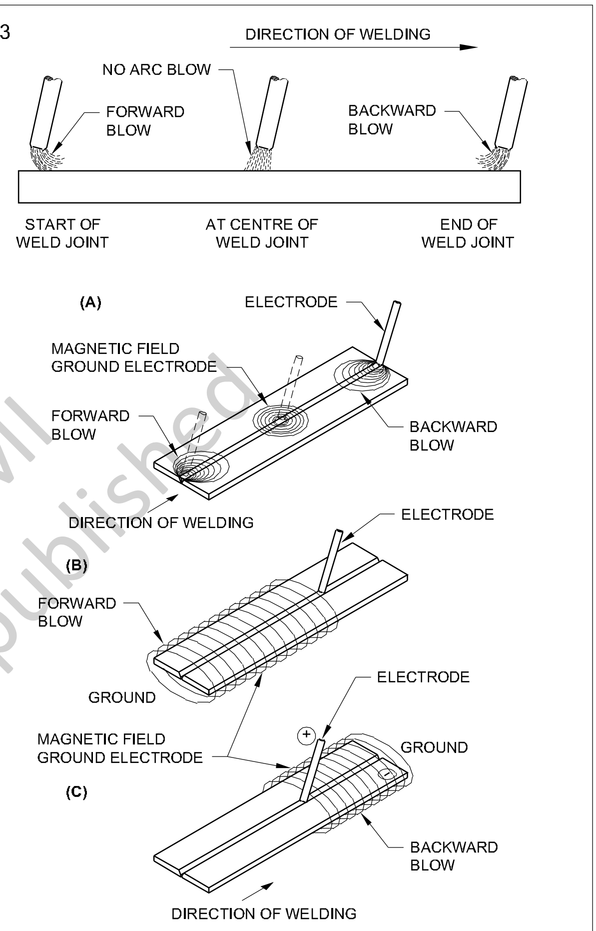
Fig 2



Due to this the following effects occur.

- more spatters with less deposition of weld metal.
- poor fusion/penetration.
- weak welds.
- Difficulty in depositing weld metal at the required place in the joint.
- The bead appearance will be poor and slag inclusion defect will also take place.

Fig 3



MAGNETIC FIELDS THAT RESULT IN FORWARD OR BACKWARD ARC BLOW (A) AROUND THE ELECTRODE/ARC (B) AND (C) AROUND THE WORK

Methods used to control the arc blow

The arc blow can be controlled by:

- Place the earth connection as far from the weld joint as possible (Fig 4)
- changing the position of the earth connection on the work
- Changing the position of the work on the welding table
- wrapping the electrode cable around the work (Fig 5)
- welding towards a heavy welding tack or a weld already made

Fig 4

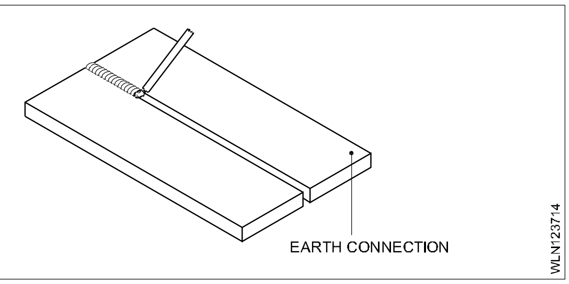
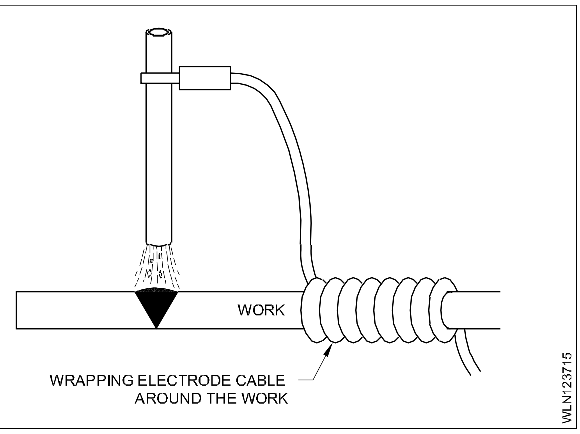


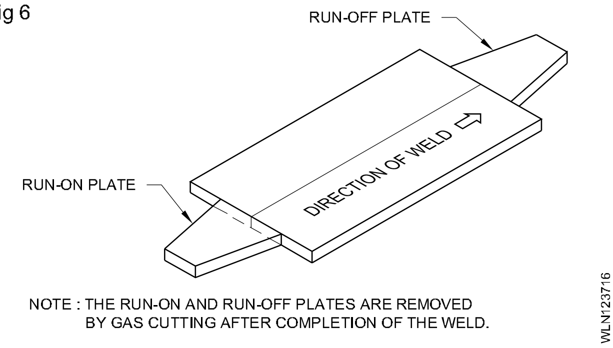
Fig 5



- keeping a magnetic bridge on the top of the groove joint
- holding the correct electrode angle with a short arc. use 'run on' and 'run off plates. Fig6.

If all the above methods fail to control the 'arc blow', change to AC supply.

Fig 6

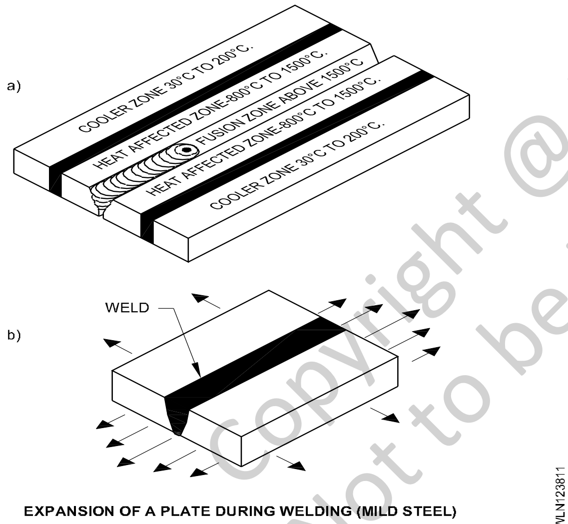


Distortion and its control

Objectives : At the end of this lesson you shall be able to
- **explain the causes of distortion**
- **describe the types of distortion**
- **explain the methods of preventing distortion**
- **explain the methods of correcting distortion.**

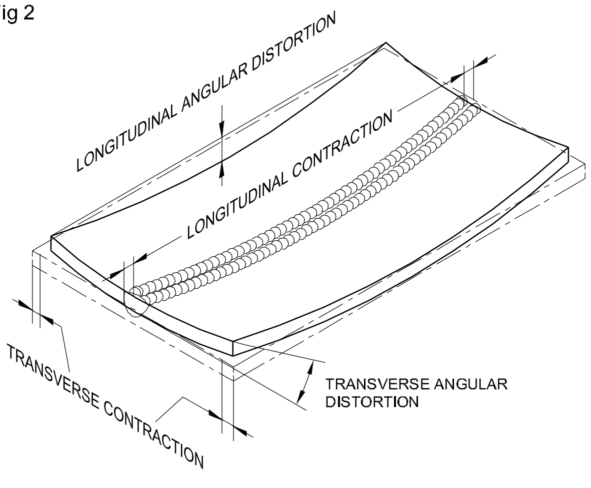
Causes of distortion: In arc welding, the temperature at different areas of the joint are different. (Fig 1a). The expansions in these areas are also different depending on the temperature (Fig 1b). In the same way after welding, different areas of the joint contract differently, But in a solid body (i.e., the parent metal) it cannot expand or contract differently at different areas. This uneven expansion and contraction of the welded joint due to uneven heating and cooling in welding creates stresses in the joint. These stresses make the welded job to change its size and shape permanently (i.e.deformation) and this is called distortion of the welded joint. (Fig 2)

Fig 1



EXPANSION OF A PLATE DURING WELDING (MILD STEEL)

Fig 2



DISTORTION IN SINGLE-SIDED WELDING OF AN UNRESTRAINED BUTT JOINT WITH SEVERAL SMALL RUNS

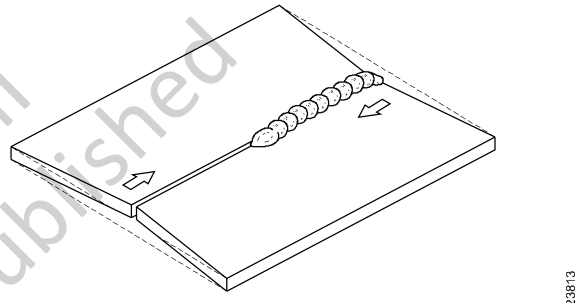
Types of distortion

The 3 types of distortion are:

- longitudinal distortion
- transverse distortion
- angular distortion.

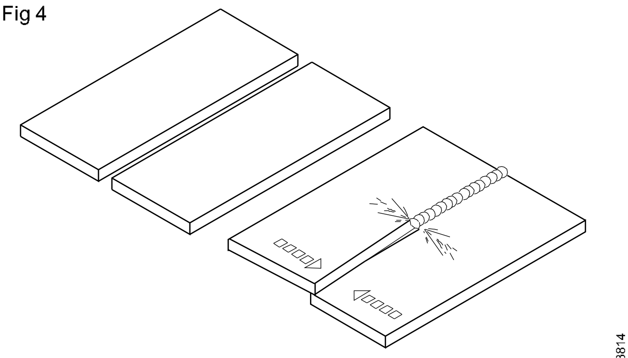
The figures (3,4,5) illustrate the different types of distortion.

Fig 3



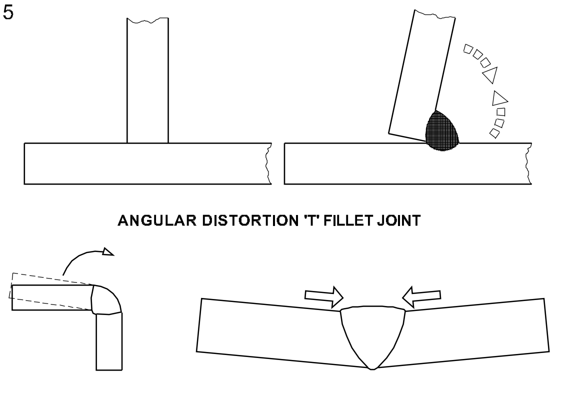
LONGITUDINAL DISTORTION

Fig 4



TRANSVERSE DISTORTION

Fig 5



ANGULAR DISTORTION 'T' FILLET JOINT

OUTSIDE CORNER JOINT SINGLE 'V' BUTT JOINT

Factors affecting distortion

Design

Parent metal

Joint preparation and set up

Assembly procedure

Welding process

Deposition technique

Welding sequence

Unbalanced heating about the neutral axis

Restraint imposed

Either one or more of these above factors are responsible for distortion, in a welded job. To avoid or reduce the distortion in a welding job these factors are to be taken care of-before, during and after welding. The methods adopted to avoid or reduce distortion are as follows.

Prevention of distortion: The following methods are used to prevent and control distortion.

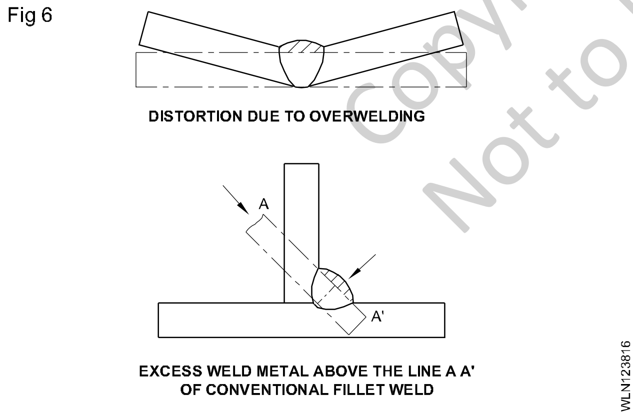
- Reducing the effective shrinkage force.
- Making the shrinkage forces to reduce distortion.
- Balancing the shrinkage force with another shrinkage force.

Methods of reducing the effective shrinkage forces

Avoiding over-welding/Excessive reinforcement: Excessive build up in the case of butt welds and fillet welds should be avoided. (Fig 6)

The permissible value of reinforcement in groove and fillet welds is T/10 where "T" is thickness of parent metal.

Fig 6



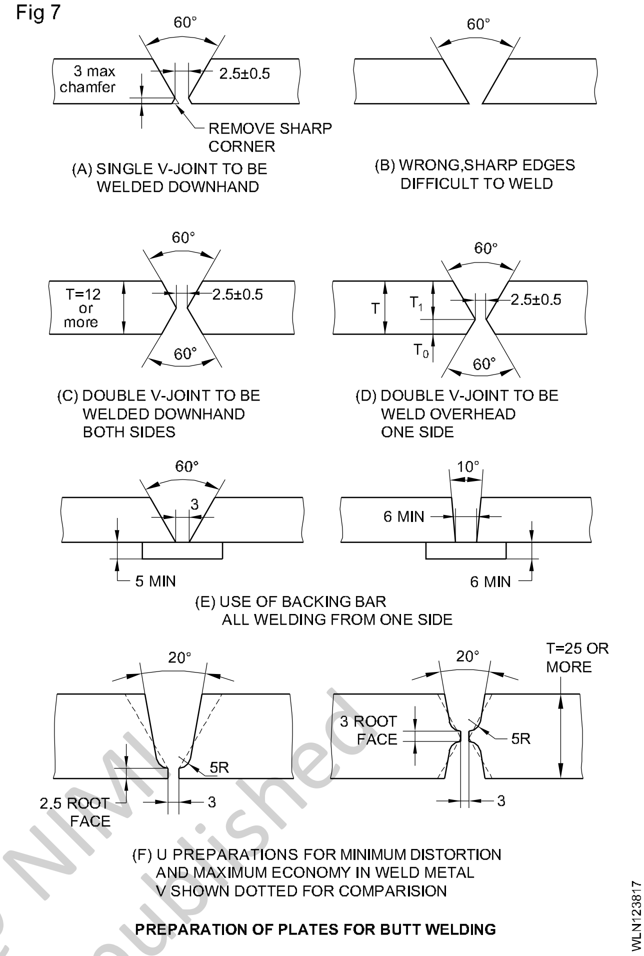
DISTORTION DUE TO OVERWELDING

EXCESS WELD METAL ABOVE THE LINE A A' OF CONVENTIONAL FILLET WELD

Use of proper edge preparation and fit up: It is possible to reduce the effective shrinkage force by correct edge preparation. This will ensure proper fusion at the root of the weld with a minimum of weld metal.(Fig 7)

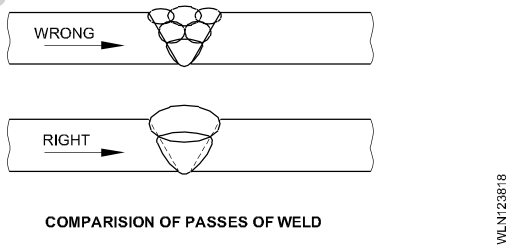
Use of few passes: Use of fewer passes with large dia. electrodes reduces distortion in the lateral direction. (Fiig 8)

Fig 7



PREPARATION OF PLATES FOR BUTT WELDING

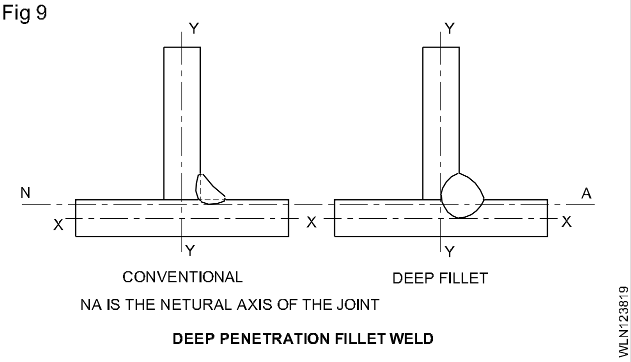
Fig 8



COMPARISION OF PASSES OF WELD

use of deep fillet weld: Place the weld as possible to the neutral axis by using the deep fillet method. This will reduce the leverage of pulling the plates out of alignment. (Fig 9)

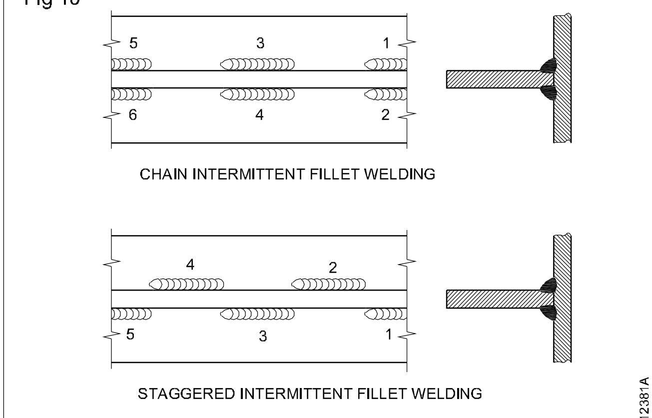
Fig 9



DEEP PENETRATION FILLET WELD

Use of intermittent welds: Minimize the amount of weld metal with the help of intermittent welds instead of continuous welds. This can be used with fillet welds only. (Fig 10)

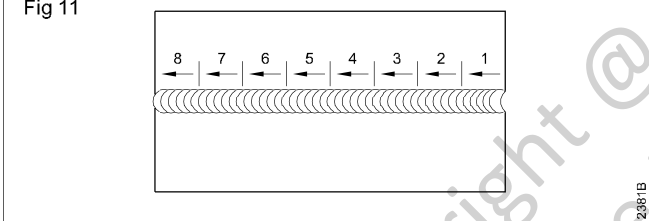
Fig 10



INTERMITTENT WELDING

Use of 'back step' welding method: The general direction of welding progression is from left to right. But in this method each short bead is deposited from right to left. In this method. the plates expand to a lesser degree with each bead because of the locking effect of each weld. (Fig 11)

Fig 11

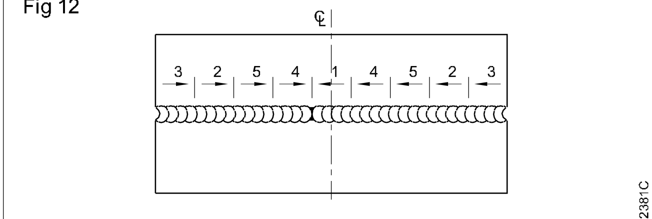


BACK STEP WELDING METHOD

Welding from center: Welding of long joints from centre outwards breaks up the progressive effect of high stresses on continuous weld.

Use of planned wandering method: In this method welding starts at the centre, and thereafter portions are completed on each side of the centre in turn. (Fig 12)

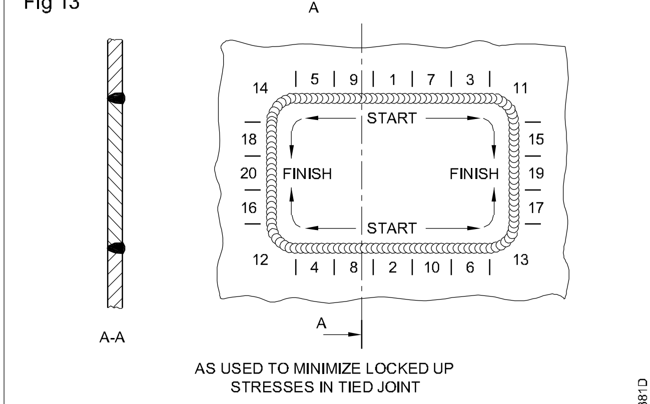
Fig 12



PLANNED WANDERING METHOD

Use of skip welding: In this method, the weld is made not longer than 75 mm at one time. Skip welding reduces locked up stresses and warping due to more uniform distribution of heat. (Fig 13)

Fig 13

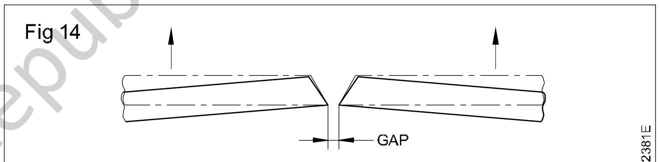


SKIP WELDING

Methods used for making the shrinkage forces work to reduce distortion

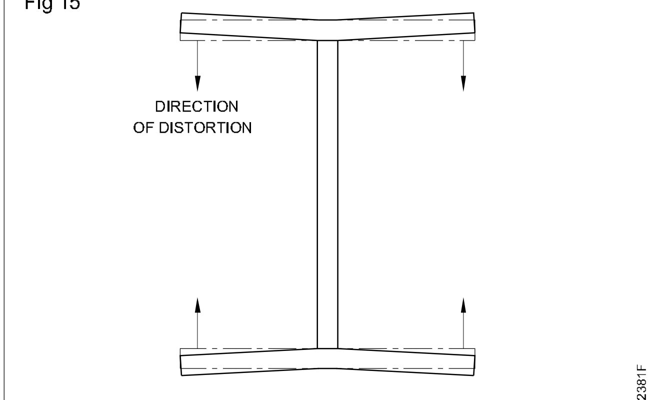
Locating parts out of position: Distortion may be allowed for by pre-setting the plates in the opposite way so that the weld pulls them to the desired shape. When the weld shrinks it will pull the plate to its correct position (Fig 14 & 15)

Fig 14



PRE-SETTING TO COMPENSATE FOR ANGULAR DISTORTION

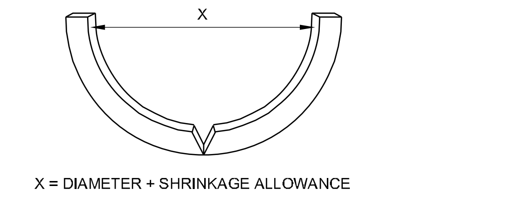
Fig 15



PRE-CAMBERING TO COMPENSATE FOR ANGULAR DISTORTION

Spacing of parts to allow for shrinkage: Correct spacing of the parts prior to welding is necessary. This will allow the parts to be pulled in correct position by the shrinkage force of the welding. (Fig 16)

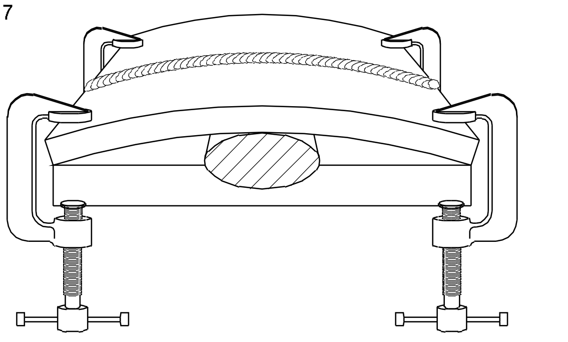
Fig 16



SPACING OF PARTS TO ALLOW FOR SHRINKAGE

Pre-bending: Shrinkage forces may be put to work in many cases by pre-bending. (Fig 17)

Fig 17

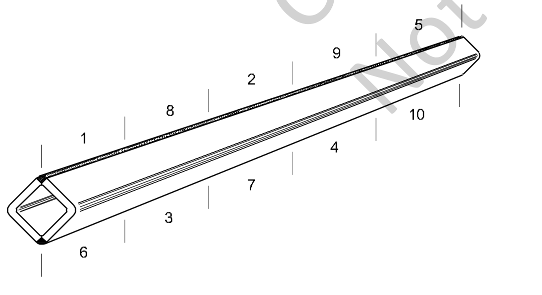


PRE-BENDING

Methods of balancing of one shrinkage force with another shrinkage force

Use of proper welding sequence: This places the weld metal at different points about the structure. In this method, welds are made from each side alternately so that when a second run of weld metal shrinks it will counteract the shrinkage forces of the first weld. (Figs 18, 19 a and 19b)

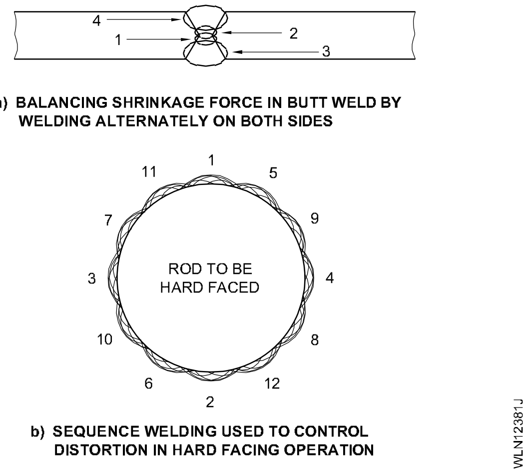
Fig 18



AS USED WHEN FABRICATING SQUARE SECTIONS FROM ANGLES OR CHANNELS

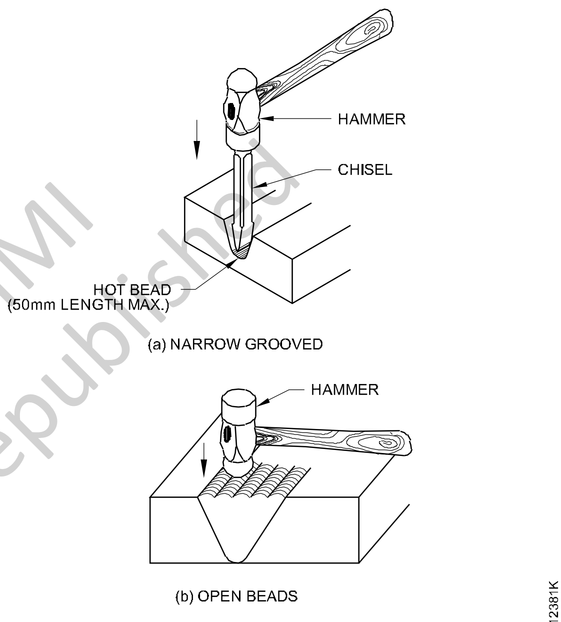
Peening: This is light hammering of the weld metal immediately after it is deposited. By peening the bead, it is actually stretched counteracting its tendency to contract as it cools. Fig 20.

Fig 19



b) SEQUENCE WELDING USED TO CONTROL DISTORTION IN HARD FACING OPERATION

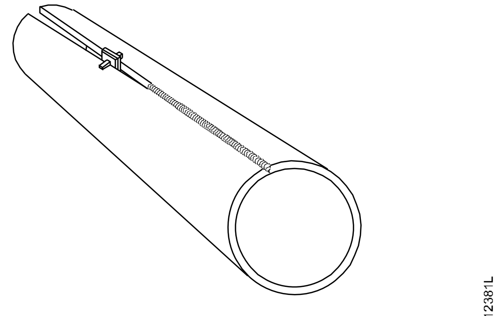
Fig 20



PEENING

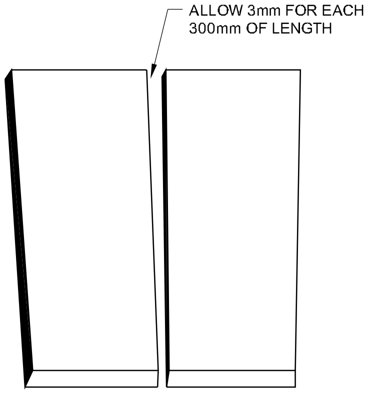
Divergence allowance: As there is a tendency of the plates to extend & converge along the seam during welding, this technique is used to diverge the plates from the point where welding commences by placing a wedge or an alignment clamp between the plates ahead of the weld. (Fig 21)

Fig 21



DIVERGENCE ALLOWANCE

Fig 22



PROVIDE SPACE BETWEEN THE EDGES TO BE WELDED

DIVERGING ALLOWANCE

The spacing allowances are as follows.

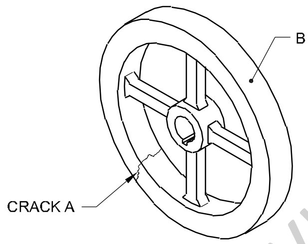
3mm/m for (mild steel) Ferrous metals

10 mm/m for non ferrous metals

While cooling, the shrinkage stresses will pull the plate in correct alignment.

Preheating: Some metals would normally fracture if welded in the cold state. They may be welded successfully by preheating and subsequent controlled cooling. (Fig 23)

Fig 23

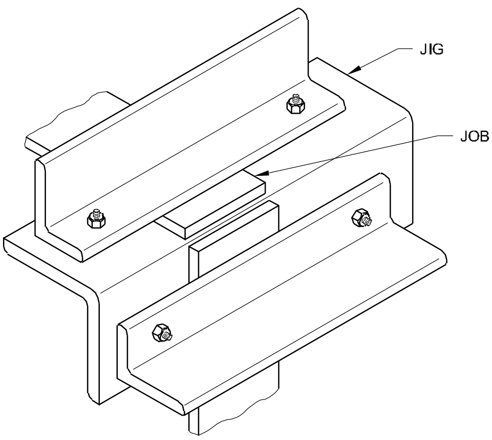


IF THE FRACTURE IN THE WHEEL AT 'A' IS TO BE REPAIRED. THE PREHEATING FLAME SHOULD BE APPLIED AT 'B' TO AVOID CRACKING.

TECHNIQUE OF LOCAL PREHEATING

Jigs and fixtures: Jigs and fixtures are used to hold the work in a right position during welding. By using them the shrinkage forces of the weld are balanced with sufficient counterforce of the jigs and fixtures. (Fig 24)

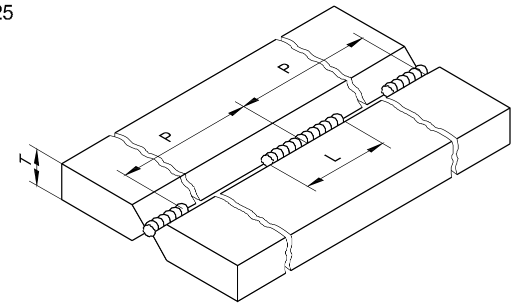
Fig 24



USE OF JIGS AND FIXTURES TO AVOID DISTORTION

Tack-welding: A tack weld is a short weld made prior to welding to hold the plates in perfect alignment and with uniform root gap. Tack welds are made at regular intervals along the joint with high current to obtain proper penetration. (Fig 25) They are necessary where the plates cannot be held by a fixture. (Fig 26)

Fig 25



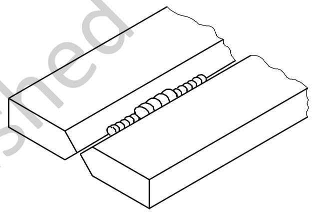
P = 100mm + 16T

L = 3T

WHERE T = PLATE THICKNESS IN mm

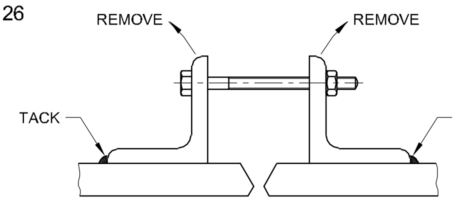
L = LENGTH OF EACH TACK IN mm

TACK WELD IN SINGLE LAYER

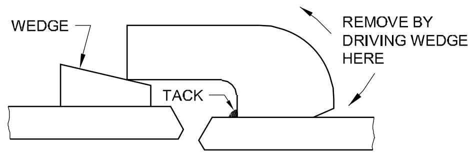


TACK WELD IN TWO LAYERS. TOP WELD IS SHORTER IN LENGTH THAN BOTTOM LAYER.

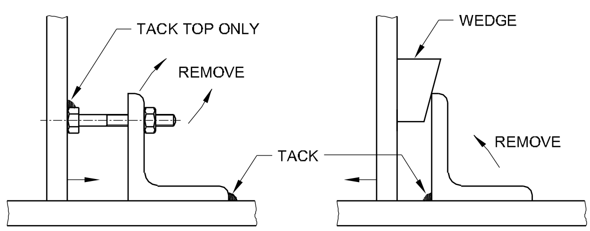
Fig 26



CLOSING A BUTT WELD



LINING UP A BUTT WELD



PULLING INTO POSITION PUTTING INTO POSITION

TACK WELDING ERECTION CLEATS AND AIDS TO ASSEMBLY

Methods of correcting distortion: Distortion may take place even after following a planned procedure as it is difficult to control distortion to the full extent. So some mechanical means and application of heat are used to remove distortion after it occurs.

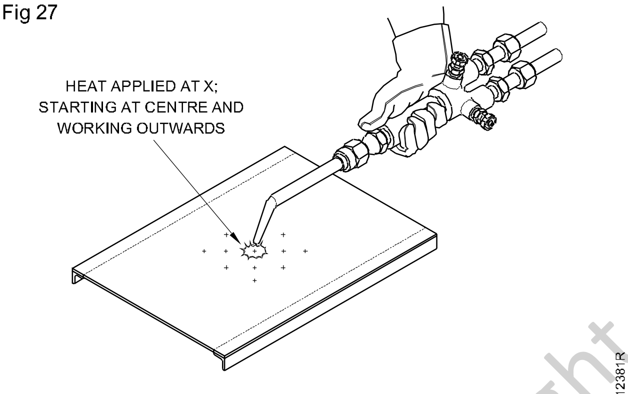
Mechanical methods: Small parts, deformed by angular distortion can be straightened by using a press. If the parts of the assembly are not restrained, they can be brought into alignment by hammering, drifting or jacking without giving excessive force (stress}.

Heating methods: The distorted part is heated locally and rapidly keeping the surrounding metal reasonably cool.

Heat small areas at a time. It should not exceed bright red hot condition.

If thin plates are buckled they can be corrected by local spot heating on the convex side. Starting at the centre of the buckled area heat symmetrically outwards as shown in Fig 27.

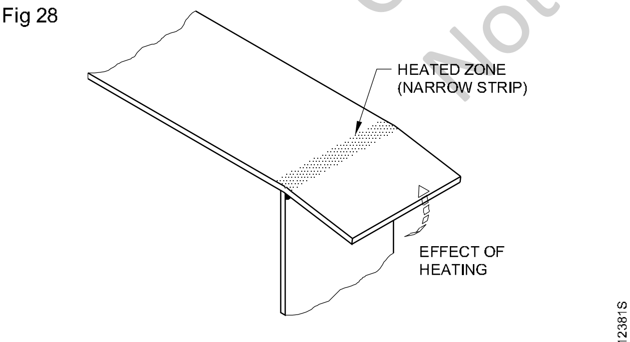
Fig 27



SPOT HEATING TO CORRECT BUCKLING OF THIN SHEET

Correction of distortion caused by fillet welds is done by local heating on the underside of the plate in a narrow strip following the line of the joint. (Fig 28)

Fig 28



CORRECTION OF DISTORTION CAUSED BY FILLET WELD

Straightening by flame heating: The most common distortion-removal technique is to use a flame and heat the part at selected spots or along certain lines and then to aircool it. The area to be straightened is heated to between 600 and 650°C for plain carbon and low alloy steels and suddenly cooled in air, or if necessary with a spray of water in low carbon steels.

The methods of flame straightening are shown in Fig 29.

In Line heating (Fig 29a) heat from the torch is applied along a line or a set of parallel lines. This method is frequently used for removing the angular distortion produced by the fillet welds attaching a plate to its stiffener.

In pipe-needle (Fig 29b) heating, heat is applied along two short lines crossing each other. This method is half way between line heating and spot heating. Since the shrinkage and angular distortion occur in two directions, this method produces a uniform distortion-removal effect.

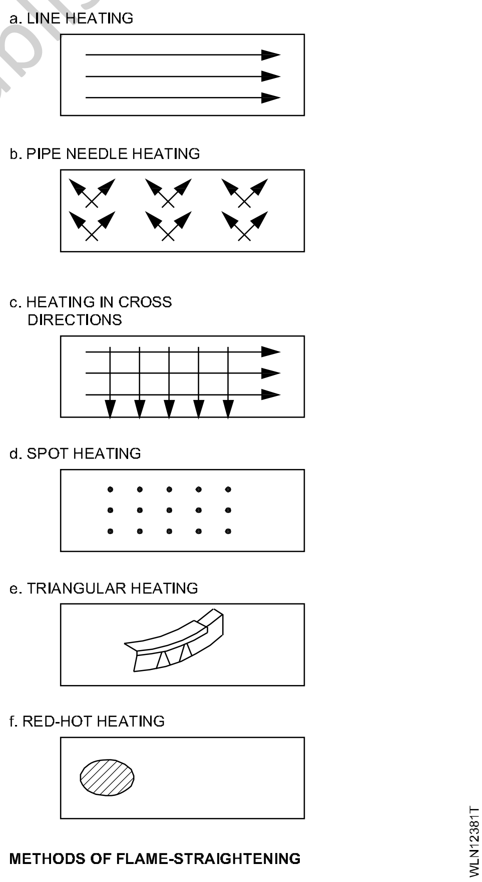
In checker board (cross-directions) heating, (Fig 29c) heat is applied along a pair of two lines crossing each other. This method is used to remove severe distortion.

In spot heating. (Fig 29e) heat is applied on a wedge shaped area, and this method is useful for the removal of bending distortion in frames.

In triangular heating (Fig 29e) heat is applied on a wedgeshaped area, and this mehod is useful for the removal of bending distortion in frames.

Red hot heating (Fig 29f) is used when severe distortion has occured in a localised area, and it may be necessry to heat the area to a high temprature and beat it with a hammer. This method can cause metallurgical changes.

Fig 29



METHODS OF FLAME-STRAIGHTENING

Thermal treatments: To reduce distortion, various thermal treatments are done. They inculde preheat and postweld thermal treatments.

Preheating: Weld shrinkage is generally reduced by preheating. Actual measurements across welds during cooling have shown that less than 30% total contraction occured in joints preheated to 200°C, compared to nonpreheating joints.

Stress relief: In many cases thermal stress relief is necessary to prevent further distortion being developed before the weldment is brought to its finished state. Residual tensile stress in welds are always balanced by compressive reidual stresses. If a considerable portion of the stressed material is machined out, a new balance of residual stress will result, causing new distortion. Weld stress-relieving prior to machining is thus very important for prolonged dimensional accuracy of sliding and rotating parts.

Vibration stress relieving: This technique reduces distortion by means of vibrating the weldments. The equipment consists of a variable speed vibrator, which is clamped to the workpiece, and an electronic amplifier, by varying the speed of the vibrating motor, the frequency can be varied until a resonant frequency has been reached for the workpiece. The piece is then allowed to vibrate for a period which varies in relation to the weight of the workpiece. Usually it ranges from 10 to 30 minutes. 30 to even 50% of the residual stresses are relieved using vibrating methods. The component thus balances roughly its residual stresses, and it remains undistorted

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Defects in arc welding - its effect

Objectives: At the end of this lesson you shall be able to
- **name different weld defects in arc welded joints**
- **define weld defect**
- **state the effect of defects on the welded joints**
- **differentiate between external and internal defects.**

Introduction: The strength of a welded joint should be more than or equal to the strength of the base metal. If any weld defect is in a welded joint, then the joint becomes weaker than the base metal. This is not acceptable.

So a strong or good weld should have uniformly rippled surface, even contour, bead width, good penetration and should not have defect.

Definition of a weld defect/fault: A defect or fault is one which does not allow the finished joint to withstand or carry the required load.

Effects of weld defect/fault: Always a defective welded joint will have the following bad effects.

– The effective thickness of the base metal is reduced.

– The strength of the weld is reduced

– The effective throat thickness is reduced

– The joint will break, when loaded, causing accident.

– The properties of base metal will change.

– More electrodes are required which will also increase the cost of welding.

– Waste of labour and materials.

– The weld appearance will be poor.

Since the weld defects will give bad effects on the joint, always proper care and action has to be taken before and during welding to avoid/prevent the defects. If the defects have already taken place then proper action has to be taken to correct/rectify the defect after welding.

The action/measure taken to avoid/prevent and correct/ rectify a weld defect is also called as a remedy.

So some remedies may help to avoid/prevent a weld defect and some remedies may help to correct/rectify a weld defect which has already taken place.

Weld defect may be considered under two heads.

– External defects

– Internal defects

The defects which can be seen with bare eyes or with a lens on the top of the weld bed, or on the base metal surface or on the root side of the joint are called external defects.

Those defects, which are hidden inside the weld bead or inside the basemetal surface and which cannot be seen with bare eyes or lens are called internal defects.

Some of the weld defects are external defects, some are internal defects and some defects like crack, blow hole and porosity, slag inclusion, lack of root penetration in fillet joints, etc will occur both as external and internal defects.

External defects

1 Undercut

2 Cracks

3 Blow hole and porosity

4 Slag inclusions

5 Edge plate melted off

6 Excessive convexity/Oversized weld/Excessive reinforcement

7 Excessive concavity/insufficient throat thickness/ insufficient fill

8 Incomplete root penetration/lack of penetration

9 Excessive root penetration

10 Overlap

11 Mismatch

12 Uneven/irregular bead appearance

13 Spatters

Internal defects

1 Cracks

2 Blow hole and porosity

3 Slag inclusions

4 Lack of fusion

5 Lack of root penetration

6 Internal stresses or locked-up stresses or restrained joint.

Defects in arc Welding - Definition, Causes and Remedies

Objectives: At the end of this lesson you shall be able to
- **define common weld defects in arc welded joints**
- **describe the causes, remedies and corrections of weld defects.**

A sound or good weld will have uniformly rippled surface, even contour, bead width, good penetration and no defects.

Definition of a defect: A defect is one which does not allow the finished joint to withstand the required strength (load).

Causes for weld defects means wrong actions taken which creates the defect.

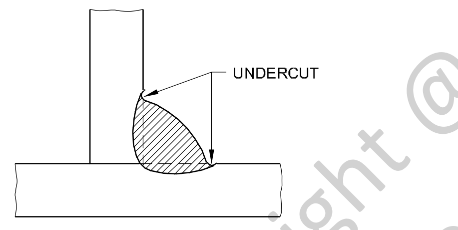
A remedy can be

a. Preventing the defect by taking proper actions before and during welding.

b. Taking some corrective actions after welding to rectify a defect which has already taken place.

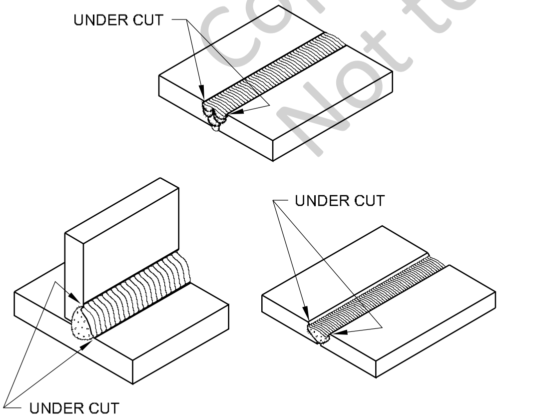
Undercut: A grooved or channel formed in the parent metal at the toe of the weld. (Figs 1, 2 & 3)

Fig 1



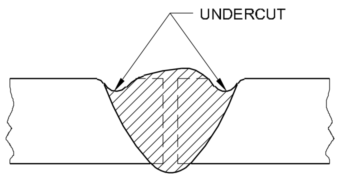
TEE-JOINT FILLET WELD

Fig 2



A SCHEMATIC DIAGRAM OF UNDERCUTS IN FILLET AND BUTT WELDS.

Fig 3



SQUARE-BUTT WELD

Causes

Current too high

Use of a very short arc length

Welding speed too fast

Overheating of job due continuous welding

Faulty electrode manipulation

Wrong electrode angle

REMEDIES

(a) Preventive action

Ensure

- proper current is set
- correct welding speed is used
- correct arc length is used
- correct manipulation of electrode is followed

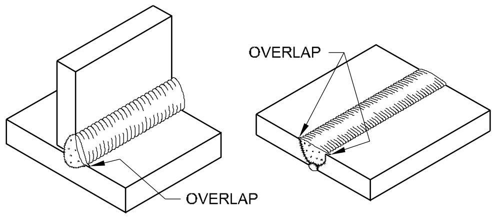
(b) Corrective action

- deposit a thin stringer bead at the top of the weld using a 2mm ø electrode to fill up the undercut.

Overlap

An overlap occurs when the molten metal from the electrode flows over the parent metal surface without fusing into it. (Fig 4)

Fig 4



SCHEMATIC DIAGRAM OF OVERLAP IN FILLET AND BUTT WELDS

CAUSES

Low current.

Slow arc travel speed.

Long arc.

Too large a diameter electrode.

Use of wrist movement for electrode weaving instead of arm movement.

REMEDIES

(a) Preventive actions

Correct current setting.

Correct arc travel speed.

Correct arc length.

Correct diameter electrode as per metal thickness.

Proper manipulation of electrode.

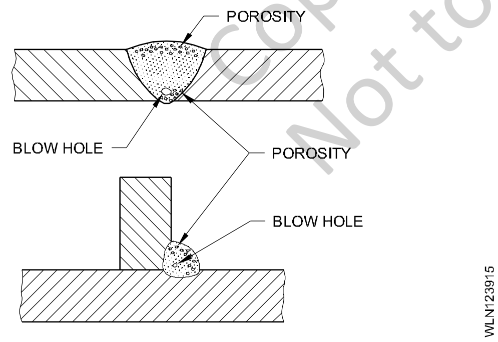
(b) Corrective actions

Remove the overlap by grinding without an undercut.

Blowhole and porosity

Blow hole or gas pocket is a large diameter hole inside a bead or on the surface of the weld caused by gas entrapment. Porosity is a group of fine holes on the surface of the weld caused by gas entrapment. (Fig 5)

Fig 5



CAUSES

Presence of contaminants/impurities on the job surface or on electrode flux, presence of high sulphur in the job or electrode materials. Trapped moisture between joining surfaces. Fast freezing of weld metal. Improper cleaning of the edges.

REMEDIES

(a) Preventive actions

Remove oil, grease, rust, paint, moisture, etc. from the surface. Use fresh and dried electrodes. Use good flux-coated electrodes. Avoid long arcs.

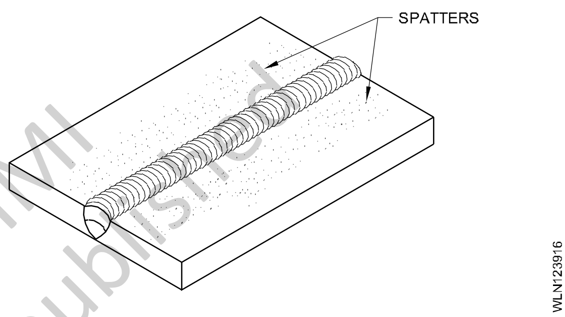
(b) Corrective action

If the blowhole or porosity is inside the weld then gouge the area and reweld. If it is on the surface then grind it and reweld.

Spatter

Small metal particles which are thrown out of the arc during welding along the weld and adhering to the base metal surface. (Fig 6)

Fig 6



CAUSES

Welding current too high. Wrong polarity (in DC). Use of long arc. Arc blow. Uneven flux coated electrode.

REMEDIES

(a) Preventive actions

Use correct current.

Use correct polarity (DC).

Use correct arc length.

Use good flux-coated electrode.

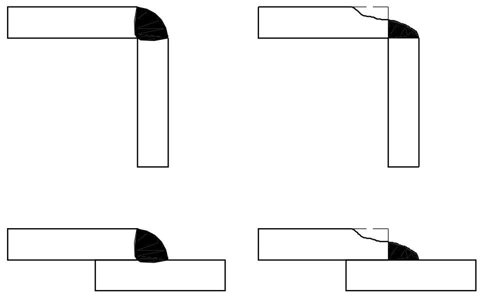
(b) Corrective actions

Remove the spatters using a chipping hammer and wire brush.

Edge of plate melted off

Edge of plate melted off defect takes place in lap and corner joints only. If there is excess melting of one of the plate edges resulting in insufficient throat thickness then it is called edge of plate melted off defect. (Fig 7)

Fig 7



EDGE OF PLATE MELTED OFF

WLN123917

CAUSES

Use of oversize electrode.

Use of excessive current.

Wrong manipulation of the electrode i.e. excessive weaving of electrode.

REMEDIES

(a) Preventive action

Select correct size electrode.

Set correct current.

Ensure correct manipulation of electrode.

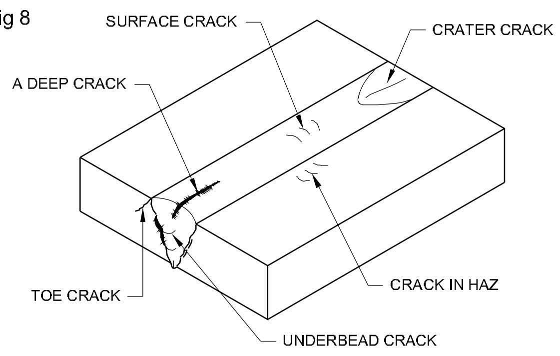
(b) Corrective action

Deposit additional weld metal to increase throat thickness.

Crack

A hairline separation exhibits in the root or middle or surface and inside of the weld metal or parent metal. (Fig 8)

Fig 8



DIFFERENT TYPES OF CRACKS

WLN123918

CAUSES

Wrong selection of electrode.

Presence of localized stress.

A restrained joint.

Fast cooling.

Improper welding techniques/sequence.

Poor ductility.

Absence of preheating and post-heating of the joint.

Excessive sulphur in base metal.

REMEDIES

(a) Preventive actions

Preheating and post-heating to be done on copper, cast iron, medium and high carbon steels.

Select low hydrogen electrode.

Cool slowly.

Use fewer passes.

Use proper welding technique/sequence.

Cracks

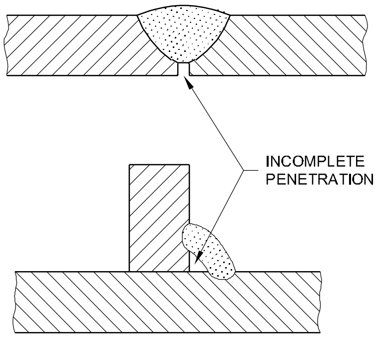
(b) Corrective actions

- For all external cracks to a smaller depth, take a V groove using a diamond point chisel upto the depth of the crack and reweld (with preheating if necessary) using low hydrogen electrode. Cool the job slowly.
- For internal/hidden cracks gouge upto the depth of the cracks and reweld (with preheating if necessary) using low hydrogen electrode. Cool the job slowly.

Incomplete penetration

Failure of weld metal to reach and fuse the root of the joint. (Fig 9)

Fig 9



WLN123919

CAUSES

Edge preparation too narrow - less bevel angle.

Welding speed too much.

Key-hole not maintained during welding the root run of a grooved joint.

Less current.

Use of larger dia. electrode.

Inadequate cleaning or gouging before depositing sealing run.

Wrong angle of electrode.

Insufficient root gap.

REMEDIES

(a) Preventive actions

Correct edge preparation is required.

Ensure correct angle of bevel and required root gap.

Use correct size of electrode.

Correct welding speed is required.

Maintain a key-hole throughout the root run.

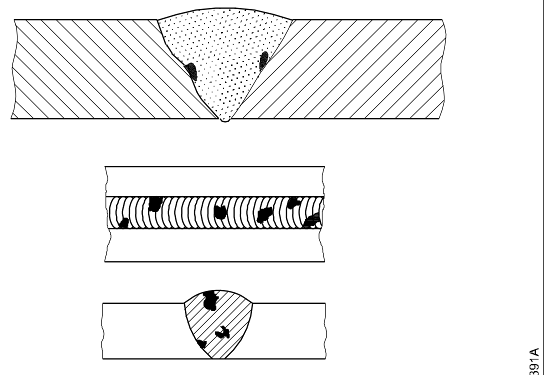
Correct current setting is required.

(b) Corrective actions

For butt welds and open corner welds gouge the root of the joint and deposit the root run from the bottom side of the joint. For a Tee & lap fillet welds blow off the full weld deposit and reweld the joint.

Slag inclusion: Slag or other non-metallic foreign materials entrapped in a weld. (Fig 10)

Fig 10



SLAG INCLUSION IN BUTT WELD

CAUSES

Incorrect edge preparation.

Use of damaged flux coated electrode due to long storage.

Excessive current.

Long arc length.

Improper welding technique.

Inadequate cleaning of each run in multi-run welding.

REMEDIES

(a) Preventive actions

Use correct joint preparation.

Use correct type of flux coated electrode.

Use correct arc length.

Use correct welding technique.

Ensure thorough cleaning of each run in multi-run welding.

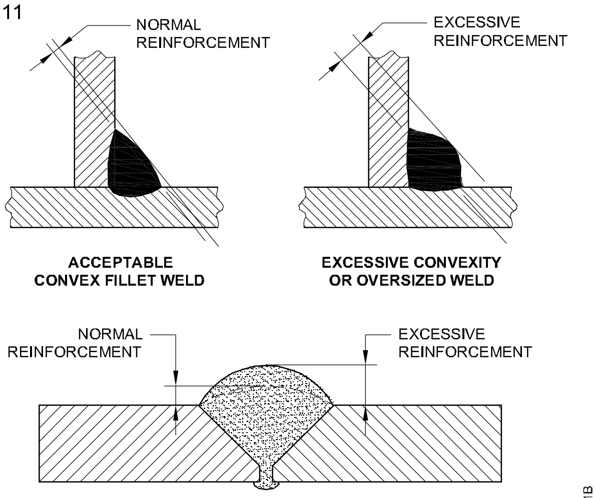
(b) Corrective actions

For external/surface slag inclusion remove them using a diamond point chisel or by grinding and reweld that area. For internal slag inclusions use gouging upto the depth of the defect and reweld.

Excessive convexity (Fig 11)

This defect is also called as oversize weld or excessive reinforcement. It is the extra weld metal deposited in the final layer/covering run.

Fig 11

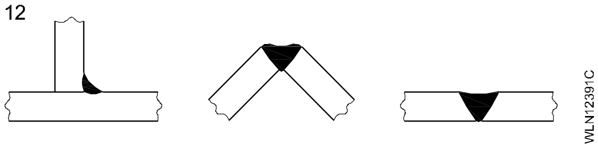


EXCESSIVE CONVEXITY OR OVERSIZED WELD OR EXCESSIVE REINFORCEMENT

Excessive concavity/insufficient throat thickness

If the weld metal deposited into a butt or fillet weld is below the line joining the toes of the weld then this defect is called excessive concavity or insufficient throat thickness. (Fig 12)

Fig 12



CAUSES

- Incorrect bead profile due to improper weaving of electrode.
- Use of small dia. electrode.
- Excessive speed of welding.
- Wrong welding sequence when using stringer beads to fill the groove.
- Sagging of weld metal is not controlled in horizontal position.
- Electrode movement is not uniform.
- Improper electrode angle between the plate surfaces.

Remedies

- Lack of fusion.
- Mismatch.
- Uneven/irregular bead appearance.
- Excessive root penetration.

Pipe joints

Objectives: At the end of this lesson you shall be able to
- **explain the advantages of welded pipes**
- **State different methods of pipes welding**
- **explain the types of pipe joint and pipe welding positions**
- **describe the methods of welding pipes in '1G' position.**

Specification of Pipes

- In a pipe its size is measured by nominal diameter (or) nominal outside diameter (OD).
- It is also mentioned as nominal pipe size (NPS).
- Pipe is normally used to transport gases or liquids in a process.

Tube is normally used for standard purpose and it is mentioned as outside diameter and its wall thickness as tube.

As per Indian standard 1161-1998, it is specified as steel tubes of nominal force, and thickness having outside diameter in mm under light, medium and heavy class.

Refer Table 1 as per IS 1161:1998.

Table 1

Sizes and Properties of Steel Tubes for Structural Purposes

(*Clauses* 3.1, 6.1, 6.1.1 *and* 6.1.2)

Nominal Bore	Outside Diameter	Class	Thickness	Mass	Area of Cross Section	Internal Volume	Surface		Moment of Inertia	Modulus of Section	Radius of Gyration	Square of Radius of Gyration
							External	Internal				
mm (1)	mm (2)	(3)	mm (4)	kg/m (5)	cm^2 (6)	cm^3/m (7)	cm^3/m (8)	cm^3/m (9)	cm^4 (10)	cm^3 (11)	cm (12)	cm^2 (13)
15	21.3	Light	2.0	0.947	1.21	235		543	0.57	0.54	0.69	0.47
		Medium	2.6	1.21	1.53	203	669	506	0.69	0.64	0.66	0.44
		Heavy	3.2	1.44	1.82	174		468	0.75	0.70	0.55	0.42
20	26.9	Light	2.3	1.38	1.78	390		700	1.36	1.01	0.87	0.76
		Medium	2.6	1.56	1.98	370	845	681	1.48	1.10	0.86	0.74
		Heavy	3.2	1.87	2.38	330		644	1.70	1.26	0.84	0.71
25	33.7	Light	2.6	1.98	2.54	638		895	3.09	1.83	1.10	1.21
		Medium	3.2	2.41	3.06	585	1 059	857	3.61	2.14	1.08	1.17
		Heavy	4.0	2.93	3.73	518		807	4.19	2.48	1.05	1.11
32	42.4	Light	2.6	2.54	3.25	1 086		1 168	6.47	3.05	1.41	1.98
		Medium	3.2	3.10	3.94	1 017	1 332	1 130	7.62	3.59	1.39	1.93
		Heavy	4.0	3.79	4.82	929		1 080	8.99	4.24	1.36	1.86
40	48.3	Light	2.9	3.23	4.13	1 418		1 335	10.70	4.43	1.61	2.59
		Medium	3.2	3.56	4.53	1 378	1 517	1 316	11.59	4.80	1.59	2.54
		Heavy	4.0	4.37	5.56	1 275		1 265	13.77	5.70	1.57	2.47
50	60.3	Light	2.9	4.08	5.23	2 332		1 711	21.59	7.16	2.03	4.13
		Medium	3.6	5.03	6.41	2 213		1 667	25.88	8.58	2.00	4.02
		Heavy	4.5	6.19	7.88	2 066		1 611	30.90	10.2	1.98	3.92
65	76.1	Light	3.2	5.17	7.32	3 814		2 189	48.79	12.82	2.58	6.66
		Medium	3.6	6.42	8.20	3 727	2 391	2 163	54.02	14.20	2.57	6.60
		Heavy	4.5	7.93	10.1	3 534		2 107	65.12	17.1	2.54	6.43
80	88.9	Light	3.2	6.72	8.61	5 343		2 591	79.23	17.82	3.03	9.19
		Medium	4.0	8.36	10.7	5 138	2 793	2 540	96.36	21.68	3.00	9.00
		Heavy	4.8	9.90	12.7	4 936		2 490	112.52	25.31	2.98	8.88
90	101.6	Light	3.6	8.70	11.1	6 995		2 964	133.27	26.23	3.47	12.03
		Medium	4.0	9.63	12.3	6 877	3 192	2 939	146.32	28.80	3.45	11.91
		Heavy	4.8	11.5	14.6	6 644		2 889	171.44	33.75	3.43	11.76

Nominal Bore	Outside Diameter	Class	Thickness	Mass	Area of Cross Section	Internal Volume	Surface External	Surface Internal	Moment of Inertia	Modulus of Section	Radius of Gyration	Square of Radius of Gyration
mm (1)	mm (2)	(3)	mm (4)	kg/m (5)	cm^2 (6)	cm^3/m (7)	cm^3/m (8)	cm^3/m (9)	cm^4 (10)	cm^3 (11)	cm (12)	cm^2 (13)
100	114.3	Light	3.6	9.75	12.5	9 004		3 363	192.03	33.60	3.92	15.36
		Medium	4.5	12.2	15.5	8 704	3 591	3 306	234.3	41.0	3.89	15.10
		Heavy	5.4	14.5	18.5	8 409		3 250	274.5	48.0	3.85	14.86
110	127.0	Light	4.5	13.6	17.3	10 930		3 705	325.3	51.2	4.33	18.78
		Medium	4.8	14.5	18.4	10 819	3 990	3 686	344.58	54.27	4.32	18.69
		Heavy	5.4	16.2	20.6	10 599		3 649	382.0	60.2	4.30	18.52
125	139.7	Light	4.5	15.0	19.1	13 410		4 104	437.2	62.6	4.78	22.87
		Medium	4.8	15.9	20.3	13 287	4 389	4 085	463.44	66.35	4.77	22.76
		Heavy	5.4	17.9	22.8	13 043		4 047	514.5	73.7	4.75	22.58
135	152.4	Light	4.5	16.4	20.9	16 142		4 503	572.2	75.1	5.23	27.37
		Medium	4.8	17.5	22.2	16 008	4 788	4 484	606.92	79.65	5.22	27.25
		Heavy	5.4	19.6	25.0	15 740		4 446	674.5	88.5	5.20	27.05
150	165.1	Light	4.5	17.8	22.7	19 128		4 902	732.6	88.7	5.68	32.27
		Medium	4.8	18.9	24.2	18 981	5 187	4 883	777.32	94.16	5.67	32.14
		Heavy	5.4	21.3	27.1	18 690		4 845	864.7	105.0	5.65	31.92
150	168.3	Light	4.5	18.2	23.1	19 921		5 002	777.2	92.4	5.79	33.56
		Medium	4.8	19.4	24.7	19 771	5 287	4 983	824.78	98.01	5.78	33.42
		Heavy 1	5.4	21.7	27.6	19 473		4 946	917.7	109.0	5.76	33.21
		Heavy 2	6.3	25.2	32.0	19 030		4 889	1 053	125.0	5.73	32.85
175	193.7	Light	4.8	22.4	28.5	26 606		5 781	1 271.71	131.31	6.68	44.63
		Medium	5.4	25.1	32.0	26 260	6 085	5 743	1 417	146	6.66	44.36
		Heavy	5.9	27.3	34.8	25 974		5 712	1 535.2	158.65	6.64	41.11
200	219.1	Light	4.8	25.4	32.3	34 454		6 578	1 856.51	169.47	7.58	57.45
		Medium	5.6	29.5	37.5	33 930	6 883	6 528	2 141	195	7.55	57.02
		Heavy	5.9	31.0	39.5	33 734		6 509	2 247	205	7.54	56.86
225	244.5	Heavy	5.9	34.7	44.2	42 507	7 681	7 307	3 149	258	8.44	71.21
250	273.0	Heavy	5.9	38.9	49.5	53 557	8 578	8 202	4 412	323	9.45	89.30
300	323.9	Heavy	6.3	49.3	62.8	76 073	10 177	9 775	7 992	493	11.2	125.44
350	355.6	Heavy	8.0	68.6	87.3	90 533	11 173	10 663	13 111	737	12.3	151.29

Welded pipe joints

Pipes of all types and sizes are used in great deal today in transporting oil, gas, water etc. They are also used extensively for piping systems in building, refineries and industrial plants.

Advantages of welded pipe

Pipes are mostly made of ferrous and non-ferrous metals and their alloys. They possess the following advantages.

- Improved overall strength.
- Ultimate saving in cost including maintenance.
- Improved flow characteristics.
- Reduction in weight due to its compactness.
- Good appearance.

Method of pipes welding

The following are the methods of pipe welding by arc.

- Metallic arc welding
- Gas metal arc welding
- Tungsten inert gas welding
- Submerged arc welding
- Carbon arc welding

All these methods, except carbon arc welding are commonly used and the choice of welding depends upon the size of the pipe and its application.

Types of pipe joints

1 Butt joint
2 'T' joint
3 Lap joint (Fig 1)
4 Angle joint
5 composite joint
6 Pipe flange joint
7 Y joint (Fig 2)
8 Elbow joint (Fig 3)

Welding of pipe butt joints: Normally joints in pipes and tubes cannot be welded from the inside of the bore. Hence before starting to learn pipe welding, a person should be proficient in welding in all positions i.e. flat, horizontal, vertical and overhead.

All these positions are used to weld pipes.

Pipes welding positions (Figs 4 and 5)

Fig 1

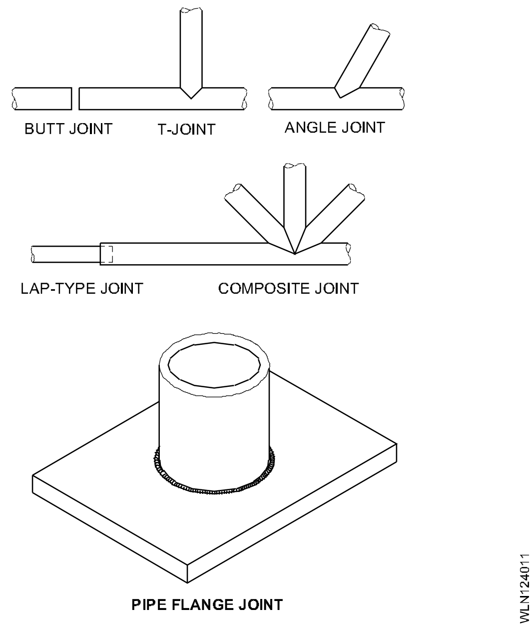


Fig 2

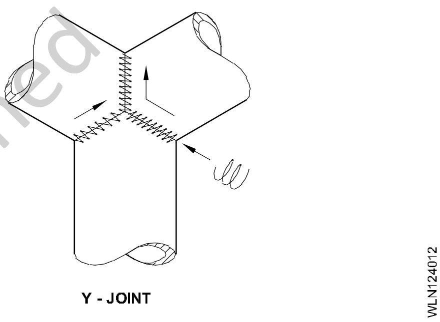
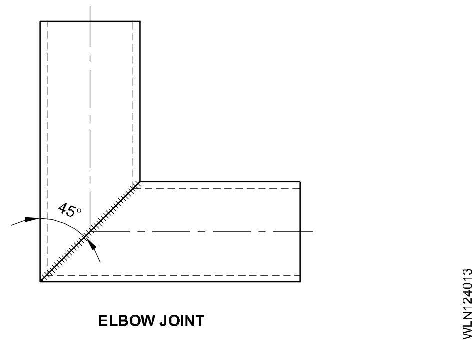


Fig 3



1 G - Pipe weld in flat (roll) position i.e. pipe axis is parallel to the ground.

2 G - Pipe weld in horizontal position i.e. pipe axis is perpendicular to the ground.

5 G - Pipe weld in flat (fixed) position i.e. pipe axis is parallel to the ground.

6 G - Pipe weld in including (fixed) position i.e. pipe axis is including to both horizontal and vertical planes.

Fig 4

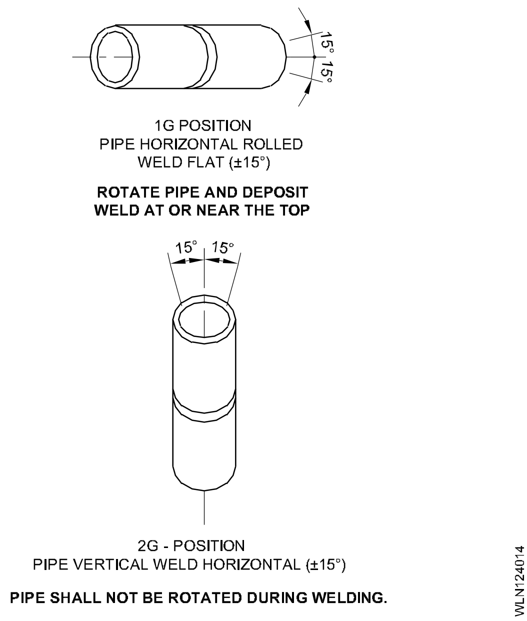
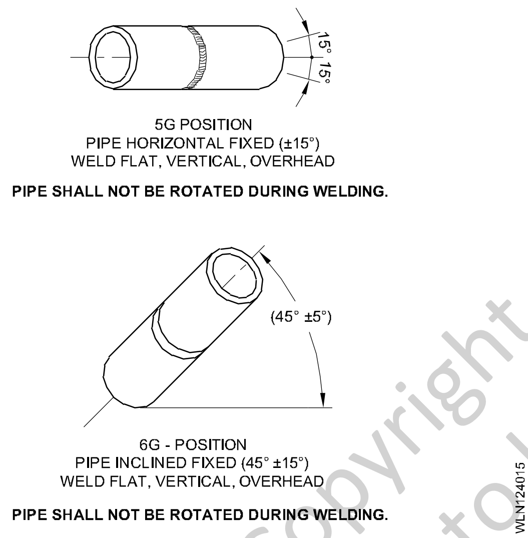


Fig 5



During the welding of butt joints the pipe may be

1 rolled or rotated (1G position)

2 fixed (2G, 5G and 6G position).

Welding of pipe butt joints by arc can be done in 1G position by (a) continuous rotation method and (b) Segmental method.

1a Pipe welding by arc (in 1G position) by continuous rotation method: Satisfactory welding of butt joints in pipes depends upon the correct preparation of pipe ends and careful assembly of the joint to be welded. Ensure that the bores and root faces are in correct alignment and that the gap is correct.

Clean the edges. Prepare an angle of bevel 35° by gas cutting and filing. A root face 1.5 to 2.5 mm is to be provided.

Setting the pipes for welding: Tack weld together with 4 small equally spaced tacks. The gap should be equal to the root face dimension plus 0.75 mm. Support the tacked assembly on V blocks or rollers so that the assembly can be rolled or rotated with the free hand.

Select a 2.5 mm rutile electrode for 1st run and a 3.15 mm rutile electrode for 2nd run.

Set a current of 70-80A for 1st run and 100-110 for the 2nd run.

Rotate the assembly as welding proceeds. (Fig 6) keeping the welding arc within an area between vertical and 10° from the vertical in the direction of welding Fig 7. (Use a helmet type screen).

Fig 6

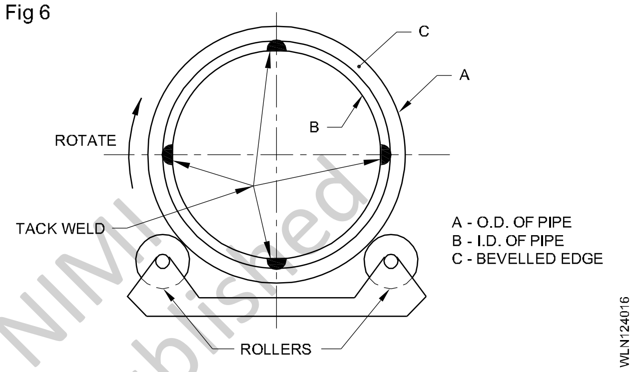
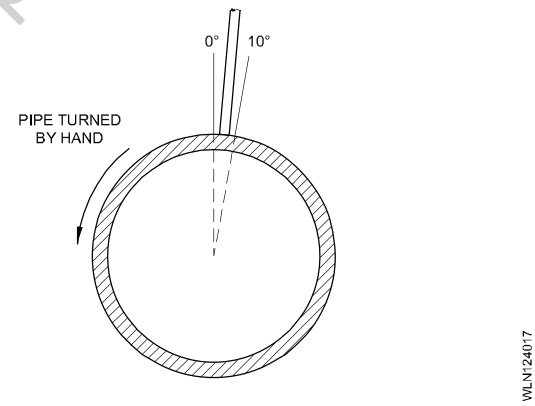


Fig 7



– Direct the electrode centrally at the root of the joint and in line with the radius of the pipe at the point of welding.

– Strike the arc near the top dead centre and hold the arc length as short as possible. Continue to weld as the pipe is rotated manually at steady speed.

– Deposit first run by weaving the electrode very slightly from root face to root face.

– Adjust the speed of rotation to obtain full fusion of the root faces without excessive penetration.

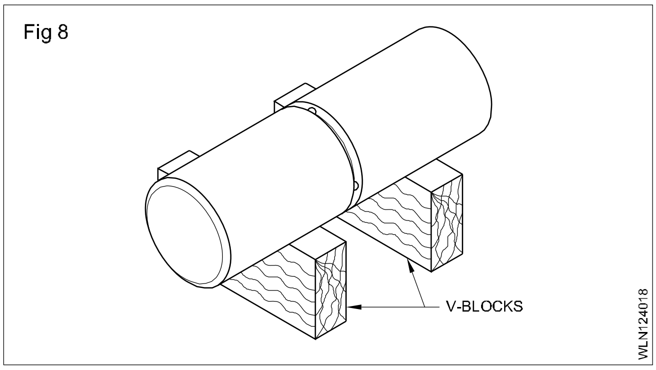
– Chip out tack weld as they are approached. Do not weld over tacks otherwise loss of penetration at the tacking points may occur.

- Complete the weld with the second run. Adjust the speed of rotation to secure fusion to the outer edge of each fusion face. The amount of reinforcement should be even around the edge of the joint.

1b Welding of a pipe butt (IG position i.e. by rotation) by segmental welding.

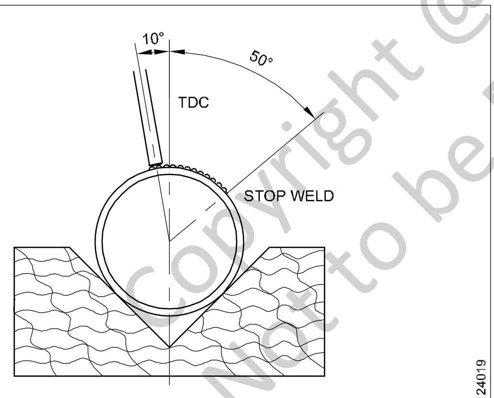
- The edges of the pipe are bevelled to 35 to 40° angle with a root gap of 2.5 mm.
- Tack the pipe as before and support the assembly on two vee blocks. (Fig 8)

Fig 8



- Strike the arc at 10° from Top Dead Centre (TDC) and deposit the root run. Use a small weaving motion to achieve fusion of the root faces. Adjust travel speed to control root penetration. (Fig 9)

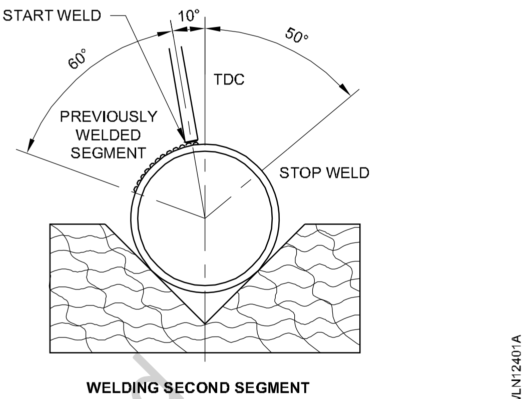
Fig 9



WELDING FIRST SEGMENT

- When a segment equivalent to 60° has been welded, terminate/stop the weld run. Avoid the formation of a crater.
- Move the pipe until the end of the segment is at 10° before TDC.
- Strike the arc on the end of the previous weld run and establish a weld pool.
- Weld a further 60° segment. (Fig10)

Fig 10



WELDING SECOND SEGMENT

- Continue welding in segments until the root run has been completed.
- Move the pipe until the mid point of the segments is at TDC.
- Strike the arc and deposit the second (filling) run, use a side-to-side weaving position to fill the preparation and to achieve fusion of the pipe edges.
- Complete the filling run in 60° segments.

Pipe welding by arc in fixed positions

Objectives: At the end of this lesson you shall be able to
- **state different fixed pipe welding positions**
- **explain different methods of pipe welding in 5G position**
- **explain the welding producer of M.S. pipe butt joint by arc in fixed (5G) position.**

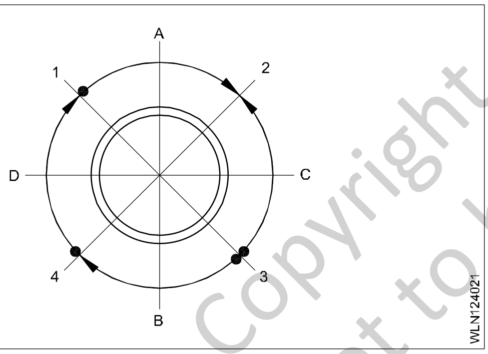
Whenever the pipes to be welded cannot be rotated or whenever the pipes are to be welded in the field i.e. at worksite, then they are welded in fixed position. If the fixed pipe axis is horizontal, then the welding position is called 5G position.

The other pipe welding positions in which the pipes are fixed during welding are 2G and 6G positions. If the axis of the fixed pipes to be welded are vertical then this position is called 2G position. If the axis of the fixed pipes in inclined at 45° to both horizontal and vertical planes, then the welding position is called 6G position.

In 5G position, a pipe butt joint can be welded by the following method.

Method 1: The pipe joint circumference is divided into four positions as A, B, C and D. First portion 'A' is welded from 1 to 2 in more or less in flat position. Then portion B is welded from 3 to 4 in overhead position. Next portion C from 3 to 2 and then portion D from 4 to 1 are welded in vertical up position. (Fig 1)

Fig 1



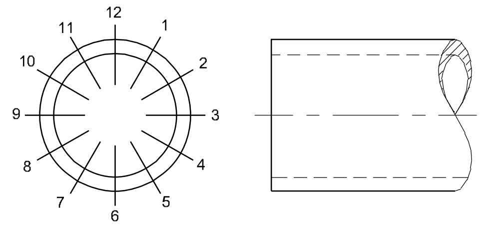
It is important that a key hole is maintained throughout the welding operation to ensure proper root penetration. Also the electrode position is continuously changed as the joint surface is curved. In addition, the starting and ending of each weld portion i.e. A, B, C and D properly done so that they merge with the previous portion.

Method 2: The pipe outer circumference is divided into 12 equal divisions as in a clock.

The top of the pipe is 12 O'clock position and the bottom is in 6 O'clock position. (Fig 2)

The weld is started from 12 O'clock position to 6 O'clock position on the right side vertically downwards. Then welding is done again from 12 O'clock to 6 O'clock position on the left side (Fig 3). This method is called down hill method and is normally used for thin walled pipes with wall thickness of 3 to 4 mm.

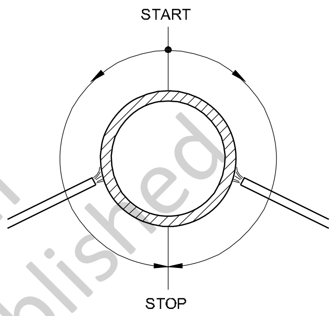
Fig 2



THE IDENTIFICATION OF THE WELDING POSITION AROUND THE THE PIPE JOINT BYTHE NUMBERS ON THE FACE OF A CLOCK.

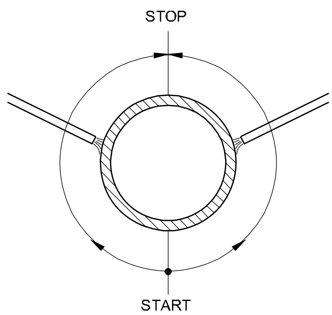
WLN124022

Fig 3



Method 3: The weld is started from 6 O'clock to 12 O'clock position on the right side first and then again from the 6 O'clock to 12 O'clock position on the left side (Fig4). This method is called uphill method or vertical up method. This uphill method is used to weld pipes of 5 mm and above wall thickness.

Fig 4

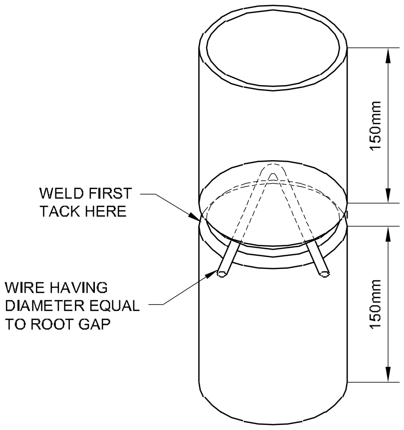


Welding in 2G and 6G positions are done based on the position of the pipe axis.

In the 2G position, the horizontal pipe welding with its axis being vertical, the weld joint connecting the two pipes is in the horizontal position. The weld must be made around the pipe. (Fig 5)

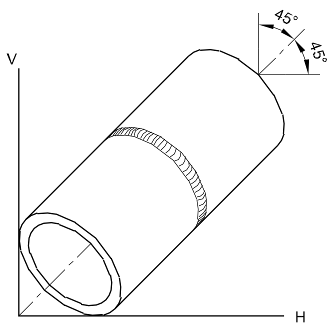
In the 6G position welding is usually done by using one of the methods i.e. uphill or downhill welding. (Fig 6)

Fig 5



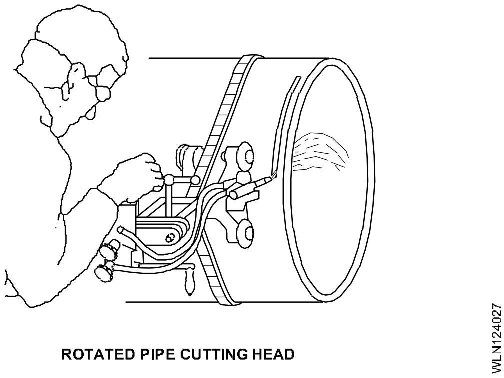
USE OF BEND WIRE OF SPACER TO SET ROOT GAP

Fig 6



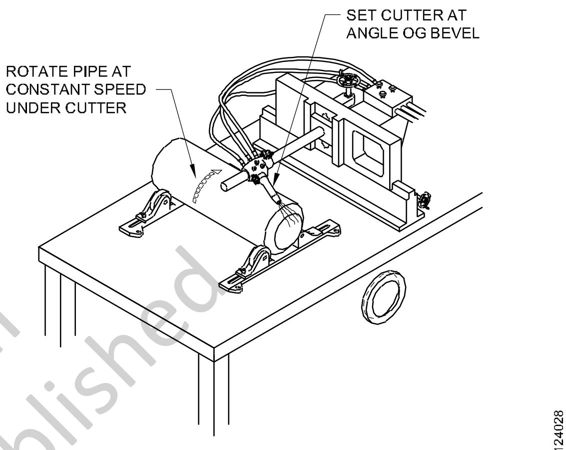
POSITION 6 G

Fig 7



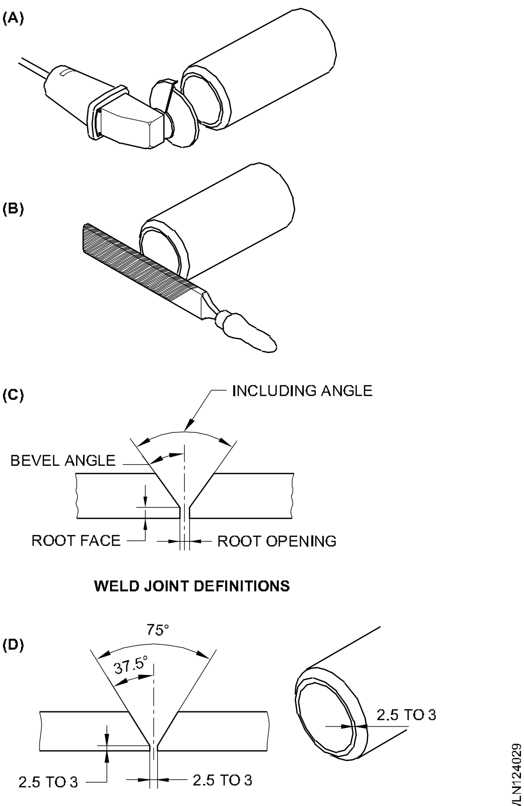
ROTATED PIPE CUTTING HEAD

Fig 8



CUTTING BEVEL ON PIPE

Fig 9



Use electrodes specially manufactured for pipe welding to get good penetration, appearance and strength, (low hydrogen electrodes, deep penetration electrodes etc.)

Welding procedure of M.S. pipe butt joint by arc in fixed (5G) position.

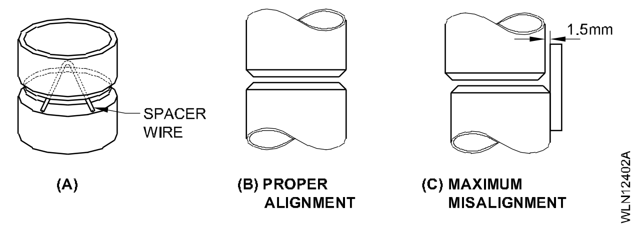
Edge preparation and cleaning: If the wall thickness is 3 mm and below the edges of the pipe end is filed square i.e. perpendicular to the pipe axis. The welding of the joint is complete in one pass using the down hill method or by segmental method i.e. welding the top quarter in flat, bottom quarter in overhead and the two side quarter portion in vertical up position. The electrode has to be held at angles as shown in Fig 14 for welding the root pass of a thicker pipe explained later in this lesson.

For welding pipes with higher wall thickness the following procedure is to be followed.

Edge preparation: The pipe ends are bevelled by flame cutting or machining in the shop (Figs 7 and 8) The including angle is 75° the root face and root gap are 2.5 mm to 3 mm. All traces of oxide from and other contaminations must be removed before starting the weld. (Fig 9)

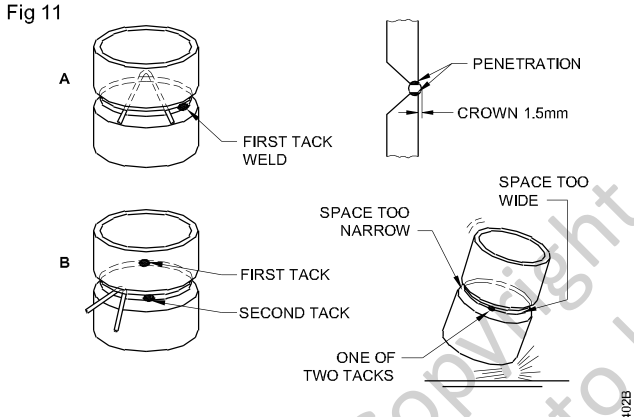
Setting of pipe: Pipe to be joined together must be accurately aligned prior to welding. The inside surface of the pipe must be blended together smoothly as in the outer surface. Maintain the root opening 2.5 mm, use a M.S. angle and strength bar for checking the alignment of the pipe. (Fig 10)

Fig 10



Tacking: Place a 2.5 mm bend wire between the edges. The tack length should be 3 times the metal thickness. Put the first tack at the root side and the second tack at the opposite side of the first tack. Arrange the third and fourth tacks at 90° from the first and second tacks. (Fig 11)

Fig 11



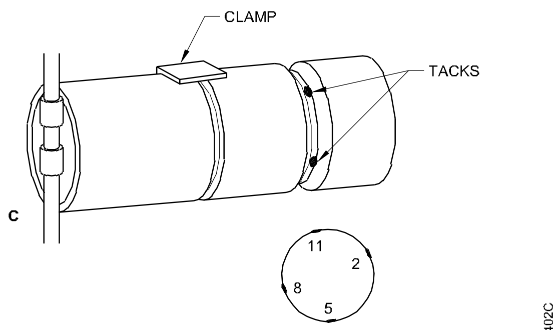
A. FIRST TACK WELD WITH WIRE SPACERS IN PLACE.
B. SECOND TACK WELD OPPOSITE TO FIRST TACK.

Root pass: Fix the job in the clamp and adjust the height to a position convenient to you. The position of tack weld should be fixed as in Fig 12. The keyhole is an essential part in the welding of the root pass. (Fig 13) It should be about $\sqrt{1\frac{1}{3}}$ of the diameter of the electrode. Maintain the electrode angle as shown in Fig 14 Weld the root pass on side 2 of the pipe joint. (Fig 14)

The side 1 of the root pass is started at 6½ hrs position and stopped at 11½ hrs position. The side 2 is started at 5½ hrs position and stopped at 12½ hrs position.

The weld beads on side 1 and side 2 will overlap for a short distance at the start and at the stop positions.

Fig 12



PIPE CLAMPED IN PLACE AFTER TACK WELD.

Fig 13

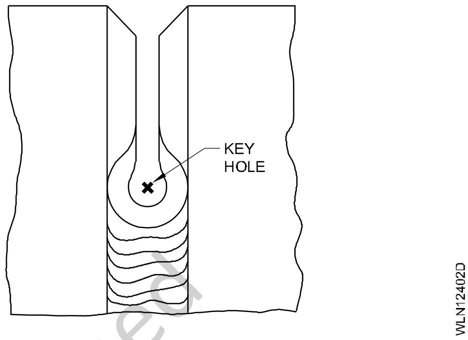
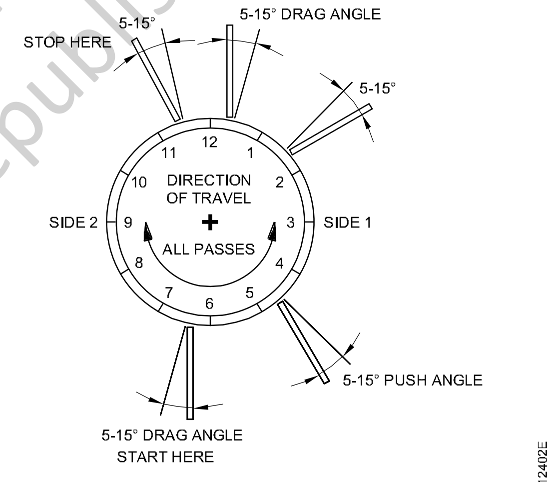


Fig 14



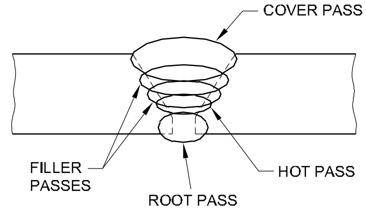
EECTRODE DRAG AND PUSH ANGLES.

After completing the root pass, depending on the wall thickness of the pipe there will be further weld deposits either 2 or 3 or more passes. These passes can be a mixture of stringer beads and weaved beads by vertical up/uphill method.

The names of each pass is given in Fig 15. Usually the second weld bead after the root pass is deposited keeping the joint hot. So it is called hot pass.

For hot pass and cover pass maintain the electrode angle as shown in the Fig 14. Each pass should start at a different place of the joint. The second pass should fill the groove by using side-to-side movement. The final cover pass should be made wider than the second pass. The third pass should be smooth and of uniform appearance, and must have minimum reinforcement. (Fig 15)

Fig 15



THE SPECIFIC NAMES FOR THE VARIOUS PASSES IN A PIPE WELD

Advantages of H/P pipe welding

- The joint is permanent.
- Saving of material.
- Reduction of joint weight.
- Less expensive.
- Multiple lines grouped together more closely.
- Repair and maintenance cost is less.

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Welding of M.S. pipe

Objectives: At the end of this lesson you shall be able to
- **classify and specify mild steel pipes**
- **state and explain different methods of welding M.S. pipes**
- **state the method of edge preparation, tacking and necessary of key hole maintenance**
- **explain the pipe welding procedure by gas welding.**

Welding of M.S. pipe: Mild steel pipes are classified into two groups.

1 Seamless pipes manufactured by piercing a hot solid round billets/rods. (Fig 1)

2 Resistance welded pipes manufactured by continuously feeding a strip of metal through a machine which rolls the strip into cylindrical shape and the seam is electrically resistance welded. (Fig 2)

Based on the wall thickness, these pipes are further categorised as "Standard pipes", "Extra Strong pipes" and "Double extra strong pipes". Also the pipes are specified by first the material then by the diameter followed by the wall thickness. (Fig 3) For example a M.S. pipe 100 mm long with 50 mm inside diameter and 3 mm wall thickness is specified as M.S. ø 50 WT3 × 100 mm.

In the actual usage of pipes in various applications like transmitting water, oil, chemical, air, gases, etc. it is necessary to weld them as a butt, elbow and Tee joints as well as branch pipe joints at various angles.

The welding of smaller diameter pipes and bigger diameter pipes inside a welding shop can be done by rotating the pipes on roller or manually by a helper using an angle iron and tongs. (Fig 4 and Fig 5)

Fig 1

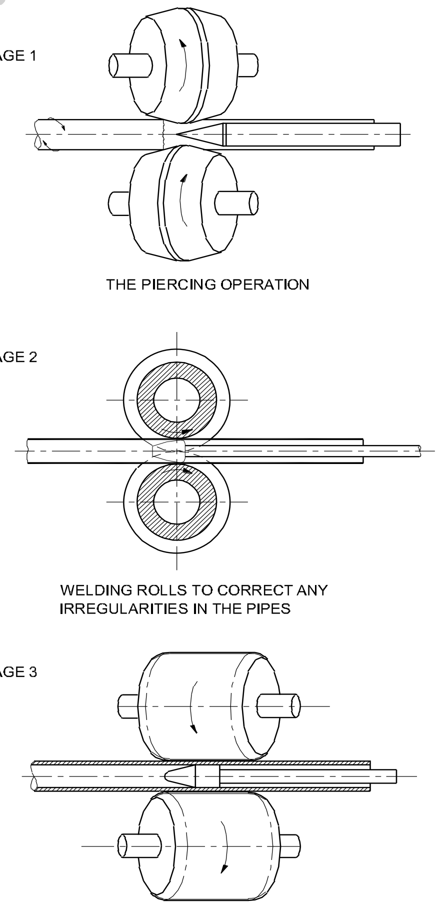
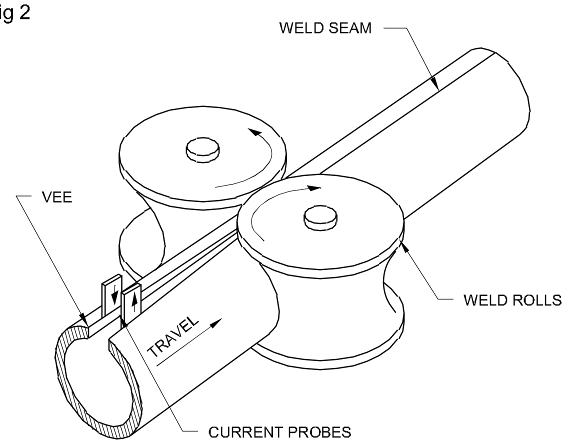


Fig 2



HIGH FREQUENCY TUBE WELDING

Fig 3

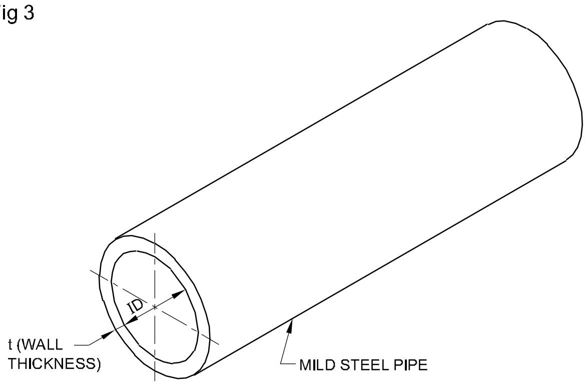
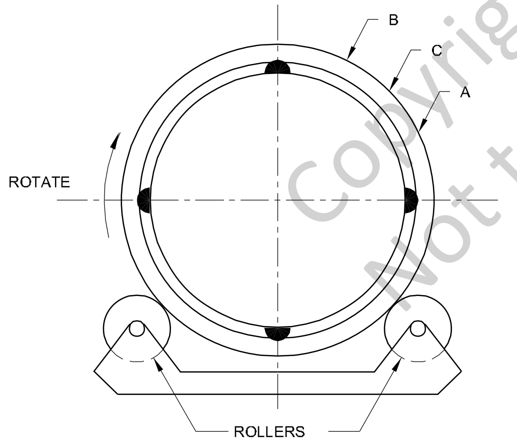
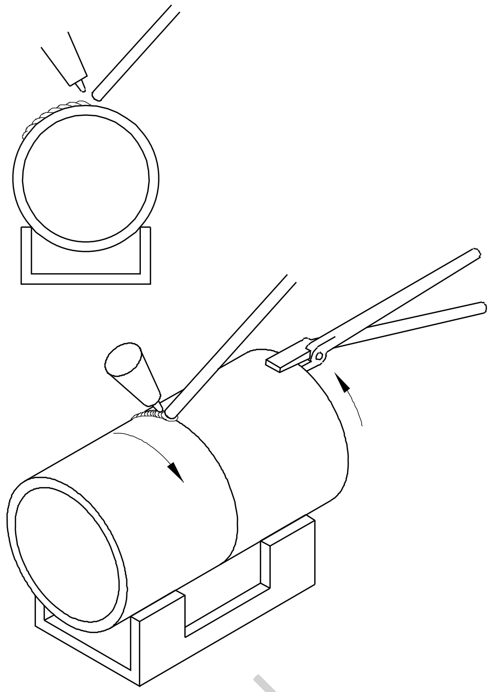


Fig 4



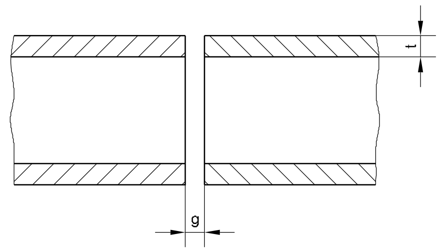
If the pipes are larger and are to be welded in the field/ work site or if the pipes cannot be rotated, then in such cases, the pipes are welded in fixed position i.e. the pipe will not ne rotated, but the welder has to move the blowpipe and filler rod along the curved line of the joint around the pipe to complete the weld.

Fig 5



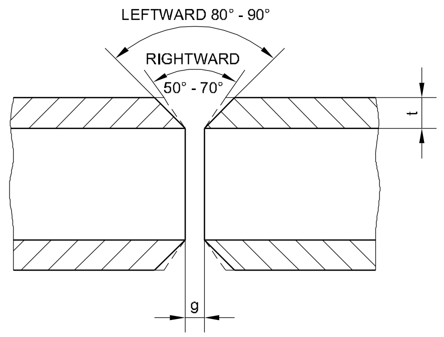
The edges of the pipe joints are prepared depending on the type of joint and the wall thickness of the pipe. For a pipe flange joint and for pipe butt joint with 1.5 to 3 mm wall thickness, the pipe edges are filed or ground square (Fig 6) for pipe butt joints above 3 mm wall thickness, the pipe edges are bevelled as shown in Fig 7 with 1.5 mm root face.

Fig 6



PIPE ENDS SQUARE

Fig 7

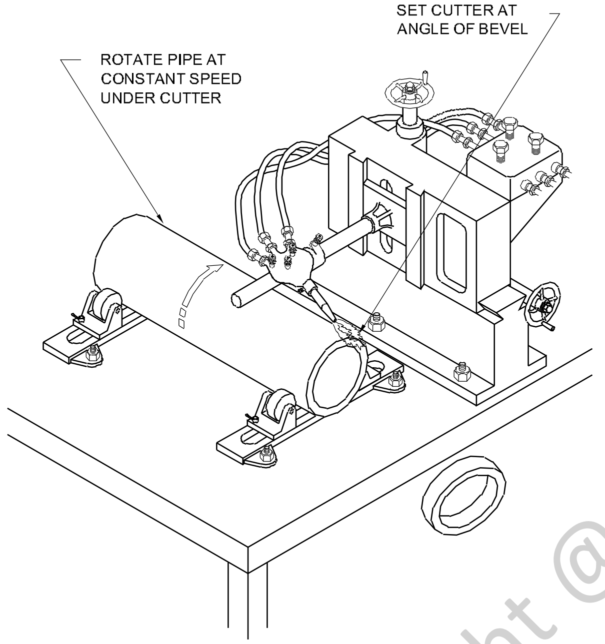


PIPE ENDS BEVELLED

Weld defects like incomplete or lack of root penetration cannot be rectified from inside small diameter pipes. Hence slightly larger root gaps are given while welding pipe butt joints to ensure proper root penetration. (Table 1) Fig 6 and Fig 7 gives the details of edge preparation.

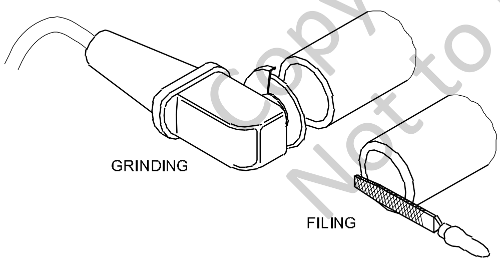
For pipes with wall thickness 3 mm and below, the edges are prepared by a file. If the wall thickness is more than 3 mm then the bevelling is done by gas cutting (Fig 8) and the root face is prepared by filing/grinding. (Fig 9)

Fig 8



CUTTING BEVEL ON PIPE

Fig 9

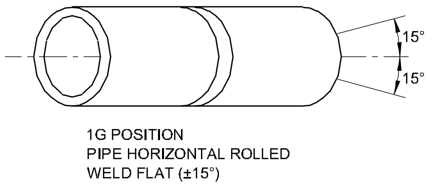


As welding of pipes is done either by rotating the pipe or by the fixed method, the pipe welding procedure also differs accordingly.

The different positions used to weld pipe butt joints are named as 1G, 2G, 5G and 6G as shown in Fig 10 to Fig 13. These positions are decided based on the position of the pipe axis and whether the welding is done by rotating the pipe or by keeping the pipe fixed.

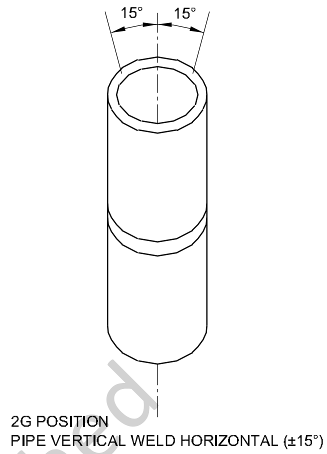
But in gas welding only 1G, 2G and 5G position are used. The 6G position welding is done by arc welding and it is usually used to test the skill/ability of a welder in pipe welding.

Fig 10



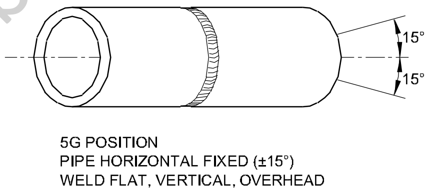
ROTATE PIPE AND DEPOSITE WELD AT OR NEAR THE TOP

Fig 11



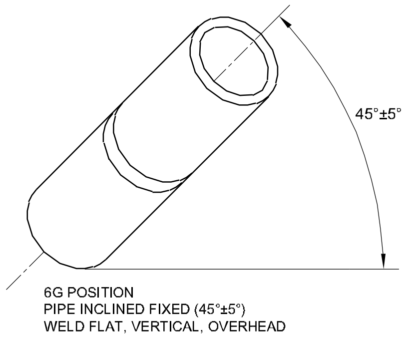
PIPE SHALL NOT BE ROTATED DURING WELDING

Fig 12



PIPE SHALL NOT BE ROTATED DURING WELDING

Fig 13



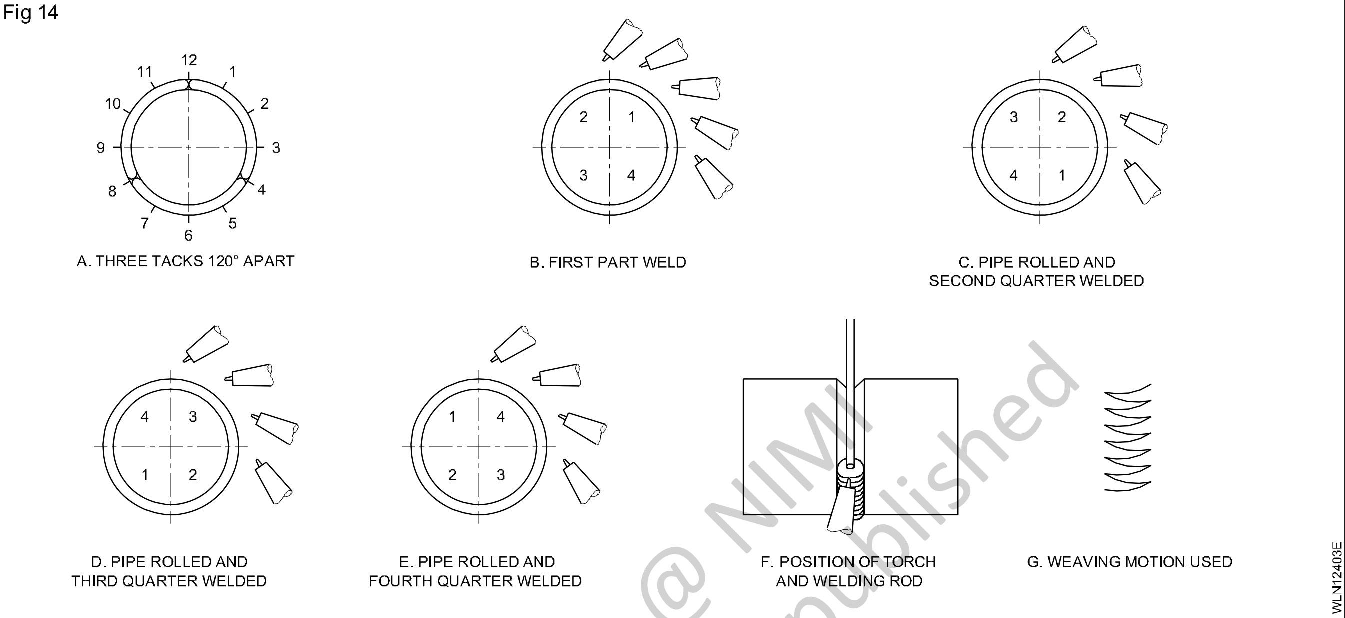
PIPE SHALL NOT BE ROTATED DURING WELDING

Pipe welding by rotation method (Position 1G): The method of welding pipes using pipe rotation is shown in the Fig 14. The two pipes after cleaning and preparing the edges, are set with proper root gap on an angle iron or channel so that the axes of the pipes are properly aligned. Then tack weld them at 3 places at 120° intervals. (Fig 14A)

Table 1

Wall thickness (t)	Pipe and preparation	Welding technique	Root gap (g)
3 mm or less	Square	Leftward	2.5 - 3 mm
5 mm or less	Square	Rightward or all-positional rightward	2.5 - 3 mm
3 - 5 mm	Bevelled	Leftward	1.5 - 2.5 mm
5 - 7 mm	Bevelled	Rightward or all-positional rightward	3 - 4 mm

Fig 14



Start the weld at 3 O'clock position and finish at 12 O'clock position. Now the first ¼ portion of the pipe joint, marked as 1 in Fig 14B is welded. Rotate the pipe joint by 90° in clockwise direction so that the 12 O'clock position on the pipe comes to 3 O'clock position. Weld the portion marked as 2 in Fig 14C as done in welding portion 1 already. Now rotate the pipe by 90° and weld portion 3 (Fig 14D). On completing welding of portion 3 rotate the pipe again by 90° so that the portion 4 can be welded (Fig 14E). The position of blowpipe/torch and filler rods is shown in Fig 14F and the blowpipe weaving motion is shown in Fig 14G. It is very important to continuously maintain a key hole both while tacking Fig 15 and during welding (Fig 16).

In this method leftward technique is used and the metal deposition starts in vertical at 3 O'clock position and ends with flat position at 12 O'clock position. Care should be taken to properly overlap the previous weld deposit while starting the 2nd, 3rd and 4th segments.

Pipe welding in fixed position (position 5G): The welding of the pipeline without rotating the pipe during welding is called fixed position welding. (5G) In this position the welder has to move according to the condition of the pipeline in different positions, such as vertical, down hand and overhead positions.

Fig 15

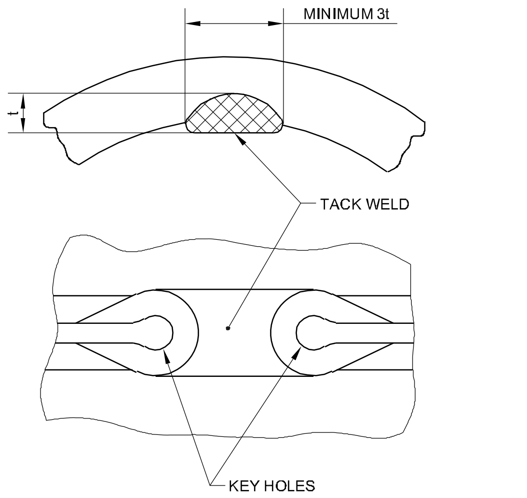
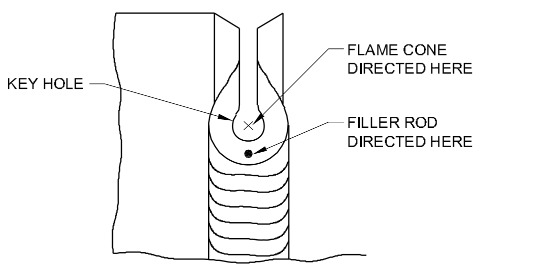


Fig 16

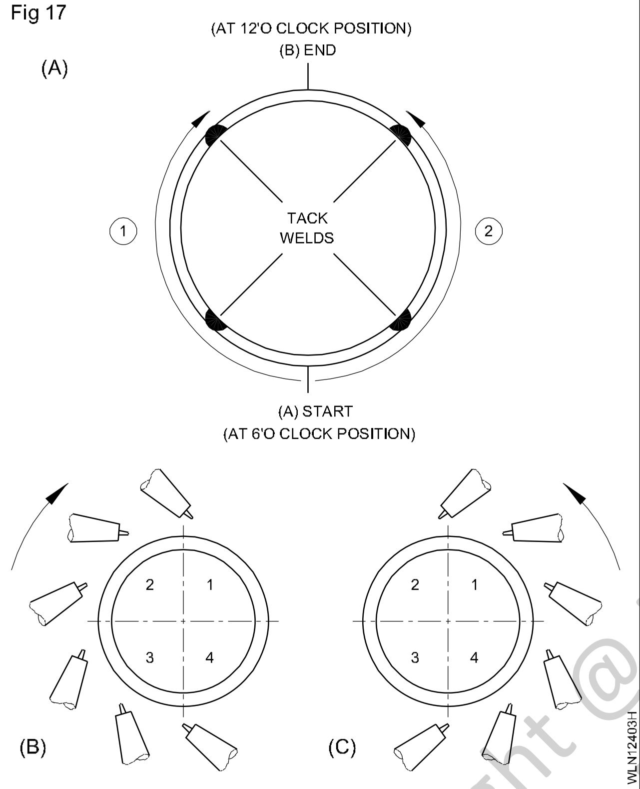


LEFTWARD WEDING

In fixed position pipe welding, the welder has to weld according to the conditions of the pipeline.

In this system, the welding should be started from 6 O'clock position and move to 12 O'clock position on either side by moving the blowpipe and the filler rod from bottom in the upward direction as shown in Fig 17a, 17b, 17c.

Fig 17



This also can be welded by the four quarter method, first by welding two quarter distance (opposite to each other) by moving the blowpipe in the upward vertical direction. (Fig 18a and Fig 18b) Then weld the top quarter distance in the down hand position. Finally weld the bottom quarter distance in the overhead position. The clock face and its relationship to pipe welding and various blowpipe and filler rod positions are illustrated in Fig 19.

Fig 18

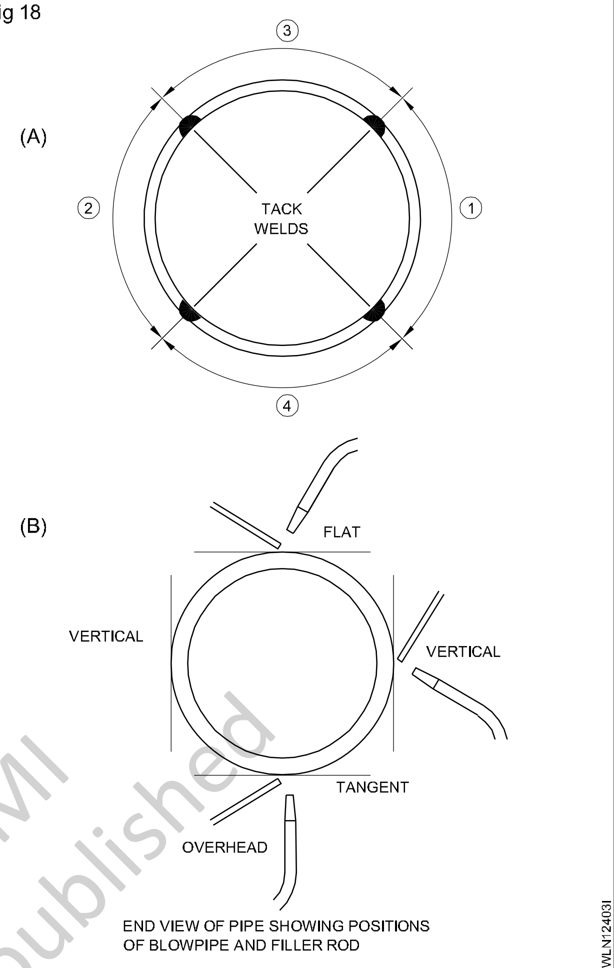
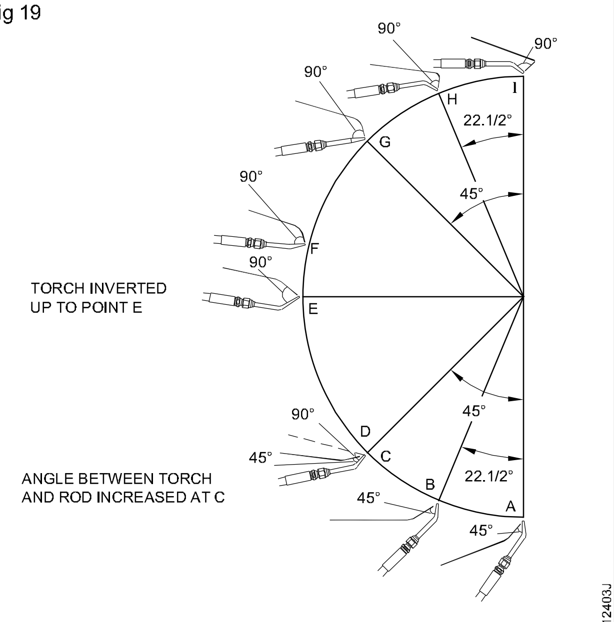


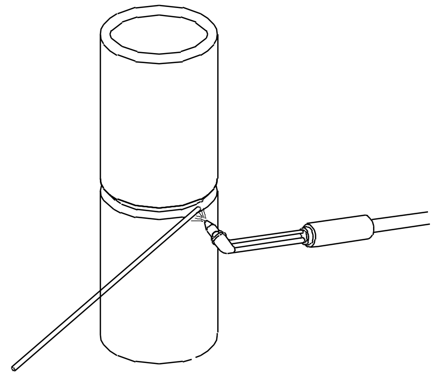
Fig 19



VARIOUS BLOW PIPE & FILLER ROD POSITIONS

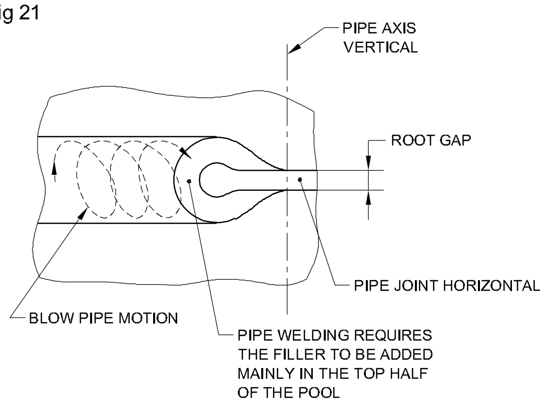
Pipe welding in 2G position (Pipe axis is vertical): In a pipe butt joint if the axis of the pipes is vertical and the weld joint is in the horizontal plane then it is called pipe welding in 2G position. (Fig 20) It is a fixed position welding and the blowpipe and filler rod are to be moved around the pipe surface. The position of blowpipe and the filler rod are given in Fig 20. To avoid sagging of weld metal the blowpipe is given a motion as shown in Fig 21 and the filler rod is fed at the top half of the molten pool.

Fig 20



2G POSITION
SINGLE "V" GROOVE PIPE JOINT
(PIPE AXIS VERTICAL)

Fig 21



Difference between plate welding 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.**

Plate welding: Plate welding is a fusion welding process. It joins plate metals using the combustion of oxygen and fuel gas. The intense heat that is produced melts and fuses together the edges of the parts to be welded generally with the help of a filler metal.

Plate welding by gas can be done in two ways. One is leftward welding and the other rightward welding.

All the-position rightward welding is used for all position of welding. (Fig 1) The path travelled by the flame and the filler rod varies with the welding position. The angles at which the flame and the filler rod are held also vary.

Metal thickness and related techniques

Position	Material thickness range	Method
Flat	Not exceeding 5 mm Exceeding 5 mm	Leftward Rightward
Horizontal-vertical	1 mm to 5 mm 5 mm and above	Leftward All-position Rightward
Vertical (single operator)	1 mm to 5 mm 5 mm and above	Leftward All position rightward
Vertical (two operators-technique)	5 mm and above	Leftward
Overhead	1 mm to 5 mm 5 mm and above	Leftward All-position rightward.

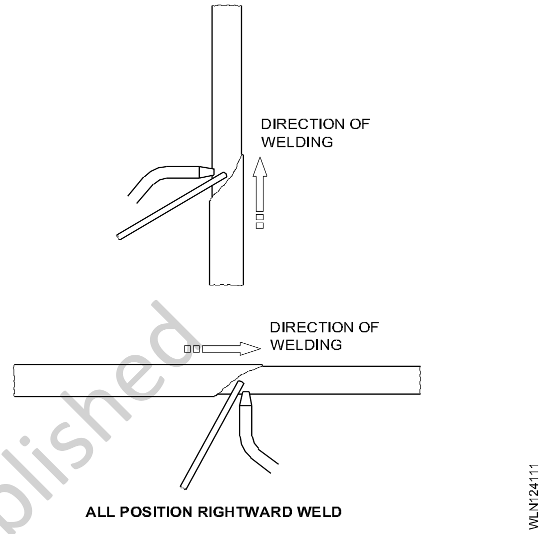
Pipe welding: When welding the circumference of a mild steel pipe, the angles of the rod and the blowpipe are given in relation to the tangent to the pipe at the point of welding.

The welding position can be seen in relation to the plane of the joint.

The techniques used will depend upon:

– the pipe wall thickness
– the welding positions
– whether the pipe is fixed or can be rotated.

Fig 1



When the pipe remains stationary, the following techniques are used.

Position	Method
At the top of the pipe, flat position.	Leftward or rightward
At the flank of a set on branch when both pipe axes are in horizontal flat position.	Leftward or rightward
The weld is made along the vertical sides of the pipe.	Leftward or rightward or all-position rightward
The weld at the bottom of a pipe is made in the overhead position.	Leftward or rightward or all-position rightward

The techniques used for the positional welding of plates are also applied when welding pipes.

For thin walled pipes up to 5 mm, the leftward technique is used in any position. (Fig 2)

The leftward, rightward or all-position rightward techniques are used as appropriate on sections of 5 mm and above. (Fig 3)

Fig 2

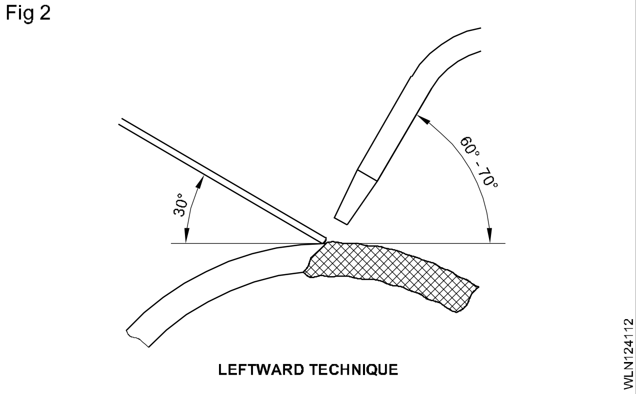
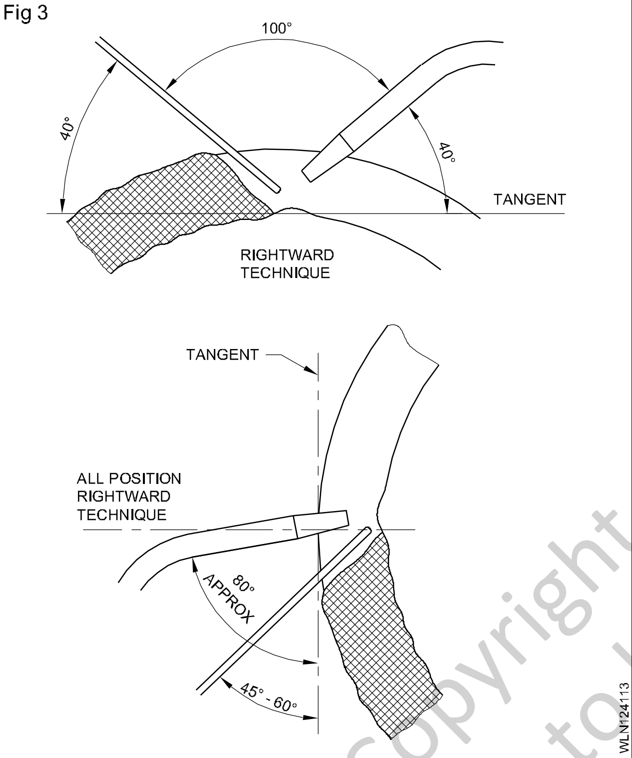


Fig 3



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. Eg. 2G Position. (Fig 5)

Fig 4

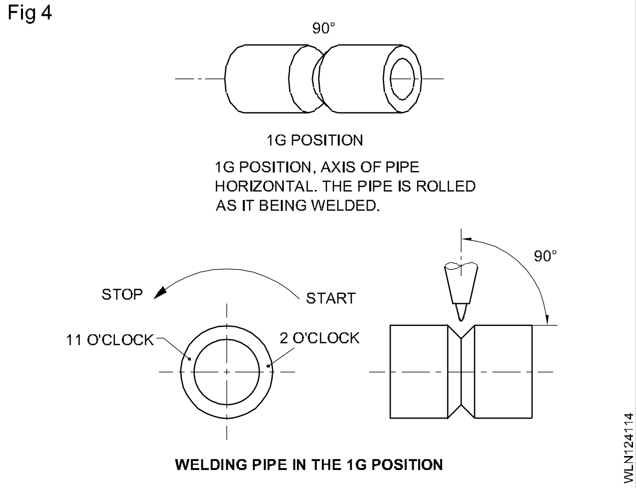
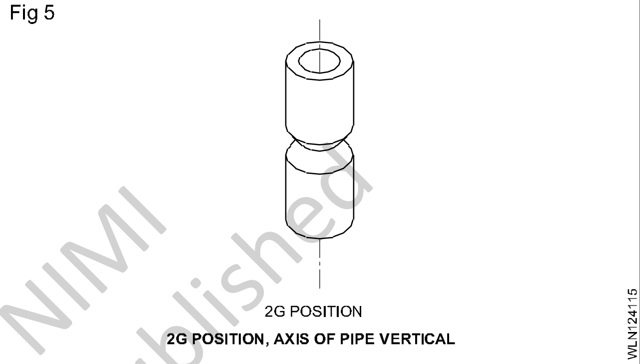


Fig 5

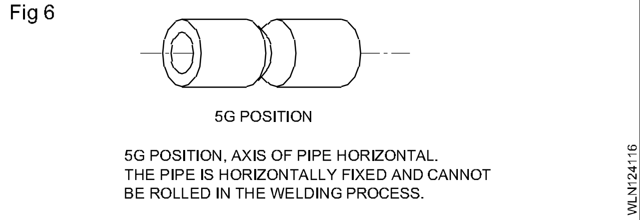


In plate welding the sealing run can easily be deposited when needed. In pipe welding the sealing run cannot be deposited in small pipes. Sealing run can be deposited only when the pipe has so large a diameter as to allow the welder to enter into the pipe.

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



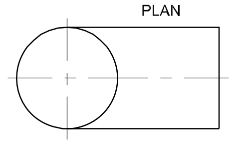
Development of a pipe elbow joint

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:

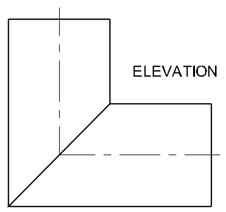
Draw plan as shown in Fig 1.

Fig 1



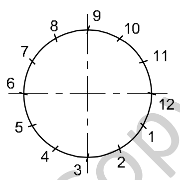
Below this, draw the front elevation as shown in Fig 2.

Fig 2



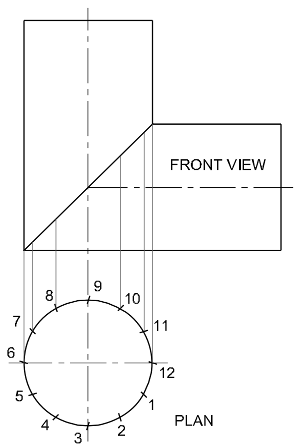
Divide the circle in the plan into twelve equal parts and number the points 0 to 12 as shown in Fig 3.

Fig 3



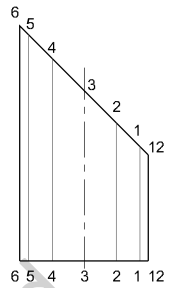
Draw the perpendicular line from these points towards the front view and number 1 to 12 as shown in Fig 4.

Fig 4



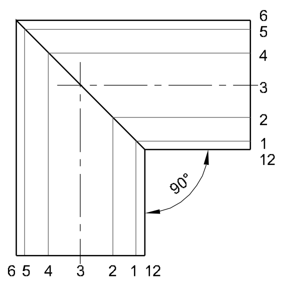
Now you find that the vertical lines are cutting at six different points top and bottom in the elevation line. Number them as shown in Fig 5.

Fig 5



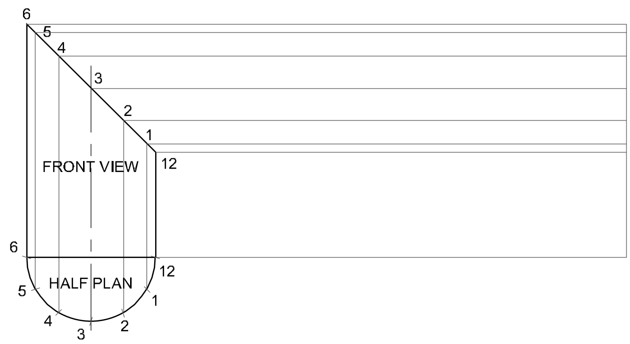
Draw horizontal parallel lines from each point and number them as shown in Fig 6.

Fig 6



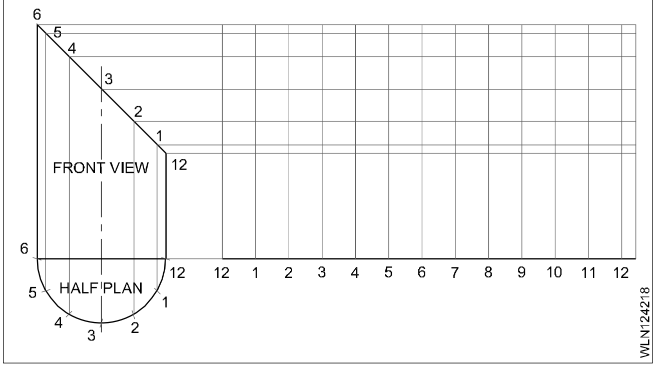
Extend the front elevation base line as shown in Fig 7.

Fig 7



Take the distance equal to one division of plan and mark twelve times on base line by a compass and draw perpendicular lines from each point as shown in Fig 8.

Fig 8



Now you find that each horizontal line and corresponding vertical line meet at a point. Number the points as 1 to 12 as shown in Fig 9.

Join these points by free hand curve as shown in Fig 10.

Fig 9

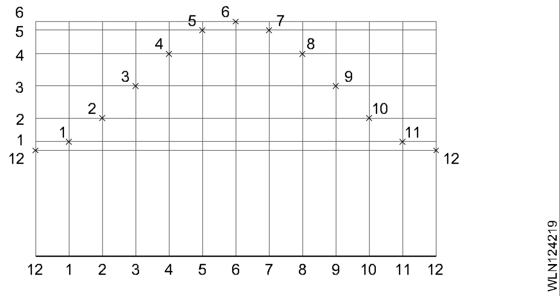
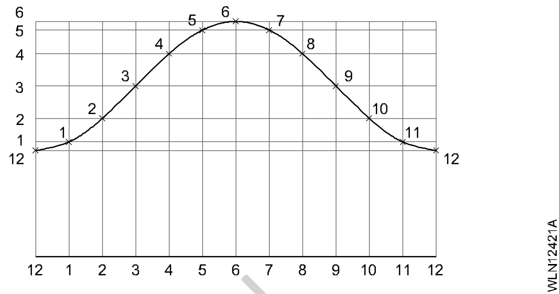


Fig 10



Development of a pipe "T" joint

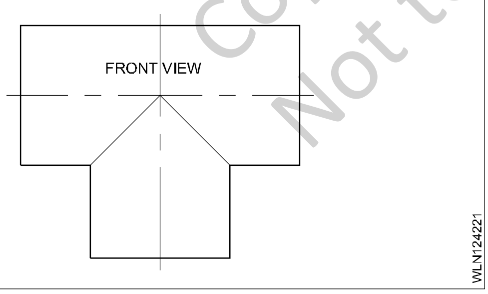
Objective: At the end of this lesson you shall be able to

- **develop and layout the pattern for 90° "T" pipe of equal diameter by parallel line method.**

Develop the pattern for a 90° "T" pipe of equal diameter by parallel line method:

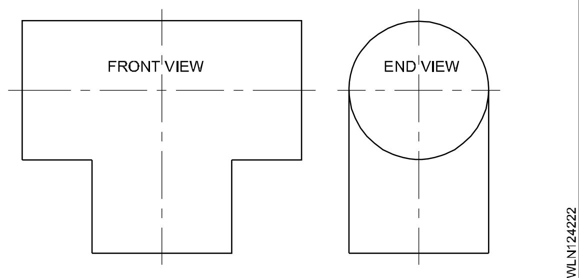
Draw the front view as shown in Fig 1.

Fig 1



Draw the side view as shown in Fig 2.

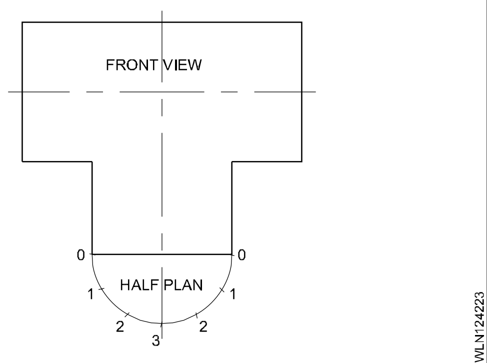
Fig 2



Draw a semi-circle on the base line of the front elevation. (Fig 3)

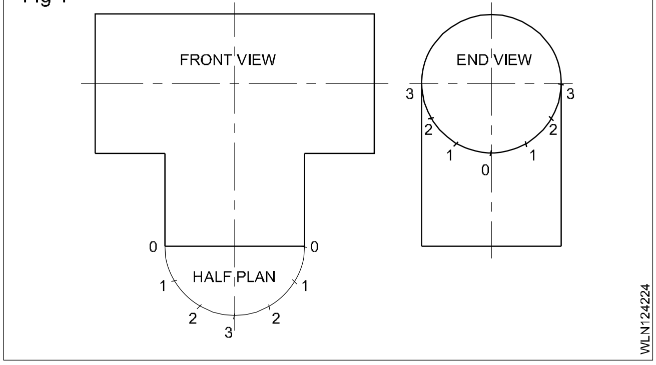
Divide the semi-circle into six equal parts and number them as 0, 1, 2, 3, 2, 1, 0. (Fig 3)

Fig 3



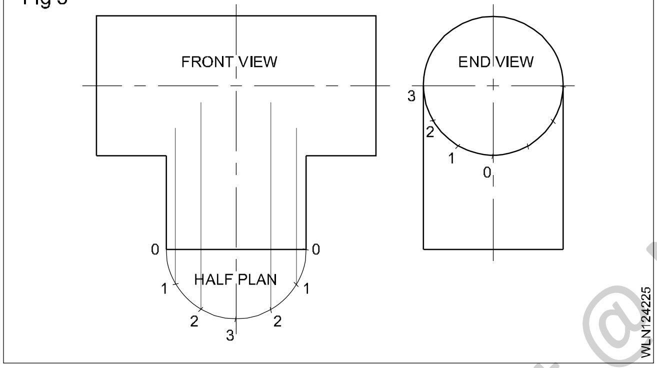
Divide a semi-circle in side view into six equal parts and number as 3, 2, 1, 0, 1, 2, 3 as shown in Fig 4.

Fig 4



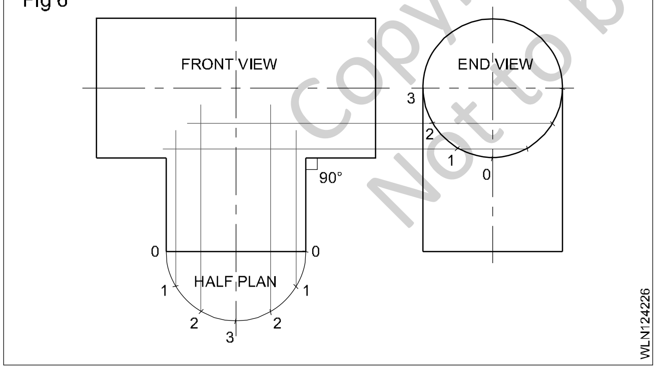
Draw the perpendicular lines from each point of the semi-circle of the view as shown in Fig 5.

Fig 5



Draw horizontal lines from the side view towards the front view as shown in Fig 6.

Fig 6



Now the vertical lines of the front view and the horizontal lines of side meet at their respective points.

Join these points to get the line of intersection of "T" pipe as shown in Fig 7.

Extend the base line of the side view and mark the end point as 0. (Fig 8)

Fig 7

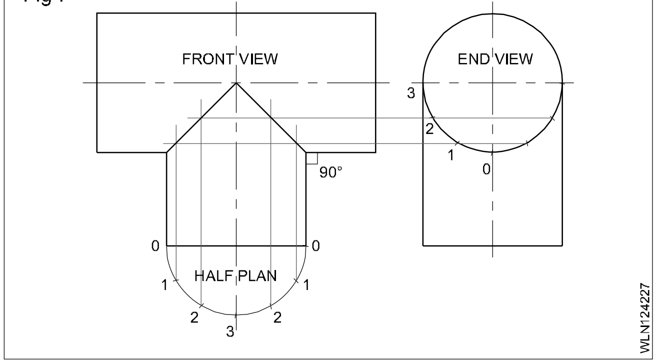
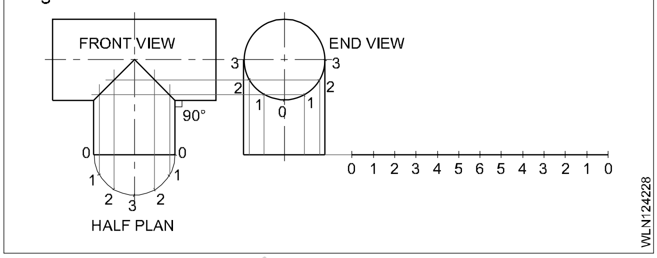


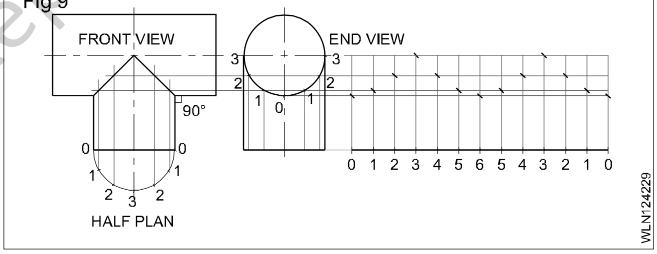
Fig 8



Take one division of the semi-circle in side view and transfer it 12 times on the base line starting from: 0: and number as 0, 1, 2, 3, 2, 1, 0, 1, 2, 3, 2, 1, 0 as shown in Fig 9.

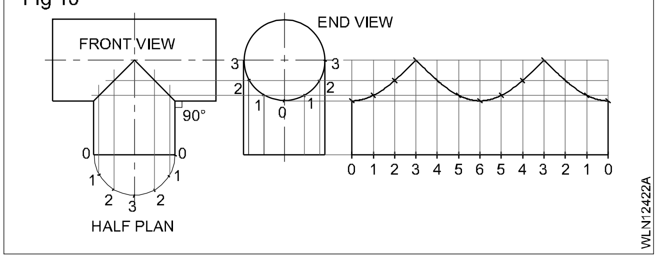
Draw perpendicular lines from these points and draw horizontal lines from the points on the line of intersection of "T". These line meet at their respective points. (Fig 9)

Fig 9



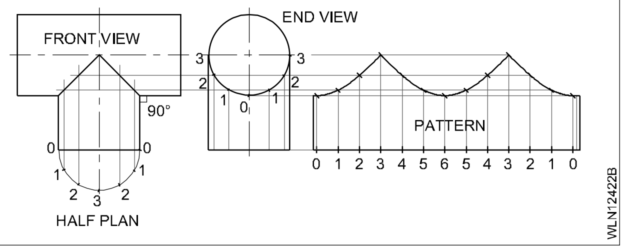
Join these points by free hand curve. (Fig 10)

Fig 10



Provide locked grooved joint allowance as shown in Fig 11.

Fig 11

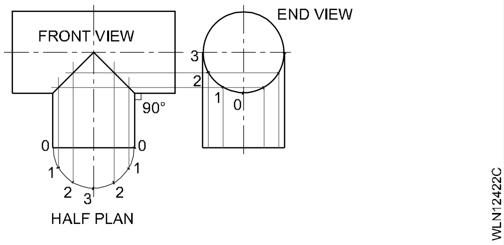


Check the pattern once again and cut. Thus you get the pattern for branch pipe.

For main pipe, develop and layout the pattern as follows:

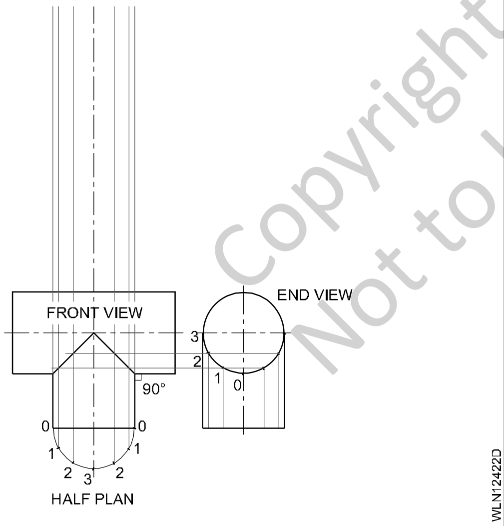
Draw the front view and end view. (Fig 12)

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.

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.

Fig 14

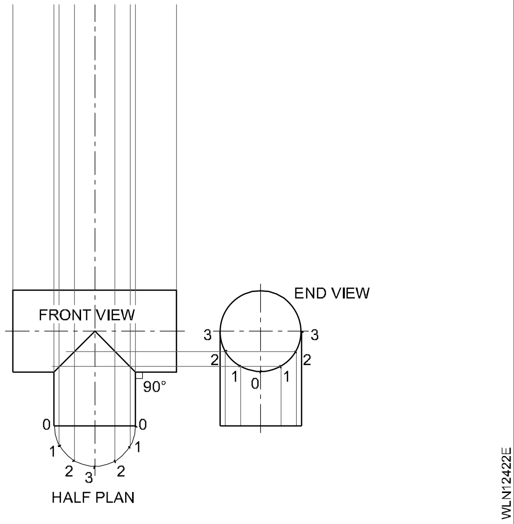


Fig 15

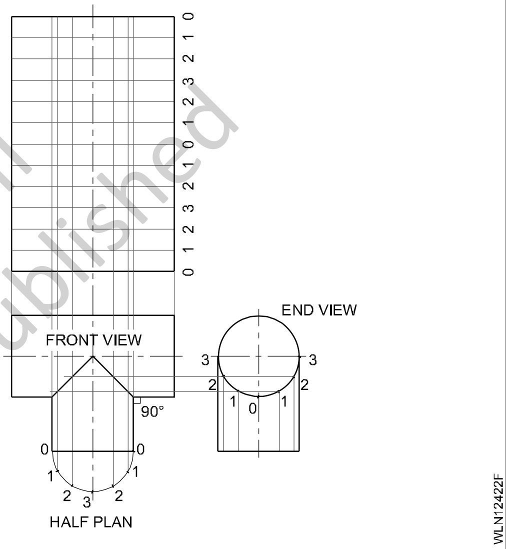
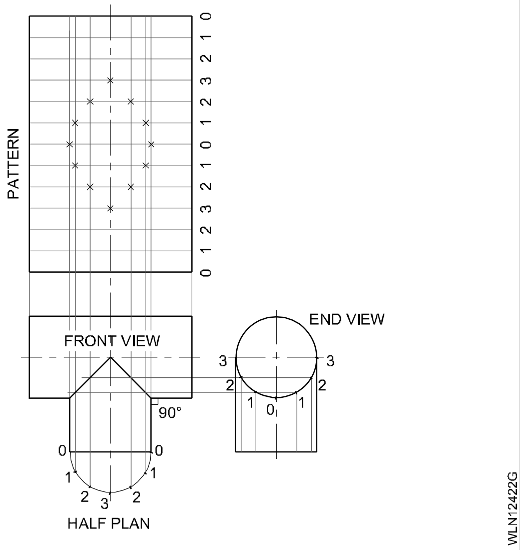


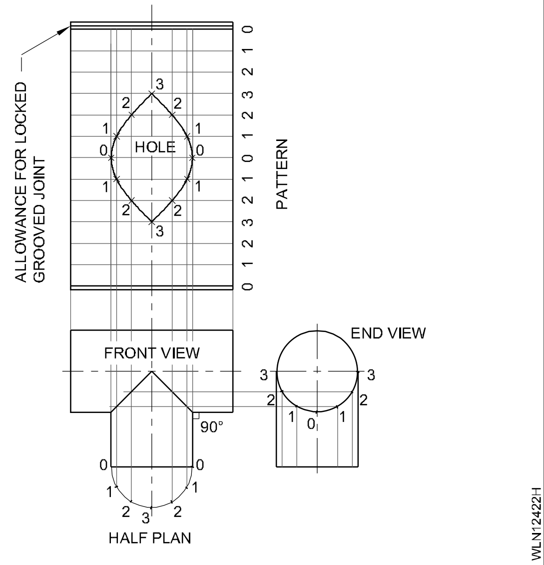
Fig 16



Join these points by free hand curve and get the pattern for the main pipe. (Fig 17)

Provide the locked grooved joint allowances as shown in Fig 17.

Fig 17



Pipe development for "Y" joint

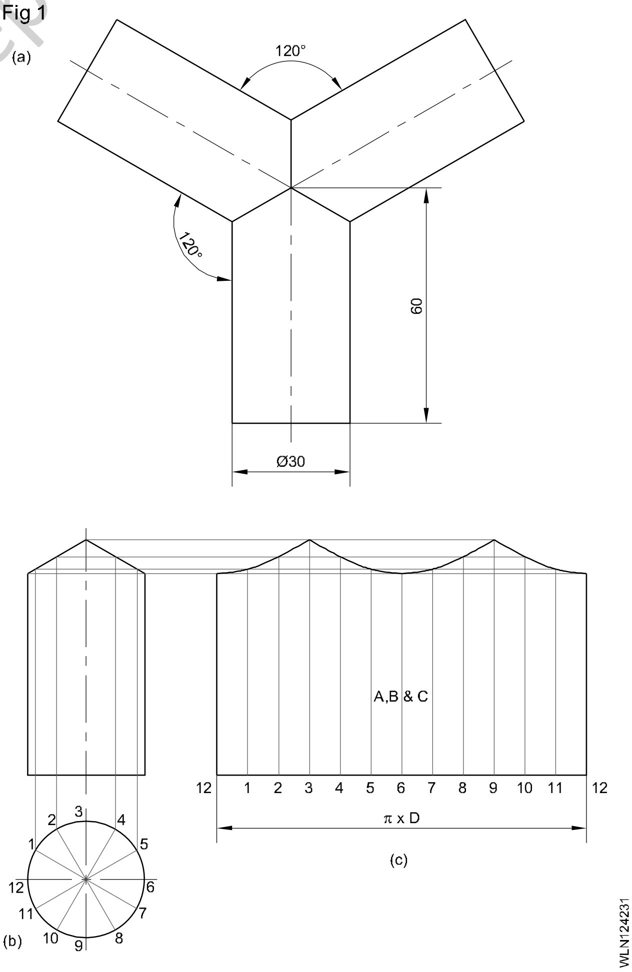
Objectives: At the end of this lesson you shall be able to
- **develop and able to layout the pattern for "Y" joint pipes intersecting at 120°**
- **develop and layout the pattern for "Y" joint pipes branching at 90°.**

Development of "Y" joint pipes intersecting at 120°: Draw the development of intersecting cylinders of dia. 30 mm at 120°. (Fig 1)

All the cylindrical pipes are of same diameter and intersecting each at equal angles. Hence in this case the development of all the pipes are same and so the development of one pipe will represent other pipes.

- Draw the plan and elevation of the pipe 'A' and mark the division on the plan. (Fig 1b)
- Draw the vertical projectors from the plan to front view to meet the line of intersection.
- Draw horizontal projectors from these points on to the development.
- Mark the intersecting points and join with a smooth curve to complete the required development.

Fig 1

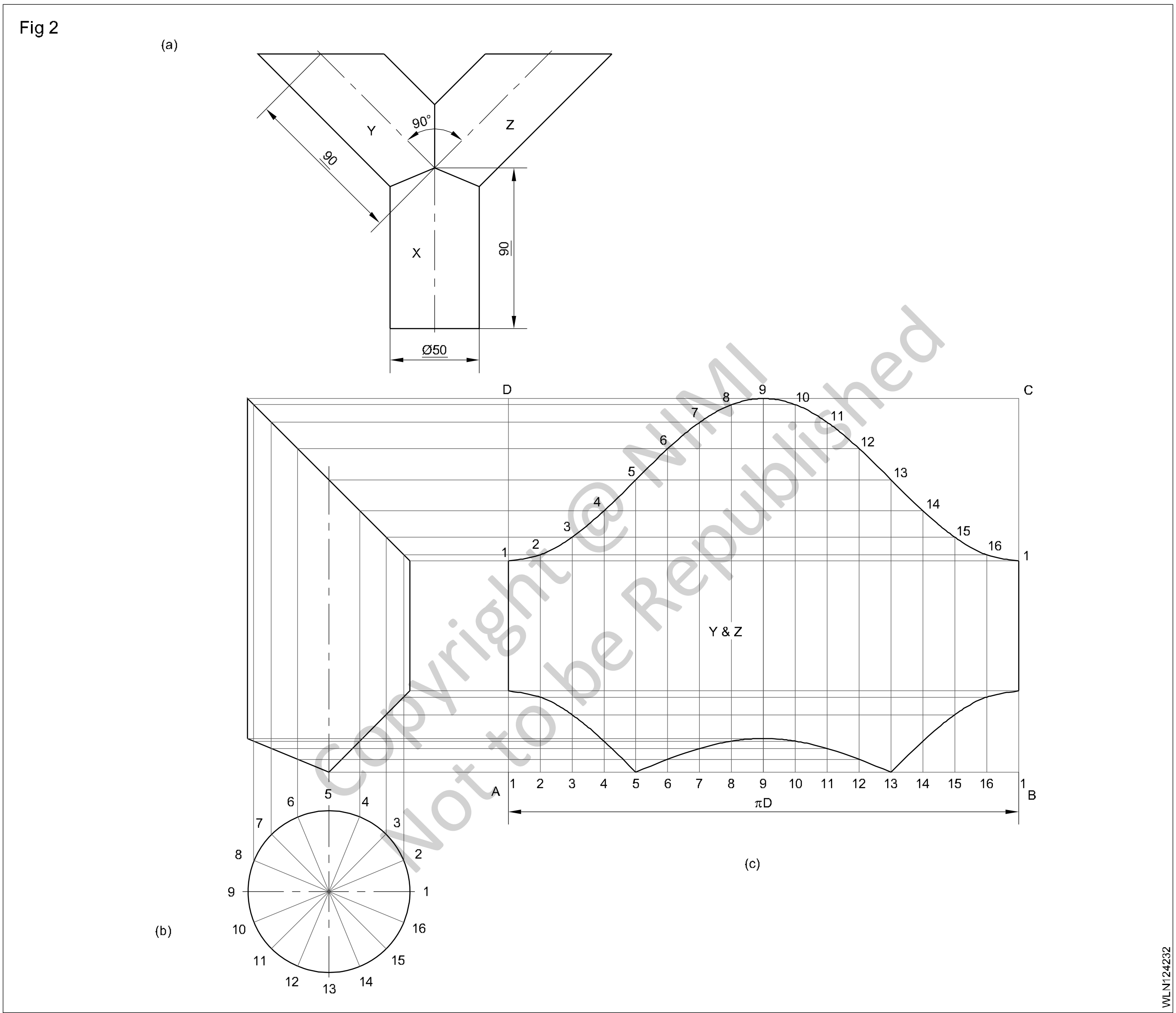


Development of 'Y' joint branching at 90°: Three cylindrical pipes of X, Y, Z form a 'Y' piece. (Fig 2) Draw the lateral surface development of each pipe.

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 π D.
- Draw the development of pipe Y as shown in Fig 2.

Fig 2

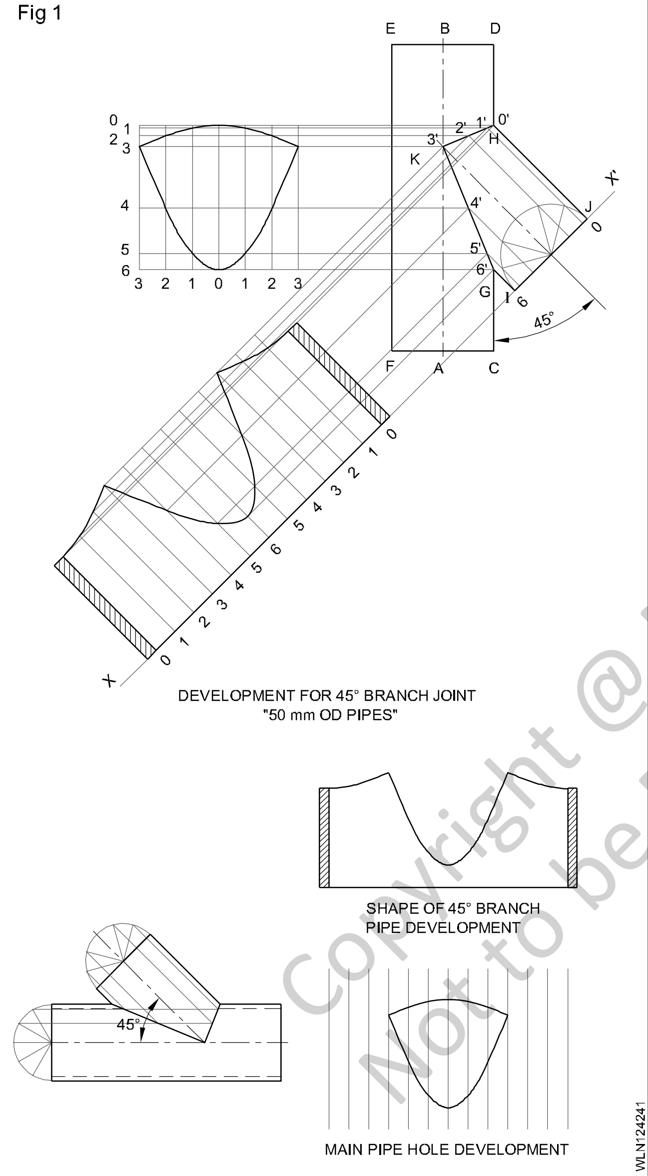


Development of 45° and 90° branch pipe

Objective: At the end of this lesson you shall be able to
- **prepare the development of pipe for 45° and 90° branch pipe.**

Procedure for development of 45° branch pipe: Refer Fig 1. Draw a centre line AB.

Fig 1



Mark the points C, D, E and F taking the radius and the length of the given pipe with the centre line AB as reference line.

On the line "CD" locate the position of the 45° branch pipe. This will be "G".

Draw a 45° angle at the point "G".

Choose a suitable height and mark the height of the branch pipe (GI) in 45° line from point G.

From I, draw a horizontal line on both sides (XX'). This XX' will be the base line for drawing development.

From I, plot the outside diameter of the branch pipe IJ on the line XX'.

Draw a centre line for the branch pipe. This line will cut the main pipe's centre line AB at K.

Join GK. Draw a perpendicular line to GK at K which meets CD at H. Join KH. Now IHKHJ will be the shape (outline) of the branch pipe.

Draw a semi-circle equal to the branch pipe outside diameter.

Divide the semi-circle into 6 equal parts as 0-1; 1-2; 2-3; 3-4; 4-5 & 5-6.

Draw vertical lines from these points 1, 2, 3, 4, 5. Already there will be two vertical lines IG from the points 6 and JH from point 0. These vertical lines will cut the branch pipe lines 'GK' and 'KH' at points 6', 5', 4', 3', 2', 1', & 0'. Note that points 6' and G as points 0' and H are the same points. In the base line XX' plot 12 points equal to the distance of '0-1' as 0, 1, 2, 3, 4, 5, 6, 5, 4, 3, 2, 1, 0.

Draw vertical lines to XX' from these 13 points.

Draw horizontal lines parallel to XX' from points 6', 5', 4', 3', 2', 1', 0'. These 7 horizontal lines will cut the 13 vertical lines from the base line at 13 points.

Join the 13 cutting points with a regular smooth curve. Now the required development for the 45° branch pipe will be ready. Give allowance of 3 to 5 mm at the edges of the development. (Fig 1)

For developing a hole in the base pipe: Above the main pipe, draw 7 lines parallel to AB namely 3, 2, 1, 0, 1, 2, 3 equal to the distance of 0-1 on the semi circle.

Draw vertical lines from 0', 1', 2', 3', 4', 5', 6'. These vertical lines will intercept the 7 horizontal lines. Join the intercepting points with a smooth curve. The required development for hole is now ready.

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Manifold system

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of the manifold system and its types**
- **describe the construction of the manifold system**
- **explain the advantages and disadvantages of the manifold system**
- **describe the care and maintenance of the manifold system.**

When large volumes of oxygen and acetylene gas are required on a temporary or permanent basis for many welding and cutting operations in a workshop, a manifold system is most suitable one.

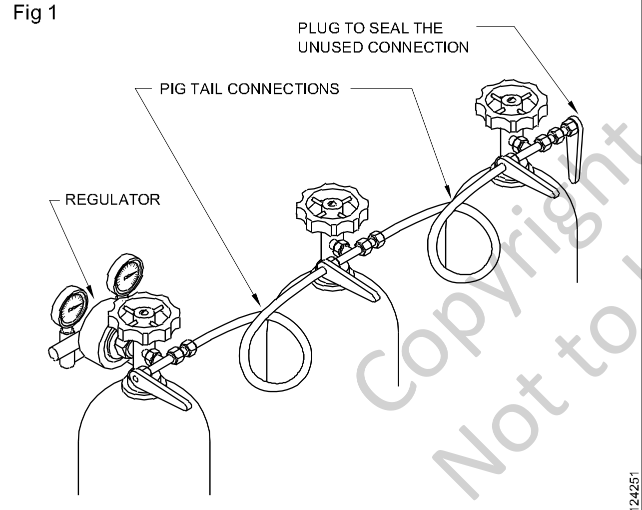
Types

– Portable manifold system

– Stationary manifold system

Portable manifold system means two or three cylinders are coupled with a suitable apparatus - namely 'PIG TAIL' and connected to a main distribution pipe. (Fig 1) Separate arrangements are made for oxygen and acetylene gases.

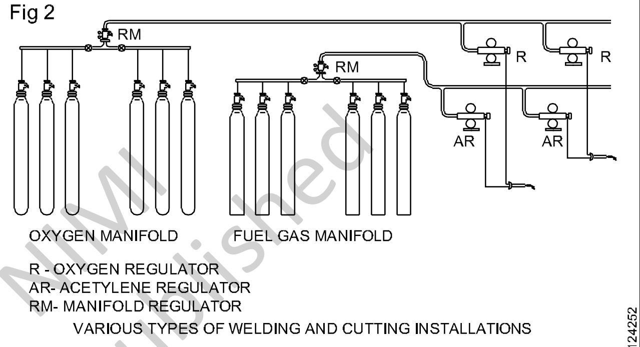
Fig 1



PORTABLE MANIFOLD SYSTEM (EXTENDABLE)

When the demand is even more, many cylinder are coupled together, and this is called stationary 'MANIFOLD' system. (Fig 2) Separate manifold systems are installed for oxygen and acetylene. These manifolds usually have two banks of cylinders. One bank is kept in reserve while the other one is in use.

Fig 2



STATIONARY MANIFOLD SYSTEM

The use of such manifolds reduces substantially the cost of handling the cylinders inside the workshop.

These manifolds are fitted with master regulators which reduce the cylinder pressure to about 15 kgf/cm^2 for feeding into the distribution pipe to the various consuming points. The consuming points are fitted with an outlet value, stop-valves and regulators for individual pressure control at the site for gas welding or cutting operations.

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Filler rods for gas welding

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 upto 4mm dia. are used. For rightward technique upto 6.3 mm dia. is used. For C.I welding filler rods of 6mm dia. and above are used. Length of filler rod:-500mm or 1000mm.

Filler rods above 4mm diameter are not used often for welding of mild steel.

The usual size of mild steel filler rods used are 1.6mm and 3.15mm diameter. All mild steel filler rods are given a thin layer of copper coating to protect them from oxidation (rusting) during storage. So these filler rods are called copper coated mild steel (C.C.M.S) filler rods.

All types of filler rods are to be stored in sealed plastic covers until they are used.

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Different types of filler rods used in gas welding

Objectives: At the end of this lesson you shall be able to
- **define a filler rod**
- **specify and state the different types of ferrous, non-ferrous and alloy filler rods**
- **explain the method of selection of filler rod in respect to the metal to be welded.**

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. alongwith zinc, lead, nickel, manganese, silicon, etc.

Selection of the correct filler rod for a particular job is a very important step for successful welding. Cutting out a strip from the material to be welded is not always possible and even when it is possible, such a strip cannot replace a recommended welding filler materials. Composition of a filler metal is chosen with special consideration to the metallurgical requirement of a weldment. A wrong choice due to either ignorance or a false consideration of economy may lead to costly failures. IS: 1278-1972* specifies requirements that should be met by filler rods for gas welding. There is another specification IS: 2927-1975* which covers brazing alloys. It is strongly recommended that filler material confirming to these specifications is used. In certain rare cases, it may be necessary to use filler rods of composition not covered by these specifications; in such cases filler rods with well established performances should be used.

To select a filler rod in respect to the metal to be welded, the filler rod must have the same composition with respect to the base metal to be welded.

Factors to be considered for selection of filler rod are:

a. the type and composition of base metal

b. the base metal thickness

c. the type of edge preparation

d. the weld is deposited as root run, intermediate runs or final covering run

e. welding position

f. whether there is any corrosion effect or loss of material from the base metal due to welding.

Care and maintenance

Filler rods should be stored in clean, dry condition to prevent deterioration.

Do not mix different types of filler rods.

Ensure that packages and their labels are in order for easy and correct selection.

Where it is not practicable to store filler rods under heated conditions, an absorbent for moisture such as silico-gel may be used in the storage area.

Ensure the rod is free from contamination such as rust, scale, oil, grease and moisture.

Ensure the rod is reasonably straight to assist manipulation during welding.

Each metal requires a suitable filler rod. Refer to IS : 1278 - 1972 and IS : 2927 - 1975 attached. (Table 1: Filler metals and fluxes for gas welding.)

Table 1
Filler metals and fluxes for gas welding

Filler metal type	Application	Flux
Mild steel - Type S-FS1	A general purpose rod for welding mild steel where a minimum butt-weld tensile strength of 35.0 kg/mm^2 is required. (Full fusion technique with neutral flame.)	Not required.
Mild steel - Type S-FS2	Intended for application in which minimum butt-weld tensile strength of 44.0 kg/mm^2 is required. (Full fusion technique with neutral flame.)	Not required.
Wear-resisting alloy steel	Building up worn out crossings and other application where the steel surfaces are subject to extreme wear by shock and abrasion. (Surface fusion technique with excess acetylene flame.)	Not required.
3 percent nickel steel Type S-FS4	These rods are intended to be used in repair and reconditioning parts which have to be subsequently hardened and tempered. (Full fusion technique with neutral flame.)	Special flux (if necessary).
Stainless steel decay-resis-tant (nobium 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.

Filler metal type	Application	Flux
Stellite: Grade 1	Hard facing of components subjected mainly to abrasion. (Surface fusion technique with excess acetylene flame.)	None is usually required. A cast iron flux may be used, if necessary
Stellite: Grade 6	Hard facing of components subjected to shock and abrasion, (Surface fusion technique with excess acetylene flame.)	-do-
Stellite: Grade 12	Hard facing of components subjected to abrasion and moderate shock. (Surface fusion technique with excess acetylene flame.)	-do-
Copper-phosphorus brazing alloy - Type BA-CuP2	Brazing copper, brass and bronze components. Brazing with slightly oxidising flame on copper; neutral flame on copper alloys.	Necessary
Copper-phosphorus brazing alloy - Type BA-CuP5	For making ductile joint in copper without flux. Also widely used on copper based alloys of the brass and bronze type in conjunction with a suitable silver brazing flux. (Flame slightly oxidising on copper; neutral on copper alloys.)	None for copper. A flux is necessary for brazing copper alloys.
Silver-copper-zinc (61 percent silver) type brazing alloys - Type BA-CuP3	Similar to type BA-CuP5 but with a slightly lower tensile strength and electrical conductivity (flame slightly oxidising on copper; neutral on copper alloys). NOTE: Phosphorus bearing silver brazing alloys should not be used with ferrous metal or alloys of high nickel content.	None for copper. A flux is necessary for brazing copper alloys.
Silver-copper-zinc (61 percent silver) - Type BA-Cu-AG6	This brazing alloy is particularly suitable for joining electrical components requiring high electrical conductivity. (Flame neutral)	Flux necessary.
Silver-copper-zinc (43 percent silver) - Type BA-Cu-Ag 16	This is a general purpose brazing alloy and is particularly suitable for joining electrical components requiring high electrical conductivity. (Flame neutral)	Flux necessary.
Silver-copper-zinc cadmium (43 percent silver) - Type BA-Cu-Ag 16A	An ideal composition for economy in brazing operation requiring a low temperature, quick and complete penetration. Suitable on steel, copper, brass, bronze, copper-nickel alloys and nickel-silver. (Flame neutral)	Flux necessary.
Silver-copper-zinc-cadmium (50 percent silver) - Type BA-Cu-Ag 11	This alloy is also suitable for steel, copper-nickel alloys and nickel-silvers. (Flame neutral)	Flux necessary.
Silver-copper-zinc-cadmium nickel (50 percent silver) -Type BA-Cu-Ag 12	Specially suitable for brazing tungsten carbide tips to rock drills, milling cutters, cutting and shaping tools; also suitable for brazing steels which are difficult to 'wet' such as stainless steels. (Flame neutral)	Flux necessary.

Gas Welding Fluxes and Function

Objectives: At the end of this lesson you shall be able to
- **explain flux and its function in gas welding**
- **describe the types of welding fluxes and their storage.**

Flux is a fusible (easily melted) chemical compound to be applied before and during welding to prevent unwanted chemical action during welding and thus making the welding operation easier.

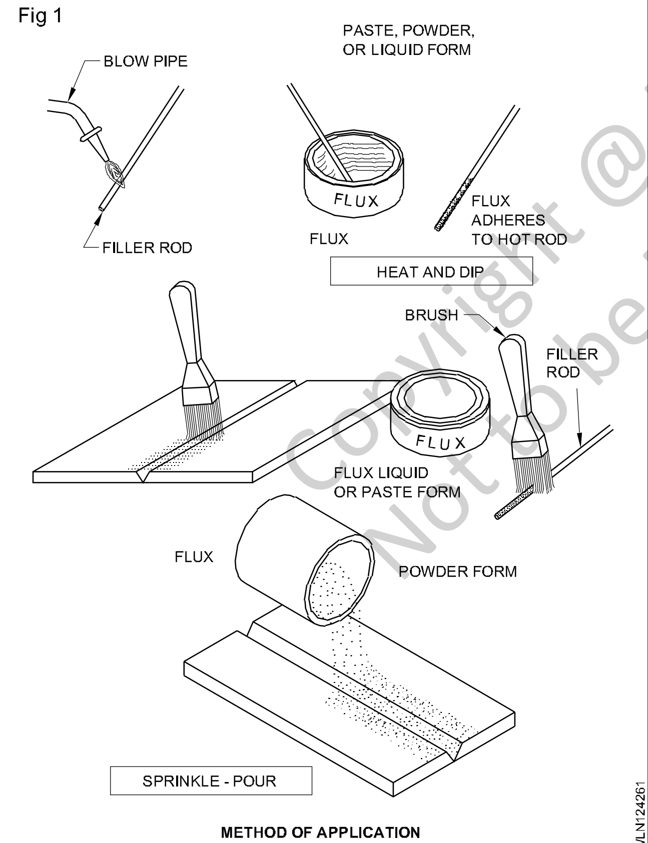
The function of flux in gas welding: To dissolve oxides and to prevent impurities and other inclusion that could affect the weld quality.

Fluxes help the flow of their metal into very small gap between the metals being joined.

Fluxes act as cleaning agents to dissolve and remove oxides and clean the metal for welding from dirt and other impurities.

Fluxes are available in the form of paste, powder and liquid. The method of application of flux is shown in Fig 1.

Fig 1

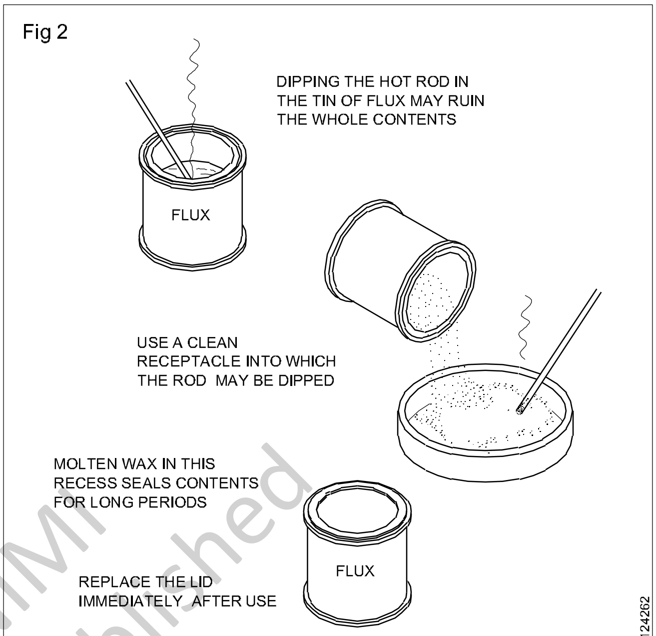


METHOD OF APPLICATION

Storing of fluxes: Where the flux is in the form of a coating on the filler rod, protect carefully at all times against damage and dampness. (Fig 2)

Seal flux tin lids when storing especially for long periods. (Fig 2)

Fig 2



METHOD OF STORING FLUX

Though the inner envelope of an oxy-acetylene flame offers protection to the weld metal, it is necessary to use a flux in most cases. Flux used during welding not only protects the weldment from oxidation but also from a slag which floats up and allows clean weld metal, to be deposited. After the completion of welding, flux residues should be cleaned.

Removal of flux residues: After welding or brazing is over, it is essential to remove the flux residues. Fluxes in general are chemically active. Therefore, flux residues, if not properly removed, may lead to corrosion of parent metal and weld deposit.

Some hints for removal of flux residues are given below:

– Aluminium and aluminium alloys - As soon as possible after welding, wash the joints in warm water and brush vigorously. When conditions allow, follow up by a rapid dip in a 5 percent solution of nitric acid; wash again, using hot water to assist drying.

When containers, such as fuel tanks, have been welded and parts are inaccessible for the hot water scrubbing method, use a solution of nitric and hydrofluoric acids. To each 5.0 liters of water add 400 ml of nitric acid (specific gravity 1.42) followed by 33 ml of hydrofluoric acid (40 percent strength). The solution used at room temperature will generally completely remove the flux residue in 10 minutes, producing a clean uniformly etched surface, free from stains. Following this treatment the parts should be rinsed with cold water and finished with a hot water rinse. The time of immersion in hot water should not exceed three minutes, otherwise staining may result; after this washing with hot water the parts should be dried. It is essential when using this treatment that rubber gloves be worn by the operator and the acid solution should preferably be contained in an aluminium vessel.

- Magnesium alloys - Wash in water followed quickly by standard chromating. Acid chromate bath is recommended.
- Copper and brass - Wash in boiling water followed by brushing. Where possible, a 2 percent solution of nitric or sulphuric acid is preferred to help in removing the glassy slag, followed by a hot water wash.
- Stainless steel - Treat in boiling 5 percent caustic soda solution, followed by washing in hot water. Alternatively, use a de-scaling solution of equal volume of hydrochloric acid and water to which is added 5 percent of the total volume of nitric acid with 0.2 percent of total volume of a suitable restrainer.
- Cast iron - Residues may be removed easily by a chipping hammer or wire brush.
- Silver brazing - The flux residue can be easily removed by soaking brazed components in hot water, followed by wire brushing. In difficult cases the work piece should be immersed in 5 to 10 percent sulphuric acid solution for a period of 2 to 5 minutes, followed by hot water rinsing and wire brushing.

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Defects in gas welding

Objectives: At the end of this lesson you shall be able to
- **name and define various weld defects**
- **identify the common faults in gas welding.**

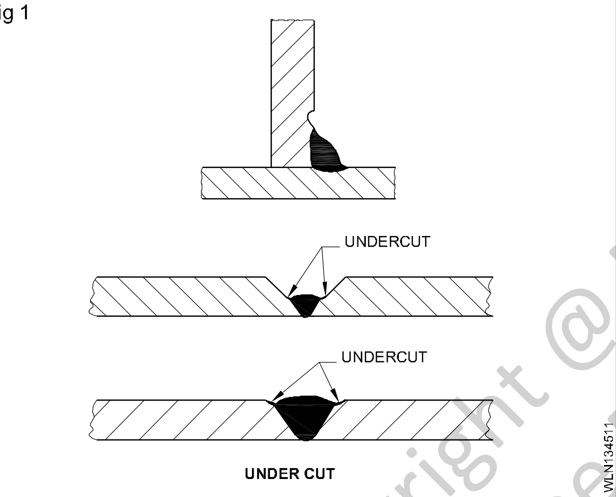
Definition

A fault is an imperfection in the weld which may result in failure of the welded joint while in service.

The following faults occur commonly in gas welding.

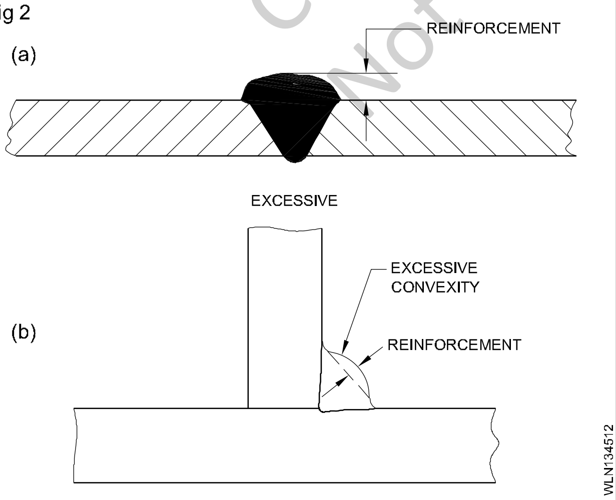
Undercut: A groove or channel formed along the toe of the weld on one side or on both sides. (Fig 1)

Fig 1



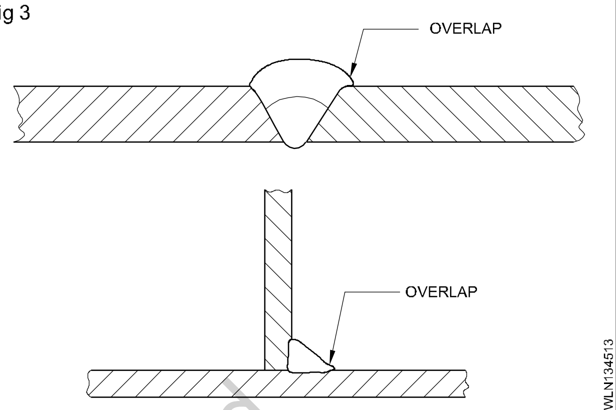
Excessive convexity: Too much weld metal added to the joint so that there is excessive weld reinforcement. (Fig 2)

Fig 2



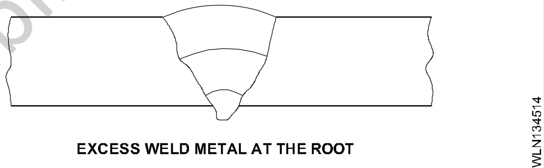
Overlap: Metal flowing into the surface of the base metal without fusing it. (Fig 3)

Fig 3



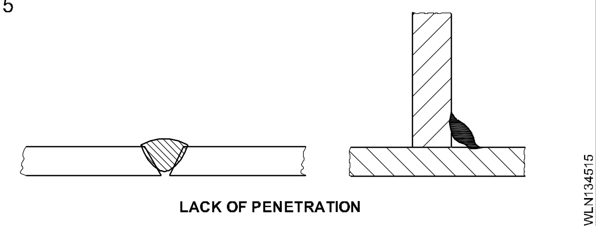
Excessive penetration: Depth of fusion at the root of the grooved joint is more than the required amount. (Fig 4)

Fig 4



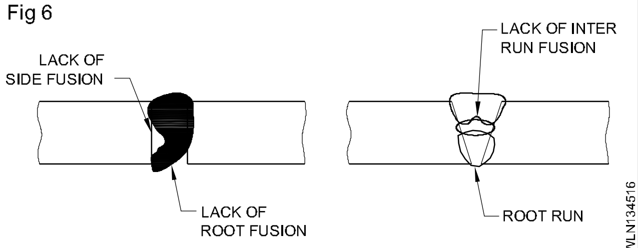
Lack of penetration: Required amount of penetration is not achieved, i.e. fusion does not take place up to the root of the weld. (Fig 5)

Fig 5



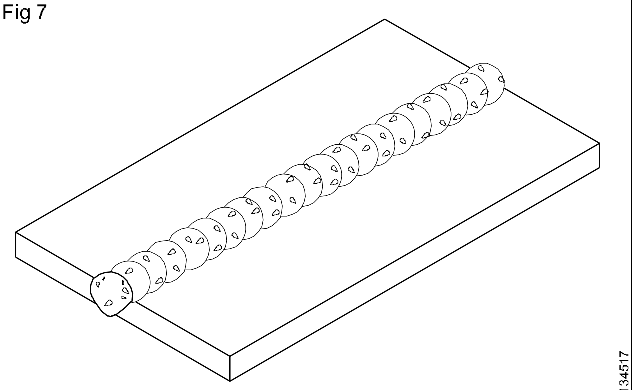
Lack of fusion: If there is no melting of the edges of the base metal at the root face or on the side face or between the weld runs, then it is called lack of fusion. (Fig 6)

Fig 6



Porosity: Number of pinholes formed on the surface of the deposited metal. (Fig 7)

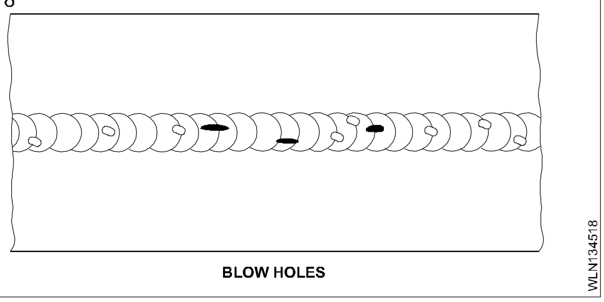
Fig 7



POROSITY

Blow-holes: These are similar to pinholes but have a greater diameter. (Fig 8)

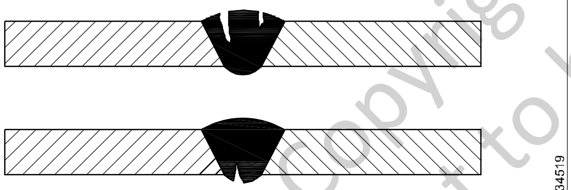
Fig 8



BLOW HOLES

Cracks: A discontinuity in the base metal or weld metal or both. (Fig 9)

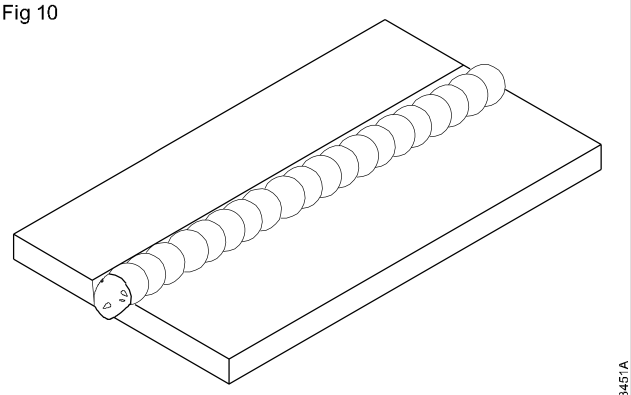
Fig 9



CRACKS

Unfilled crater: A depression formed at the end of the weld. (Fig 10)

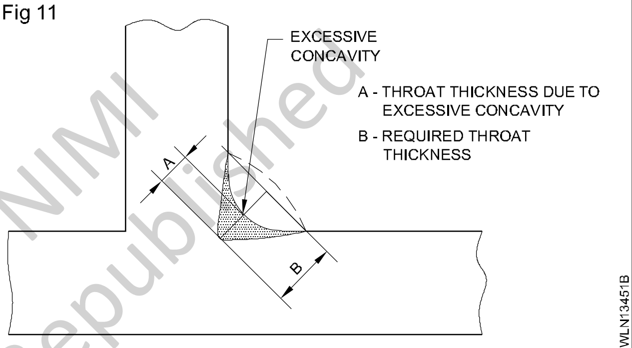
Fig 10



UNFILLED CRATER

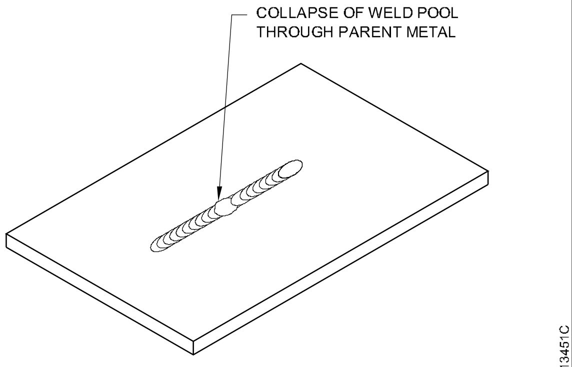
Excessive concavity/insufficient throat thickness: Enough weld metal is not added to the joint so that there is insufficient throat thickness. (Fig 11)

Fig 11



Burn through: A collapse of the molten pool due to excessive penetration, resulting in a hole in the weld run. (Fig 12)

Fig 12



BURN THROUGH

Weld defects - Causes and remedies

Objectives: At the end of this lesson you shall be able to
- **explain the causes of weld defects**
- **state the remedies to prevent the defects.**

Welding defects: Possible causes and remedies

	Defect	Possible causes	Appropriate remedies
1	Fillet weld with insufficient throat thickness.	Incorrect angle of filler rod and blowpipe.	Maintain filler rod and blowpipe at the appropriate angles.
2	Excessive concavity in butt weld profile.	Excess heat build-up with too fast a speed of travel or filler rod too small.	Use the appropriate size nozzle and filler rod with the correct speed of travel.
3	Excessive penetration. Excess fusion of root edges.	Angle of slope of nozzle too large. Insufficient forward heat. Flame size and/or velocity too high. Filler rod too large or too small. Speed of travel too slow.	Maintain the nozzle at the correct speed of travel. Select correct nozzle size. Regulate flame velocity correctly. Use correct size of filler rod.
4	Burn through.	Excessive penetration has produced local collapse of weld pool resulting in a hole in the root run.	Maintain blowpipe at the correct angles. Check nozzle size, filler rod size. Travel at the correct speed.
5	Undercut along vertical member of filler welded Tee joint.	Incorrect angle of tilt used in blowpipe manipulation.	Maintain blowpipe at the Correct angle.
6	Undercut in both sides of weld face in butt joint.	Wrong blowpipe manipulation; incorrect distance from plate surface, excessive lateral movement. Use of too large a nozzle.	Use correct nozzle size, speed of travel and lateral blowpipe manipulation.
7	Incomplete root penetration in butt joint (single vee or double vee).	Incorrect set up and joint preparation. Use of unsuitable procedure and/or welding technique.	Ensure joint preparation and set up are correct. Appropriate procedure and/or welding technique must be used.
8	Incomplete root penetration in close square Tee joint.	Incorrect set up and joint preparation. Use of unsuitable procedure and/or welding technique.	Ensure joint preparation and set up are correct. Appropriate procedure and/or welding technique must be used.
9	Lack of root penetration.	Incorrect joint preparation and set up. Gap too small. Vee preparation too narrow. Root edges touching.	Prepare and set up the joint correctly.
10	Lack of fusion on root and side faces of double Vee butt joint.	Incorrect set up and joint preparation. Use of unsuitable welding technique.	Ensure the use of correct joint preparation, set up and welding technique.
11	Lack of inter-run fusion.	Angles of nozzle and blowpipe manipulation incorrect.	Correct the angles of slope and tilt. Use blowpipe manipulation to control uniform heat build-up.

	Defect	Possible causes	Appropriate remedies
	Overlap		
12	Weld face cracks in butt and fillet welds.	Use of incorrect welding procedure. Unbalanced expansion and contraction stresses. Presence of impurities. Undesirable chilling effects. Use of incorrect filler rod.	Use correct procedure and filler rod. Ensure uniform heating and cooling. Check suitability and surface preparation of material before welding. Avoid draughts and use appropriate heat treatment.
13	Surface porosity and gaseous intrusions.	Use of incorrect filler rod and technique. Failure to clean surfaces before welding. Absorption of gases due to incorrectly stored fluxes, unclean filler rod. Atmospheric contamination.	Clean plate surfaces. Use correct filler rod and technique. Make sure the flame setting is correct to avoid gas contamination.
14	Crater at end of weld run. Small cracks may be present.	Neglect to change the angle of blowpipe, speed of travel or increase the rate of weld metal deposition as welding is completed at the end of the seam.	Reduce the angle of the blowpipe progressively with speed of travel to lower the heat input and deposit, and deposit sufficient metal to maintain the toe of the weld pool at the correct level until it has completely solidified.

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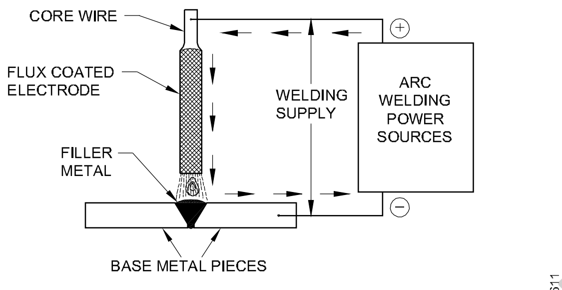
Arc welding electrodes

Objectives: At the end of this lesson you shall be able to
- **explain arc welding electrode**
- **state the types of electrodes**
- **explain the coating factor**
- **describe the characteristics of flux coating on electrode**
- **explain the functions of flux coating during welding.**

Introduction: An electrode is a metallic wire of standard size and length, generally coated with flux (may be bare or without flux coating also) used to complete the welding circuit and provide filler material to the joint by an arc, maintained between its tip and the work. (Fig 1)

Fig 1



FLUX COATED METALLIC ELECTRODE IN THE WELDING CIRCUIT

Different types of electrodes used are given in the Electrode chart.

Method of flux coating:

– Dipping

– Extrusion

Dipping method: The core wire is dipped in a container carrying flux paste. The coating obtained on the core wire is not uniform resulting in non-uniform melting; hence this method is not popular.

Extrusion method: A straightened wire is fed into an extrusion press where the coating is applied under pressure. The coating thus obtained on the core wire is uniform and concentric, resulting in uniform melting of the electrode. (Fig 2) This method is used by all the electrode manufacturers.

Coating factor (Fig 3)**:** The ratio of the coating diameter to the core wire diameter is called the coating factor.

It is 1.25 to 1.3 for **light coated**,

1.4 to 1.5 for **medium coated**,

1.6 to 2.2 for **heavy coated**, and above 2.2 for super heavy coated electrodes.

Fig 2

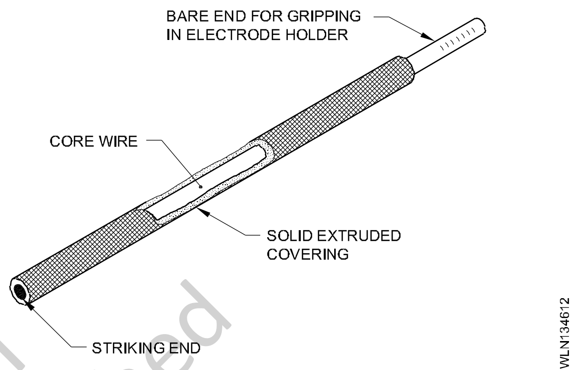
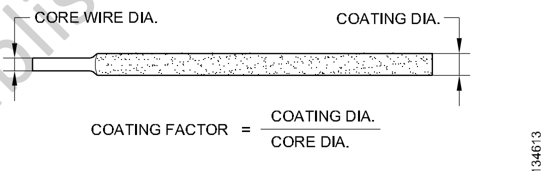


Fig 3



COATING FACTOR

Types of flux coating

– Cellulosic (Pipe welding electrode e.g. E6010)

– Rutile (General purpose electrode e.g. E6013)

– Iron powder (e.g. E7018)

– Basic coated (Low hydrogen electrode e.g. E7018)

Cellulosic electrode: Cellulosic electrode coatings are mainly made of materials containing cellulose, such as wood pulp and flour. The coating on these electrodes is very thin and the slag is difficult to remove from deposited welds. The coating produces high levels of hydrogen and is therefore not suitable for high-strength steels. This type of electrode is usually used on DC+ and suited to root pass welding of high pressure pipes.

Rutile electrodes: Rutile electrodes, are general-purpose electrodes have coatings based on titanium dioxide. These electrodes are widely used in the fabrication 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 fabrication.

Basic or hydrogen-controlled electrodes: Basic or hydrogen controlled electrode coatings are based on calcium fluoride or calcium carbonate. This type of electrode is suitable for welding high-strength steels without weld cracks and the coating have to be dried. This drying is achieved by backing at 450°C holding at 300°C and storing at 150°C until the time of use. By maintaining these conditions it is possible to achieve high strength weld deposits on carbon, carbon manganese and low alloyed steels. Most electrodes in this group deposit welds with easily removable slags, producing acceptable weld shape in all positions. Fumes given off by this electrode are greater than with other types of electrodes.

Iron powder electrodes: Iron powder electrodes get their name from the addition of iron powders to the coating which tend to increase efficiency of the electrode. For example, if the electrode efficiency is 120%, 100% is obtained from the core wire and 20% from the coating. Deposited welds are very smooth with an easily removable slag; welding positions are limited to horizontal, vertical fillet welds and flat or gravity position fillet and butt welds.

— — — — — — — —

Composition/Characteristics Flux

Composition/characteristics flux: The coating of the welding electrodes consists of a mixture of the following substances.

Alloying substances: These substances compensate for the burning of manganese, ferro-silicon. The alloying substances are:

- ferro-manganese
- ferro-silicon
- ferro-titanium.

Arc stabilizing substances: These are carbonates known as chalk and marble. These are used for the stabilisation of the arc.

Deoxidizers: These substances prevent porosity and make the welds stronger. The deoxidising substances are iron oxide, lamitite, magnetite.

Slag forming substances: These substances melt and float over the molten metal and protect the hot deposited weld metal from the atmospheric oxygen and nitrogen. Also due to the slag covering, the weld metal is prevented from fast cooling. The slag forming substances are clay, limestone.

Fluxing/cleaning substances: These substances remove oxides from the edges to be welded and controls the fluidity of the molten metal. The cleaning substances are lime stone, chlorides, fluorides.

Gas forming substances: These substances form gases which aid the transfer of metal. They also shield the welding arc and weld pool. The substances are: wood flour dixtorine and cellulose.

Binding and plasticizing substances: These substances help the applied coating to grip firmly around the core wire of the electrode.

These are: sodium and potassium silicates.

Purpose or function of flux coating: During welding, with the heat of the arc, the electrode coating melts and performs the following functions.

- It stabilizes the arc.
- It forms a gaseous shield around the arc which protects the molten weld pool from atmospheric contamination.
- It compensates the losses of certain elements which are burnt out during welding.
- It retards the rate of cooling of the deposited metal by covering with slags and improves its mechanical properties.
- It helps to give good appearance to the weld and controls penetration.
- It makes the welding in all positions easy.
- Both AC and DC can be used for the welding.
- Removes oxide, scale etc. and cleans the surfaces to be welded.
- It increases metal deposition rate by melting the additional iron powder available in the flux coating.

Types of electrodes for ferrous and alloy metals

Mild steel electrode: Mild steel is characterized by carbon content not exceeding 0.3%. Mild steel electrode core wire contains various alloying elements.

Carbon 0.1 to 0.3%
(Strengthening agent)

Keep carbon as low as possible.

Silicon above 0.5%
(Deoxidizes, prevents weld metal porosity.)

Manganese 1.65%
(Increases strength and hardness.)

Nickel
(Increases strength and notch toughness.)

Chromium
(Increases tensile strength and hardness. Lowers the ductility.)

Molybdenum 0.5%
(Increases hardness and strength.)

Indian Standard System laid down in IS:814-1991 a classification and coding of covered electrodes for metal arc welding of mild steel, and low alloy high tensile steel. Mild steel and low alloy high tensile steel electrodes are classified into seven recognised groups, depending upon the chemical composition of the flux coating.

Stainless steel electrodes: Selecting proper electrodes depends primarily on the composition of the base metal to be welded.

These electrodes are available with either lime or titanium coatings. The lime coated electrode is used only with DC reverse polarity. Titanium coated electrodes can be used in AC and DC reverse polarity, and will produce smoother and stable arc.

The coding system for stainless steel electrodes differs somewhat from that for the M.S. electrode. The I.S. 5206-1969 specification for corrosion-resisting chromium and chromium-nickel steel covered electrodes will give full details.

During welding, the electrode will tend to get red hot quickly. To avoid this, a 20 to 30% lower current than what is used for ordinary M.S. electrode is recommended.

— — — — — — — —

Sizes of Mild Steel Electrodes

Objectives: At the end of this lesson you shall be able to
- **state the size, length and current setting of M.S. electrodes**
- **explain the functions of electrode**
- **state the BIS coding for M.S. electrode.**

The electrode size refers to the diameter of its core wire.

Each electrode has a certain current range. The welding current increases with the electrode size (diameter).

Electrode sizes

Metric

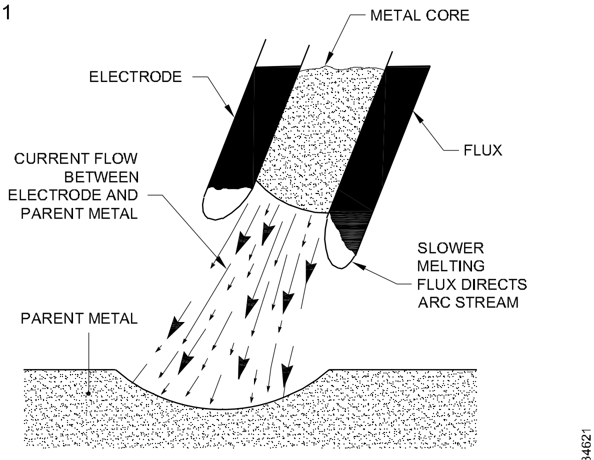
1.6mm
2.0mm
2.5mm
3.15mm
4.0mm
5.0mm
6.0mm
6.3mm
8.0mm
10.0mm

Standard length of electrodes: The electrodes are manufactured in two different lengths, 350 or 450mm.

Functions of an electrode in shielded metal arc welding: The two main functions of an electrode in SMAW are: (Fig 1)

- The core wire conducts the electric current from the electrode holder to the base metal through the arc.
- It deposits weld metal across the arc onto the base metal.

Fig 1



ELECTRODE FUNCTIONS

The flux covering melts at a slower rate than the metal core and a cup is formed at the tip of the electrode which helps to direct the molten metal to the required spot.

For easy identification and selection of a suitable arc welding electrode for welding mild steel plates, the electrodes are coded by Bureau of Indian Standards (B.I.S). According to this B.I.S., the electrodes to be used for welding mild steel for training a beginner is coded as ER4211.

Types of electrodes: Electric arc welding electrodes are of three general types. They are:

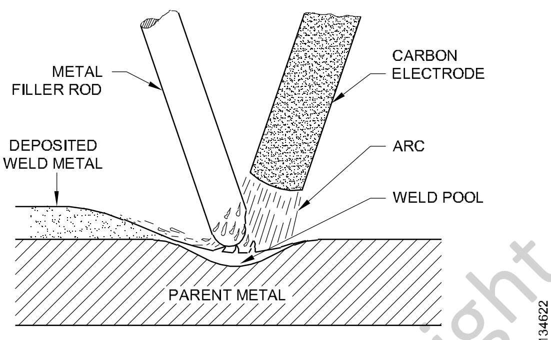
Carbon electrodes

Bare electrodes

Flux coated electrodes

Carbon electrodes are used in the carbon arc welding process (Fig 2). The arc is created between the carbon electrode and the job. The arc melts a small pool in the job and filler metal is added by using a separate rod.

Fig 2

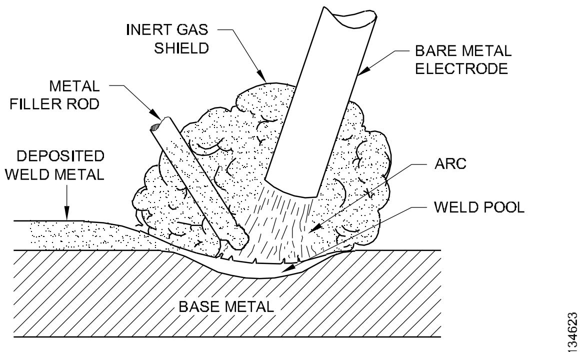


CARBON ARC PROCESS

Normally the carbon arc has very little use of welding. Its main application is in cutting and gouging operations.

Bare electrodes are also used in some arc welding processes (Fig 3). An inert gas is used to shield the molten weld metal and prevent it from absorbing oxygen and nitrogen. Filler metal is separately added through a filler rod. Usually tungsten is used as one of the bare wire electrode. In Co_2 welding and submerged arc welding processes the mild steel bare wire electrode is also used as a filler wire.

Fig 3

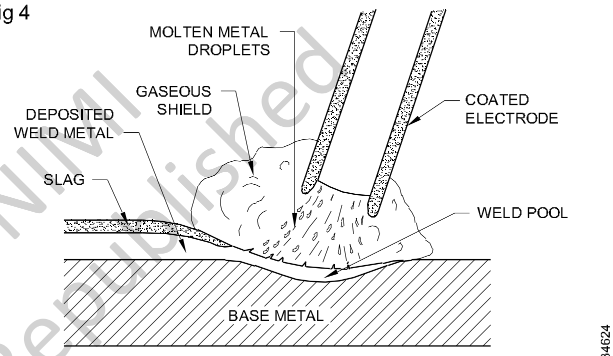


PROCESS USING BARE ELECTRODE & GASEOUS SHIELD

Flux coated electrodes are used in the manual metal arc welding process for welding ferrous and non-ferrous metals. (Fig 4)

The composition of the coating provides the flux, the protective shield around the arc and a protective slag which forms over the deposited weld metal during cooling.

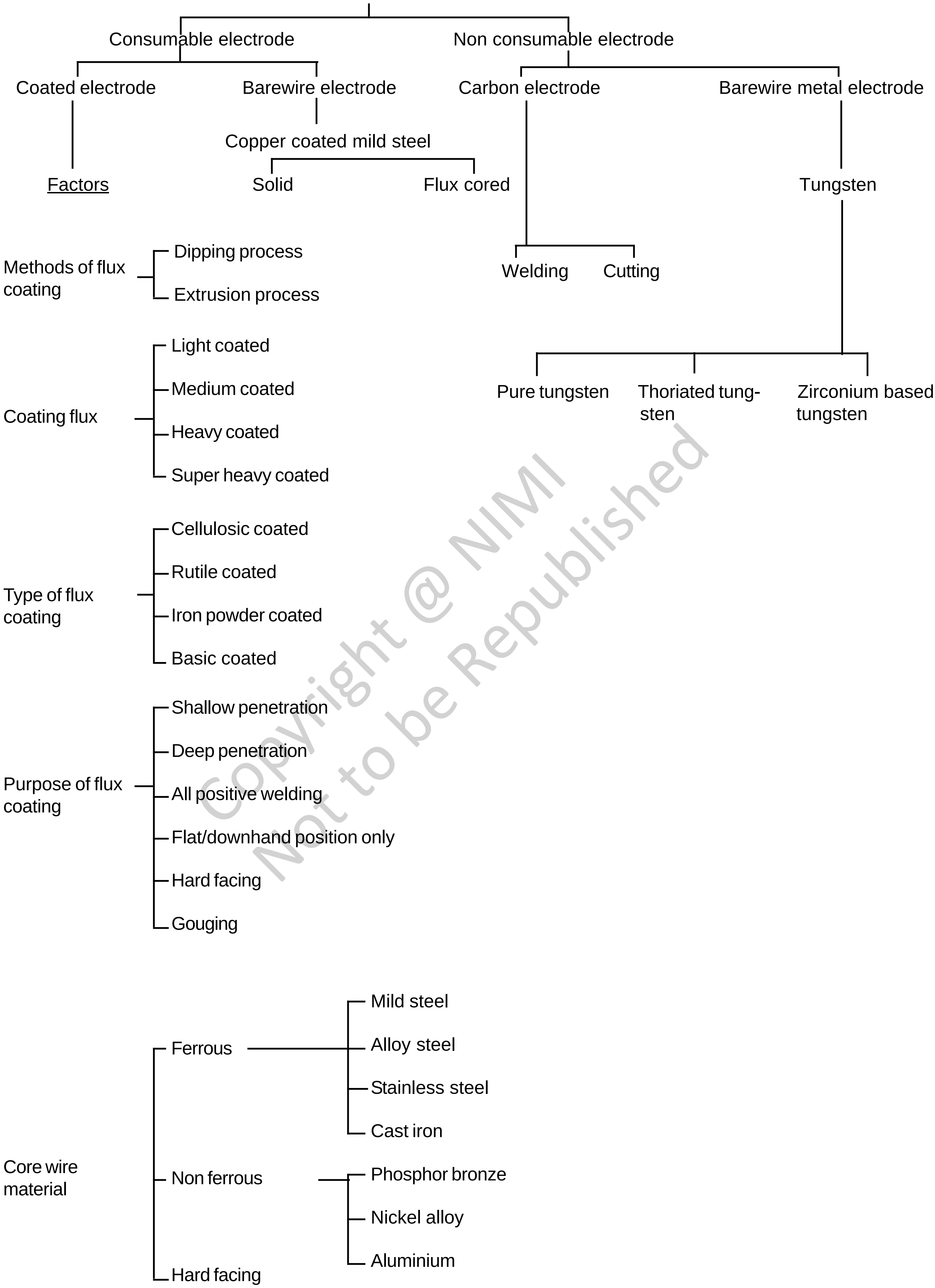
Fig 4



PROCESS USING FLUX COATED ELECTRODE

Chart

Types of Arc welding and cutting/gouging electrodes



Coding of Electrodes as per BIS, AWS and BS

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.**

Necessity of coding electrodes: Electrodes with different flux covering gives different properties to the weld metal. Also electrodes are manufactured suitable for welding with AC or DC machines and in different positions. These conditions and properties of the weld metal can be interpreted by the coding of electrodes as per Indian Standards.

The chart shown at the end of this lesson gives the specification of a particular electrode and also shows what each digit and letter in the code represents. By referring to this chart any one can know whether an electrode with a given specification can be used for welding a particular job or not.

Classification of electrodes shall be indicated by the IS: 814-1991 coding system of letters and numerals to indicate the specified properties or characteristics of the electrode.

Main coding: It consists of the following letters and numerals and shall be followed in the order stated:

a) a prefix letter 'E' shall indicate a covered electrode for manual metal arc welding, manufactured by extrusion process;

b) a letter indicating the type of covering;

c) first digit indicating the ultimate tensile strength in combination with the yield stress of the weld metal deposit;

d) second digit indicating the percentage elongation in combination with the impact values of the weld metal deposited;

e) third digit indicating welding position(s) in which the electrode may be used and

f) fourth digit indicating the current condition in which the electrode is to be used.

Additional coding: The following letters indicating the additional properties of the electrodes may be used, if required:

a) letters H_1, H_2, H_3 indicating hydrogen controlled electrodes.

b) letters J, K and L indicating increased metal recovery as 'Effective Electrode Efficiency' as per IS: 13043:91.

J = 110 - 129 percent;
K = 130 - 149 percent; and
L = 150 percent and above.

c) letter 'X' indicating the radiographic quality.

Different standards used in coding of electrodes

They are:

1 I.S. (814 - 1991)

2 A.W.S.

3 B.S.

INDIAN SYSTEM OF CODING OF ELECTRODES ACCORDING TO IS: 814-1991

Type of covering: The type of covering shall be indicated by the following letters.

A - Acid

B - Basic

C - Cellulosic

R - Rutile

RR - Rutile, heavy coated

S - Any other type not mentioned above

Strength characteristics: The combination of the ultimate tensile strength and the yield strength of the weld metal deposited shall be indicated by the digits 4 and 5. (See Table 1)

TABLE 1

Designation of strength characteristics

(Clauses 5.2 and 5.3)

Designating digit	Ultimate tensile strength N/mm^2	Yield strength Min N/mm^2
4	410-510	330
5	510-610	360

Elongation and impact properties: The combination of percentage elongation and impact properties of all weld metal deposited for the two tensile ranges (See Table 1) shall be as given in Table 2.

TABLE 2

Combination of percentage elongation and impact strength		
(Clause 5.3)		
Designation digit	**Percentage elongation (Min) on 5.65/So**	**Impact strength in joules (Min)/at °C**
(For tensile range 410-510 N/mm^2)		
0	No elongation and impact requirements	
1	20	47J/+27°C
2	22	47J/+0°C
3	24	47J/-20°C
4	24	27J/-30°C
(For tensile range 510-610 N/mm^2)		
0	No elongation and impact requirements	
1	18	47J/+27°C
2	18	47J/+0°C
3	20	47J/-20°C
4	20	27J/-30°C
5	20	27J/-40°C
6	20	27J/-46°C

Welding position: The welding position or positions on which the electrodes can be used as recommended by the manufacturer shall be indicated by the appropriate designating digits as follows.

1 All positions

2 All positions except vertical down

3 Flat butt weld, flat fillet weld and horizontal/vertical fillet weld

4 Flat butt weld and flat fillet weld

5 Vertical down, flat butt, flat fillet and horizontal and vertical fillet weld

6 Any other position or combination of positions nit classified above

Where an electrode is coded as suitable for vertical and overhead position it may be considered that sizes larger than 4 mm are not normally used for welding in these positions.

An electrode shall not be coated as suitable for particular welding position unless it is possible to use it satisfactorily in the position to comply with test requirements of this code.

Welding current and voltage conditions: The welding current and open circuit voltage conditions on which the electrodes can be operated as recommended by the manufacturer shall be indicated by the appropriate designating digits as given in Table 3.

For the purpose of coating an electrode, for any of the current conditions under 5.5 shall be size 4 mm or 5 mm and shall be capable of being operated at the condition satisfactorily within the current range recommended by the manufacturer.

Hydrogen controlled electrodes: The letters H_1, H_2 and H_3 shall be included in the classification as a suffix for those electrodes which will give diffusible hydrogen per 100 gm when determined in accordance with the reference method given in IS:1806:1986 as given below.

H_1 - up to 15 ml diffusible hydrogen
H_2 - up to 10 ml diffusible hydrogen
H_3 - up to 5 ml diffusible hydrogen

TABLE 3

Welding current and voltage conditions

(Clause 5.5)

Digit	Direct current: recommended electrode polarity	Alternating current: open circuit voltage, V, Min
0	–	Not recommended
1	+ or –	50
2	–	50
3	+	50
4	+ or –	70
5	–	70
6	+	70
7	+ or –	90
8	–	90
9	+	90

1 Symbol 0 reserved for electrodes used exclusively on direct current,

2 Positive polarity +, Negative polarity –.

The frequency of the alternating current is assumed to be 50 or 60 Hz. The open circuit voltage necessary when electrode are used on direct current is closely related to the dynamic characteristics of the welding power source. Consequently no indication of the minimum open circuit voltage for direct current is given.

Increased metal recovery: The letters J, K and L shall be included in the classification as a suffix for those electrodes which have appreciable quantities of metal powder in their coating and give increased metal recovery with respect to that of core wire melted, in accordance to the range given in 5.0.2 (b).

The metal recovery shall be determined as 'Effective Electrode Efficiency (E_E) as per the method given in IS 13043:1991.

Radiographic quality electrodes: The letter 'X' shall be included in the classification as a suffix for those electrodes which deposit radiographic quality welds.

Example 1

The classification for the electrode EB 5426H1JX

E B 5 4 2 6 H_1 J X

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.) — H_1

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 (Eongation = 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

AWS codification of carbon and low alloy steel coated electrodes

Chart - 1 shows details of AWS coding of an electrode.

In the chart, E stands for electrode. It means that it is a stick electrode.

The first two digits are very important. They designate the minimum tensile strength of the weld metal that the electrode will produce.

The third digit indicates the welding positions.

The last digit the code indicates the kind of flux coating used.

BS codification of carbon steel and low alloy steel covered electrodes (BS 639 : 1976 equivalent to ISO 2560)

As shown chart 2, E stands for covered MMA electrodes.

The first two digit indicated tensile strength and yield stress.

The next two digits indicate elongation and impact strength.

The letter after the first 4 digits indicates the type of covering.

The first 3 digits after the letter indicating the type of covering shows electrode efficiency.

The fourth digit after the letter indicating type of covering shows the welding position.

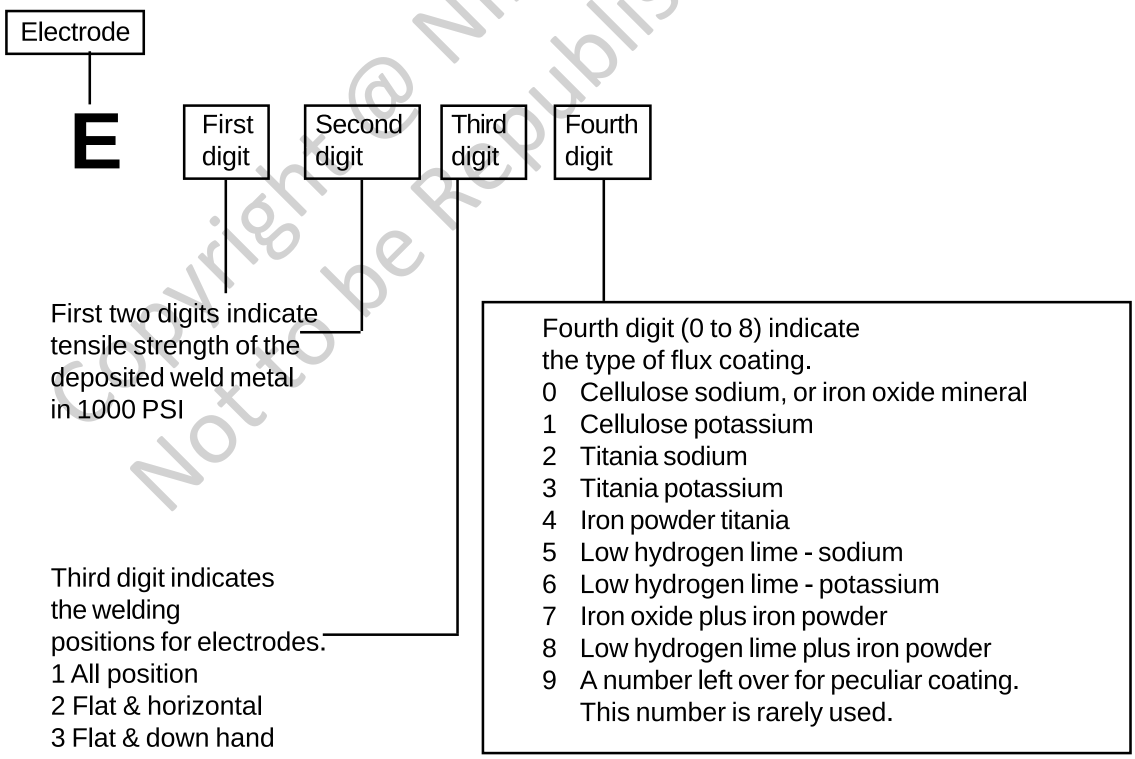
The fifth digit after the letter indicating type of covering indicates current and voltage.

In the case of rutile covered electrodes, the digits indicating the electrode efficiency after the letter indicating type of covering will not be given as shown in chart 1.

Chart 2 shows an electrode coding with electrode efficiency.

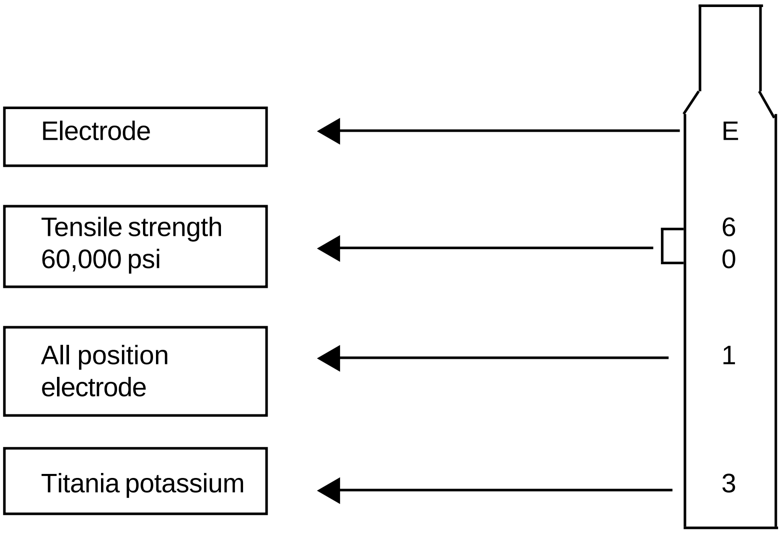
CHART 1

AWS CODIFICATION OF CARBON STEEL AND LOW-ALLOY STEEL COATED ELECTRODES

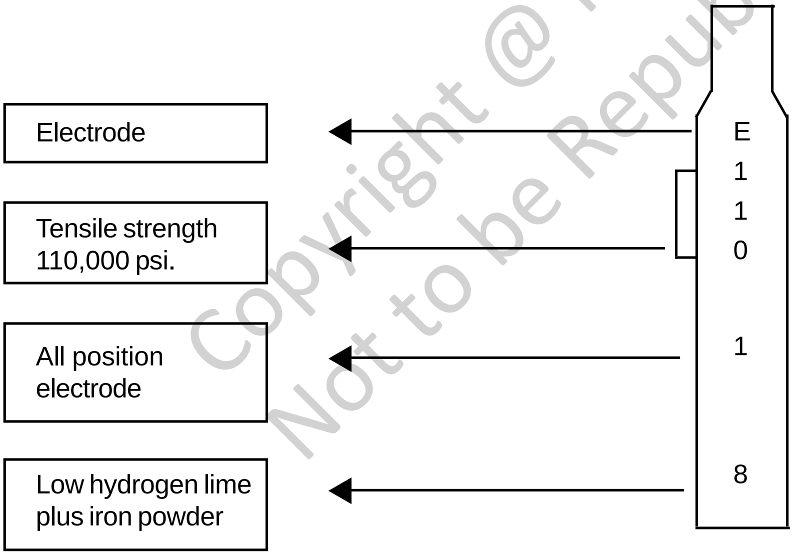


FOUR DIGITS CODIFICATION

EXAMPLE : AWS – E 6013.



FIVE DIGITS CODIFICATION



*To get the tensile strength of the weld in p.s.i., the number given here should be multiplied by 1000.

CHART 2 (BS 639 : 1976 equivalent to ISO 2560)

COVERING ④

- A Acid (iron oxide)
- AR Acid (rutile)
- B Basic
- C Cellulosic
- O Oxidising
- R Rutile (medium coated)
- RR Rutile (heavy coated)
- S Other types

ELECTRODE EFFICIENCY ⑤

% recovery to nearest 10% (> 110)

(H) ⑧

Indicates hydrogen controlled (> 15mg/100g)

STRENGTH ②

Electrode designation	Tensile strength N/mm^2	Minimum yield stress. N/mm^2
E43	430.550	330
E51	510.650	360

Example (b)	E	51	33	B	160	2	0	(H)
	1	2	3	4	5	6	7	8

PROCESS ①

Covered MMA electrode

WELDING POSITION ⑥

1 All positions
2 All positions except vertical down
3 Flat and, for fillet welds, horizontal vertical
4 Flat
5 Flat, vertical down and, flat fillet welds, horizontal vertical
6 Any position or combination of positions not classified above.

ELONGATION ③

First Digit	Minimum elongation, % E43	Minimum elongation, % E51	Temperature for impact value of 28J, °C
0	Not specified		Not specified
1	20	18	+20
2	22	18	0
3	24	20	-20
4	24	20	-30
5	24	20	-40

IMPACT ③

Second Digit	Minimum elongation, % E43	Minimum elongation, % E51	Impact properties: Impact value, J E43	Impact value, J E51	Temperature °C
0	Not specified		Not specified		
1	22	22	47	47	+20
2	22	22	47	47	0
③	22	22	47	47	-20
4	Not relevant	18	Not relevant	41	-30
6		18		47	-50

CURRENT / VOLTAGE ⑦

Code	Direct current: Recommended electrode polarity	Alternating current: Minimum open circuit voltage, V.
0	Polarity as recommended by manu-facturer	Not suitable for use on A C
1	+ or -	50
2	-	50
3	+	50
4	+ or -	70
5	-	70
6	+	70
7	+ or -	90
8	-	90
9	+	90

Example (1) Covered electrode for manual metal arc welding having a rutile covering of medium thickness and depositing weld metal with the following minimum mechanical properties. (BS 639)

Tensile Strength : 500 N/mm^2

Elongation: 23 %

Impact strength: 71 J at + 20°C, 37 J at 0°C, 20 J at -20°C.

It may be used for welding in all positions. It welds satisfactorily on alternating current with a minimum open-circuit voltage of 50 V and on direct current with positive polarity.

The complete classification for the electrode would therefore E 43 21 R 1 3

and the compulsory part would be E 43 21R 13.

Covered electrode for manual metal arc welding — E

Tensile strength — 43

Elongation and impact strength — 21

Covering — R

Welding positions — 1

Current and voltage — 3

Example (2) An electrode for manual metal arc welding having a basic covering, with a high efficiency and depositing weld metal containing 8 ml of diffusible hydrogen per 100 g of deposited weld metal with the following minimum mechanical properties.

Yield stress: 380 N/mm^2

Tensile strength: 560 N/mm^2

Elongation: 22% } Also a minimum elongation of 20%

Impact strength: 47 J at -20°C } with an impact value of 28 J at -20°C

Nominal efficiency: 158%

It may be used for welding in all positions except vertical down, direct current only.

The complete classification for the electrode would, therefore, be E 51 33 B 160 2 0 (H)

and the compulsory part would be E 51 33 B 16020(H)

Covered electrode for manual metal arc welding — E

Tensile strength and yield stress — 51

Elongation and impact strength — 33

Covering — B

Efficiency — 160

Welding positions — 2

Current and voltage — 0

Hydrogen controlled — (H)

— — — — — — — — — —

Effects of moisture pick up storage and baking of electrodes

Objectives: At the end of this lesson you shall be able to
- **explain about special purpose electrodes and their application**
- **state the necessity of baking a coated electrode**
- **store and handle the electrode properly for better weld quality.**

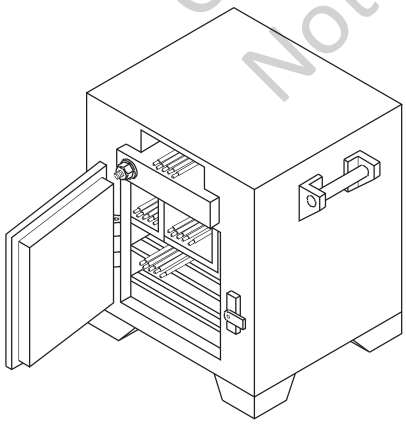
Storage of electrodes: The efficiency of an electrode is affected if the covering becomes damp.

- Keep electrodes in unopened packets in a dry store.
- Place packages on a duckboard or pallet, not directly on the floor.
- Store so that air can circulate around and through the stack.
- Do not allow packages to be in contact with walls or other wet surfaces.
- The temperature of the store should be about 5°C higher than the outside shade temperature to prevent condensation of moisture.
- Free air circulation in the store is as important as heating. Avoid wide fluctuations in the store temperature.
- Where electrodes cannot be stored in ideal conditions place a moisture-absorbent material (e.g. silica-gel) inside each storage container.

Store and keep the electrodes (air tight) in a dry place.

Bake the moisture affected/prone electrodes in an electrode drying oven at 110-150°C for one hour before using. (Fig 1).

Fig 1



ELECTRODE DRYING OVEN

WLN134711

Electrode coating can pick up moisture if exposed to atmosphere.

Baking electrodes: Water in electrode covering is a potential source of hydrogen in the deposited metal and thus may cause:

- Porosity in the weld
- Cracking in the weld.

Indications of electrodes affected by moisture are:

- White layer on covering.
- Swelling of covering during welding.
- Disintegration of covering during welding.
- Excessive spatter
- Excessive rusting of the core wire.

Electrodes affected by moisture may be baked before use by putting them in a controlled drying oven for approximately one hour at a temperature around 110 - 150°C. This should not be done without reference to the conditions laid down by the manufacturer. It is important that hydrogen controlled electrodes are stored in dry, heated conditions at all times.

Warning: Special drying procedures apply to hydrogen controlled electrodes. Follow the manufacturer's instructions.

Remember a moisture-affected electrode:

- has rusty stub end
- has white powder appearance in coating
- produces porous weld.

Always pick up the right electrode that will provide:

- **good arc stability**
- **smooth weld bead**
- **fast deposition**
- **minimum spatters**
- **maximum weld strength**
- **easy slag removal.**

Special purpose electrodes and their applications

Objectives: At the end of this lesson you shall be able to
- **state the types of special purpose electrodes**
- **explain the applications of special purpose electrodes.**

- Deep penetration electrodes
- Contact electrodes or iron powder electrodes
- Cutting and gouging electrodes
- Underwater welding and cutting electrodes
- Low hydrogen electrodes

Deep penetration electrodes: These electrodes are used to get deep penetration in the joints. Deep penetration occurs because of the very strong stream of gas produced by the burning of the cellulosic materials in the flux coating.

Butt joints on heavy sections are welded without edge preparation using these electrodes.

The depth of the penetration will be more than to the core wire diameter of the electrode used.

Contact electrodes (Iron powder): These electrodes contain a large amount of iron powder in their coatings. Therefore the arc ignites very easily. These electrodes are also called 'touch type' electrode. While using this type of electrode a large amount of weld metal is deposited per unit time.

Cutting and gouging electrodes: The cutting electrodes are of a tubular type. While cutting, air is sent through the centre at high pressure to cut ferrous metals. The gouging electrode can make 'U' grooves on the ferrous metals.

Underwater welding and cutting electrodes: These electrodes are used to cut and weld metals under the water. The coating having an external coating of varnish by 'lacquer' polishing or 'celluloid' helps to insulate and protect the electrode when immersed in water for welding or cutting purpose.

Low hydrogen electrodes: hydrogen controlled electrodes shall be such that the diffusible hydrogen content of the deposited metal will be low. This electrode is used with DC reverse polarity and can be used in all welding positions. These electrodes help to get a weld without cracks.

Weldability of metals

Objective: At the end of this lesson you shall be able to
- **explain the effects of weldable quality on ferrous and non-ferrous metals.**

Weldability:

- The ferrite and Martin site structure on carbon steels are not suitable for welding. But, the crystal fine structure enables brazing.
- Austenitic steels are suitable for welding. In present days all types of steels are welded using inert gas shielded arc process.

Weldability of cast Iron:

Cast Iron is welded after performing preheating to a temperature of 200°C-210°C. On completion of first layer of welding, the same preheating is repeated to maintain the re-inforcement of weld. Next, the whole job is evenly heated. This is called post-heating.

The job is cooled slowly, by covering under a heap of lime or ash or dry sand.

Weldability of copper:

99.9% pure copper with 0.01 to 0.08% oxygen in the form of cuprous oxide is known as electrolyte copper and this is not weldable.

A small quantity of phosphorous added to electrolyte copper to de-oxidise, so as to make it weldable.

The surface of the base metal is preheated to a fairly high temperature resulting in peacock neck blue colour; before the actual welding started.

Once the metal is cooled after welding, to reduce the grain size and locked up stresses, the pressuring is done.

Importances of preheating, post-heating and maintenance of inter-pass temperature

Objectives: At the end of this lesson you shall be able to
- **state the purpose of preheating**
- **explain the method of preheating**
- **describe the types of preheating**
- **explain the purpose of post-heating a bigger job**
- **describe the maintenance of inter-pass temperature.**

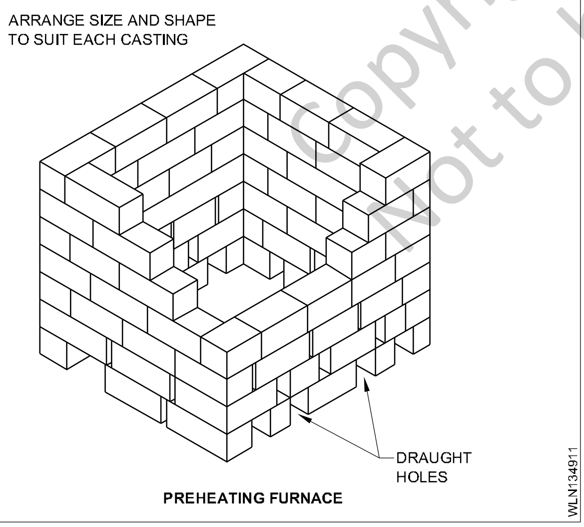
Preheating: Heating the job before welding operation is known as 'preheating'. The purpose of preheating of the cast iron job is to reduce cracking due to distortion. The rate of cooling, and gas consumption etc. are also reduced.

Small casting jobs may be preheated by the application of a blowpipe flame. But larger jobs should be preheated in a 'gas-furnace' or by means of a temporary charcoal furnace.

METHODS OF PREHEATING

Preheating methods depend upon the size of the job and the technique used for welding. Preheating can be done in a temporarily built gas or charcoal furnace (Fig 1) blacksmith's forge and even by the oxy-acetylene flame. Heavy jobs can be preheated from the furnace and small jobs by a flame from a blowpipe or from the forge.

Fig 1



PREHEATING FURNACE

TYPES OF PREHEATING

The type of preheating depends on the size and nature of the job. There are three types of preheating.

- Full preheating
- Local preheating
- Indirect preheating

Full preheating: The process of heating the entire job before commencing the welding operation is known as full preheating. This is usually done in a furnace for heavy jobs. In this type of preheating the heat of the job will be retained during welding, and also it will cool down at a uniform rate.

Local preheating: In this type, the preheating is done only at the portion to be welded. This is usually done by playing the blowpipe flame just before starting the welding. (Fig 2) In case of welding a cracked cast iron wheel, preheat the area opposite to the area crack. (Fig 3)

Fig 2

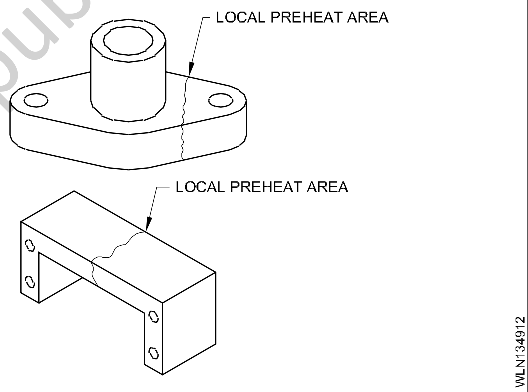
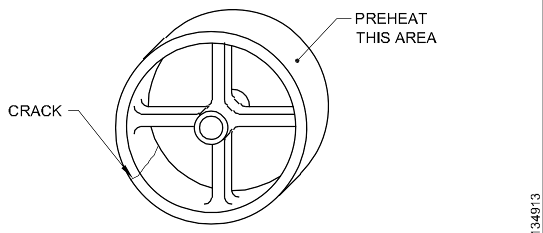


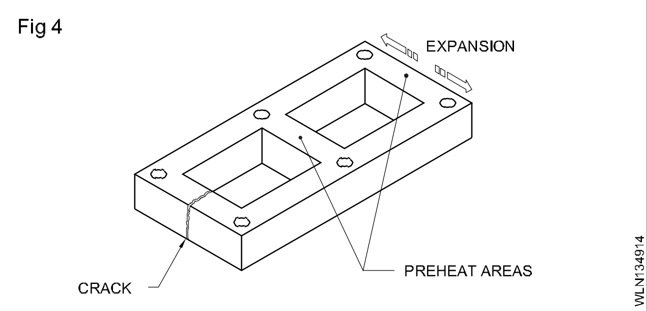
Fig 3



TECHNIQUE OF LOCAL PRE-HEATING

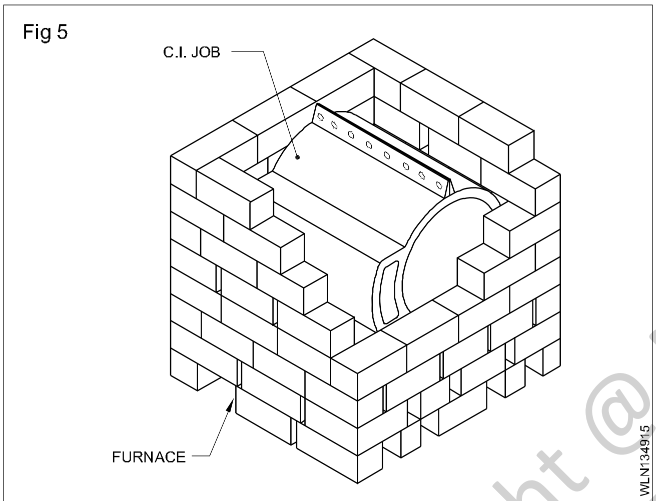
Indirect preheating: In this type, the preheating is being done on the area which may be affected by the uneven expansion and contracting due to the welding heat but not on the portion to be welded. This also can be done by the application of a blowpipe flame before commencing the weld. (Fig 4)

Fig 4



Purpose of post heating: If it is a bigger job, the welded job should be post heated in the same preheating furnace and allowed to cool slowly in the furnace itself so as to avoid any crack or any other distortion due to rapid cooling. (Fig 5)

Fig 5



The slag and oxide on the surface of the finished weld can be removed by scraping and brushing with a wire-brush after cooling. The weld should not be hammered as cast iron is brittle.

Maintenance of inter-pass temperature: The temperature of the preheated job can be checked by wax crayons. Marks are made on the cold job pieces by these crayons before preheating and after the job pieces reach the preheating temperature the marks will disappear.

This indicates that the job has been heated to the required preheating temperature. Different wax crayons are available for checking different temperatures. The temperature which is checked by the crayon will be marked on it.

Classification of 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 than 1% carbon content in steel.

Thus, the steel is classified as follows,

1) Carbon steel
2) Alloy steel

Effects of carbon content in steel: Steel can be defined as an alloy of carbon and iron, in which carbon is in a combined state. The carbon content is a very important factor to get the desired properties of steel.

Carbon: Carbon is a very important constituent of steel.

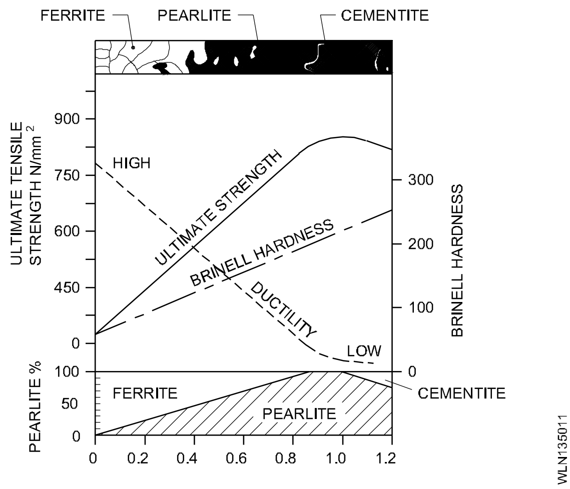
The addition of carbon at varying proportions modifies the characteristics of iron and makes it harder, stronger and of greater use in the engineering industry. Slight variations in the carbon content of steel lead to great differences in the properties of steel. Depending upon the properties it is put to different uses. (Table 1)

TABLE 1

Name	Group	Carbon content %	Examples of uses
Wrought iron	Wrought iron	Less than 0.05	Chain for lifting tackle, crane hooks, architectural iron work.
Dead mild steel	Plain carbon steel	0.1 to 0.15	Sheet for pressing out such shapes as motor car body panels. Thin wire, rod, and drawn tubes.
Mild steel	Plain carbon steel	0.15 to 0.3	General purpose workshop bars, boiler plates, girders.
Medium carbon steel	Plain carbon steel	0.3 to 0.5 0.5 to 0.8	Crankshaft forgings, axles. Leaf springs, cold chisels.
High carbon steel	Plain carbon steel	0.8 to 1.0 1.0 to 1.2 1.2 to 1.4	Coil springs, chisels used in woodwork. Files, drills, taps and dies. Fine edge tools (knives etc).

Ferrite is a very weak solid solution of carbon and iron with about 0.006% carbon. This is a very soft and ductile constituent. (Fig 1) Pearlite contains alternate layers of ferrite and cementite. This laminated structure makes pearlite stronger. As the carbon content increases, the pearlitic structure formation is also increased, and this increases the tensile strength and hardness.

Fig 1



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.

– Ferrite
– Cementite
– Pearlite

Welding of low carbon steel, medium and high carbon steel

Objectives: At the end of this lesson you shall be able to
- **state the composition of carbon percentage in low carbon steel and medium carbon steel**
- **state the type of flame needed for welding low carbon steel**
- **describe the method of welding low carbon steel**
- **explain the procedure for the welding of medium carbon steel.**

A plain carbon steel is one in which carbon is the only alloying element. The amount of carbon in the steel controls its hardness, strength and ductility. The higher the carbon the lesser the ductility of the steel.

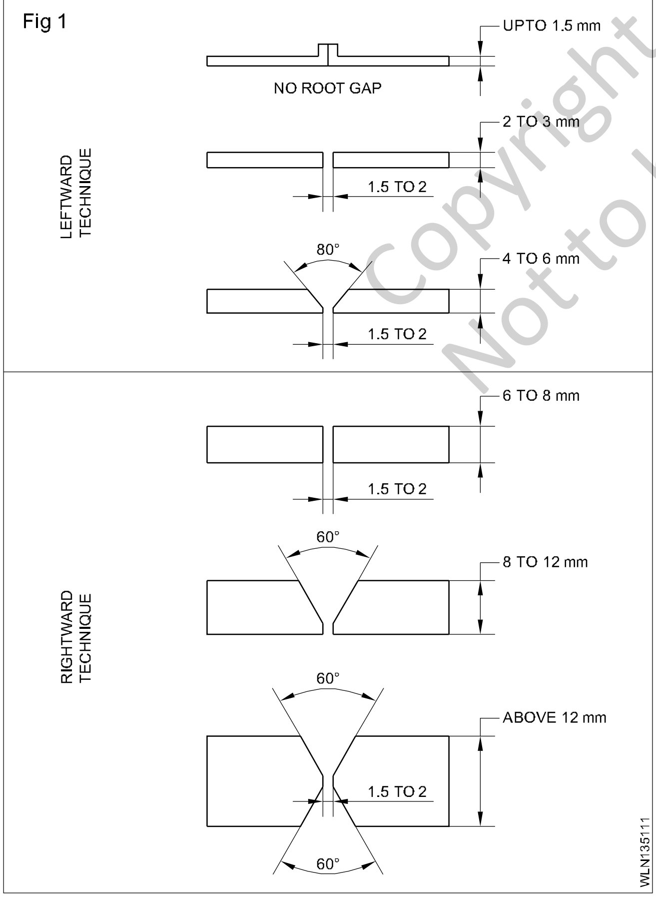
Carbon steels are classified according to the percentage of carbon they contain. They are referred to as low, medium and high carbon steels.

Low carbon steels: Steels with a range of 0.05 to 0.30 per cent are called low carbon steel or mild steel. Steels in this class are tough, ductile and easily machineable and quite easy to weld.

Welding technique: Up to 6 mm, leftward technique is a suitable one. Above 6 mm rightward technique is preferable.

Preparation: (Refer Fig 1 given below)

Fig 1



Type of flame: Neutral flame to be used.

Application of flux: No flux is required

After treatment: Most of them do not respond to any heat treatment process. Therefore except cleaning no post-heat treatment is required.

Medium carbon steel: These steel have a carbon range from 0.30 to 0.6 percent. They are strong and hard but cannot be welded as easily as low carbon steels due to the higher carbon content. They can be heat treated. It needs greater care to prevent formation of cracks around the weld area, or gas pockets in the bead, all of which weaken the weld.

Welding procedure: Most medium carbon steels can be welded in the same way as mild steel successfully without too much difficulty but the metal should be preheated slightly to 160°C to 320°C (to dull red hot). After completion of welding, the metal requires post-heating to the same preheating temperature, and allowed to cool slowly.

After cooling, the weld is to be cleaned and inspected for surface defects and alignment.

Plate edge preparation: Fig 1 shows the plate edge preparation depending on the thickness of the material to be welded.

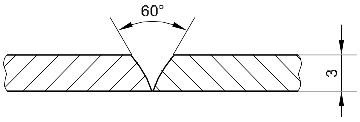
High carbon steel: High carbon steels contain 0.6% to 1.2% carbon. This type of steel is not weldable by gas welding process because it is difficult to avoid cracking of base metal and the weld.

Welding procedure

The type of edge preparation, nozzle size, filler rod size, pitch of tack for different thickness of sheets to be welded are given in Table 1.

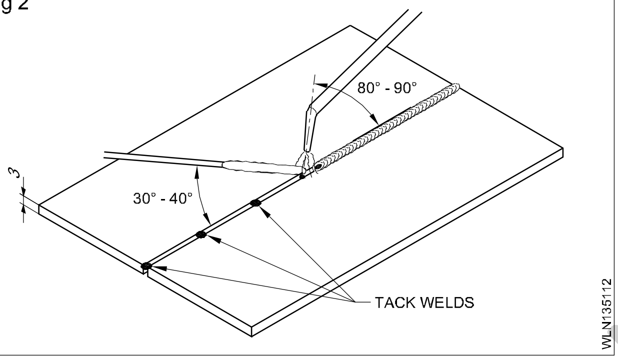
Start welding from the right hand edge of the joint and proceed in the leftward direction.

Table 1

Thickness	Preparation	Assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1 mm	Square edge	No gap	20	1	1.2 mm
1.2 mm	Square edge	No gap	20	2	1.2 mm
1.5 mm	Square edge	No gap	25	2	1.6 mm
3 mm		No gap	45	5	3 mm

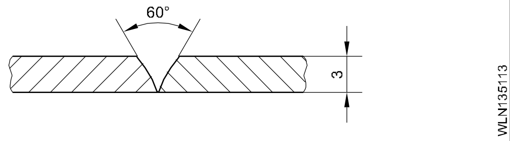
Keep the tip of the inner cone of the flame within 1 to 1.5 mm of the molten puddle, and hold the blowpipe at an angle of 80-90° to the work. (Fig 2)

Fig 2



In this way the filler rod which melts at a lower temperature than steel can flow forward and fill up the groove of the metal as it fuses. Fig 3 shows the type of edge preparation used for 3 mm thick metal.

Fig 3



Add the filler rod by holding it close to the cone of the flame. Upon withdrawing it from the puddle remove it entirely from the flame until you are ready to dip it back into the puddle.

Care must be taken not to direct too much heat on the end of the filler rod to avoid easy melting and flowing.

Complete the weld in one pass on one side and avoid multi-pass welding so as to reduce the effect of heat on the weldment.

Alloying elements and their functions on steel

Objectives: At the end of this lesson you shall be able to
- **state the necessity of alloying elements**
- **identify the common alloying elements**
- **describe the effects of each such element.**

Necessity of alloying elements: Certain elements are added to increase the mechanical properties of metals.

Common alloying elements: The following are some common alloying elements.

Carbon

Manganese

Sulphur

Phosphorus

Silicon

Chromium

Nickel

Tungsten

Vanadium

Molybdenum

Effects:

Carbon: With the addition of a small amount of carbon to pure iron, significant changes in the mechanical properties of iron will take place. An increase in hardness and a reduction in its melting point are the more significant of the changes.

Manganese: This promotes soundness and eliminates gas holes. It gives a higher tensile strength and hardness to the metal without affecting the ductility. It controls the sulphur content.

Sulphur: Sulphur forms sulphide which makes steel vary brittle at high temperatures and controls hot shortness.

Phosphorus: The presence of phosphorus in steel vary brittle at high temperature and controls hot shortness.

Silicon: This does not directly affect the mechanical properties of the metal. It is generally present in small quantities up to 0.4% and combines with oxygen in the steel to form silicon dioxide. This floats to the top of the molten pool during production, thereby removing oxygen and other impurities from steel.

Chromium: Chromium is added to steel to increase hardness and abrasion resistance. Increases resistance to corrosion.

Nickel: This metal is added for shock resistance and is used with chromium to form a wide variety of stainless steel groups.

Tungsten: Tungsten increases hardness and toughness and will not change even at high temperature.

Vanadium: This increases hardness and toughness.

Molybdenum: Molybdenum gives hardness, toughness and anti-shock properties to steel.

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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 'AUSTENTIC' which is extremely tough and has ductability. 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 austentic 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 austentic type.

All these types have a brighter colour without having any stain in appearance.

Types of stainless steel filler rods: Specially treated stainless steel filler rods, which contain stabilizing elements such as molybdenum, columbium, zirconium, titanium etc., are available.

The chromium percentage is also sometimes 1 to 1 1/2 percent more than in the base metal, so as to compensate the losses that may occur during the welding operation from the base metal. The melting point of the filler rod also will be 10° to 20°C less than the base metal. Filler rods of different sizes are available in the market.

Flux: A special type powdered flux which contains zinc chloride and potassium dichromate is available. During welding powered flux is to be made into a paste form by adding water and applied on the underside of the joint.

Method of controlling distortion: Since stainless steel has a much higher coefficient of expansion with lower thermal conductivity than mild steel, there are greater possibilities of distortion and warping.

Whenever possible clamps and jigs should be used to keep the pieces in line until they have cooled. And also a thick metal plate of copper should be used as a backing bar during welding so as to reduce distortion in the parent metal. Tacks at frequent intervals (i.e. pitch of tack is 20 - 25 mm) will also reduce distortion.

Welding procedure

The type of edge preparation, nozzle size, filler rod size, pitch of tack for different thickness of sheets to be welded are given in Table 1.

Start welding from the right edge of the joint and proceed in the leftward direction.

Keep the tip of the inner cone of the flame within 1 to 1.5 mm of the molten puddle, and hold the blowpipe at an angle of 80-90° to the work. (Fig 1)

Fig 1

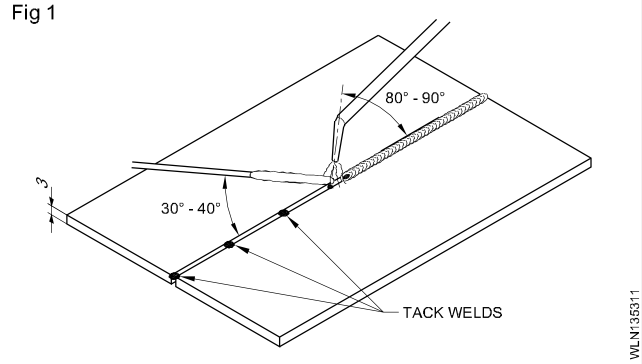
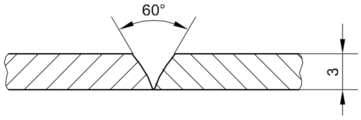
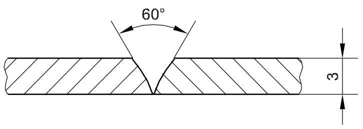


Table 1

Thickness	Preparation	Assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1 mm	Square edge	No gap	20	1	1.2 mm
1.2 mm	Square edge	No gap	20	2	1.2 mm
1.5 mm	Square edge	No gap	25	2	1.6 mm
3 mm		No gap	40	5	3 mm

In this way the filler rod which melts at a lower temperature than steel can flow forward and fill up the groove of the metal as it fuses. Fig 2 shows the type of edge preparation used for 3 mm thick metal.

Fig 2



Add the filler rod by holding it close to the cone of the flame. upon withdrawing it from the puddle remove it entirely from the flame until you are ready to tip it back into the puddle.

Care must be taken not to direct too much heat on the end of the filler rod to avoid easy melting and flowing.

Complete the weld in one pass on one side and avoid multi-pass welding so as to reduce the effect of heat on the weldment.

Success in welding stainless steel depends upon keeping the heat to a minimum. Re-tracking a hot weld produce excessive heat which is likely to increase the loss of the corrosion-resistant property in the stainless steel.

Cleaning after welding

Scale and oxide must be removed from the finished weld by grinding, polishing or by the use of a descaling of a solution as given below.

50 parts of water
50 parts of hydrochloric acid
1/2 percent PICKLETTE or FERROCLEANOL

The solution should be used at a temperature of about 50°C.

Always use a stainless steel wire brush for cleaning.

Weld decay - its effects and remedy

When austenetic 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.

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Welding of brass

Objectives: At the end of this lesson you shall be able to
- **state the composition of brass**
- **state the selection of nozzle, flame and flux**
- **explain the necessity of oxidising flame and welding technique.**

Composition of brass: Brass is an alloy of copper and zinc in various proportion, possibly with the addition of other elements in very less percentage.

The percentage of zinc various from 1 to 50% which makes available 15 individual commercial brasses. These brasses containing 20 to 40% zinc have a variety of uses.

Melting temperature of brass: The melting point of copper is 1083°C and that of zinc is 419°C. Brass melts at intermediate temperatures. The greater the amount of copper the higher the melting point. The melting point of brass is generally around 950°C.

Selection of nozzle, flame and flux: The main difficulty in welding of brass is the vapourisation of zinc, because the melting point of zinc is lower than that of brass. Due to the loss of zinc, below holes or porosity is produced in the weld and only copper is left over.

The strength is thereby reduced, and the weld gives a pitted appearance when polished.

Therefore excess burning of zinc should be controlled.

These 'zinc' problems are minimized by excess oxygen in the oxidising flame. The excess oxygen in the oxidising flame will convert zinc into zinc oxide whose melting point is more than that of zinc. So use of oxidising flame prevents evaporation of zinc. The flux helps to retain the zinc while solidification of weld metal occurs. The copper-zinc alloys, most of which are called BRASS, are more difficult to weld than copper. The zinc in the alloy produces irritating and destructive fumes or vapours during the welding process. Be sure to provide adequate ventilation and avoid inhaling zinc fumes.

For oxy-acetylene welding of brass, an oxidising flame is used and the nozzle is one size larger than the one used for welding mild steel plate of the same thickness. This will give a soft oxidising flame.

It is difficult to weld brass by electric arc process.

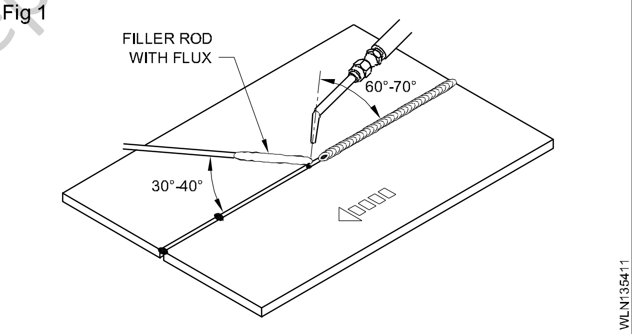
Flux is very important in welding brass. A fresh mixture of borax paste makes a good flux for brass welding.

The flux should be applied on the underside of the joint area and to the filler rod.

Edge preparation is as shown in Table 1.

Welding technique: Adopt leftward technique and keep the angle of the blowpipe at 60°-70° and the filler rod at 30°-40°. At the end of the joint reduce the blowpipe angle and withdraw entirely to reduce the heat input at the crater. (Fig 1)

Fig 1



Ensure complete removal of all traces of flux because the residual flux will react and reduce the strength of the joint.

Use a respirator and avoid inhaling zinc fumes during welding.

Table 1

Thickness	Preparation	Assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1 mm	Square edge	No gap	25	2	1.6 mm
1.2 mm	Square edge	0.8 mm gap	38	3	2 mm
1.5 mm	Square edge	0.8 mm gap	38	3	2 mm
3 mm	Single V	1.5 mm gap	75	5 to 7	3 mm

Copper-Properties-Types and Weldability

Objectives: At the end of this lesson you shall be able to
- **describe the various types of copper**
- **state the physical properties of copper**
- **explain the welding procedure.**

Electrolyte copper: This type contains 99.9% pure copper with 0.01 to 0.08% oxygen in the form of cuprous oxide. (Cu_2O). This type of copper is not weldable.

De-oxidized copper: In this type a small quantity of phosphorous, a de-oxidising element is added to the electrolyte copper. This type of copper is weldable.

Characteristics of copper

Reddish in colour.

High thermal and electrical conductivity.

Excellent resistance to corrosion.

Excellent workability in either hot or cold condition and in forming wires, sheets, rods, tubes and castings.

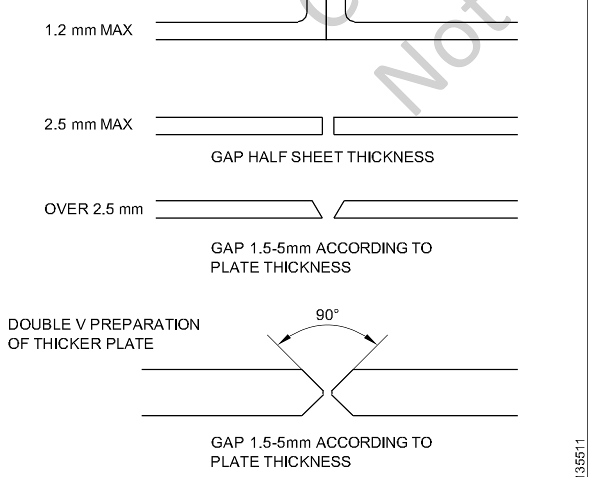
Melting point: 1083°C.

Density: 8.98 g/cm^3

Coefficient of linear expansion (ic): 0.000017 mm/mm/°C

Edges preparation (Fig 1)

Fig 1



PREPARATION OF COPPER PLATES FOR WELDING

Up to 1.2 mm - edge or flange point.

Over 1.5 mm up to 2.5 mm - square butt with 50% of sheet thickness as root gap.

2.5 mm to 16 mm - a angle 'V' of 80°-90°.

Over 16 mm - Double 'V' preparation of 90°.

Types of cleaning

Mechanical cleaning is done to remove dirt and any other foreign material. Chemical cleaning is done by applying solutions to remove oil, grease, paint etc.

Filler rod and flux: A completely de-oxidized copper rod (copper-silver alloy filler rod) having a lower melting point than the base metal is used.

Flux: Copper-silver alloy flux is applied on the edges to be joined in paste form.

Nozzle size: Use a nozzle which is one size larger than that used for mild steel.

Flame: Adjust a strictly neutral flame.

Effects of setting 'carburizing' or 'oxidising' flame

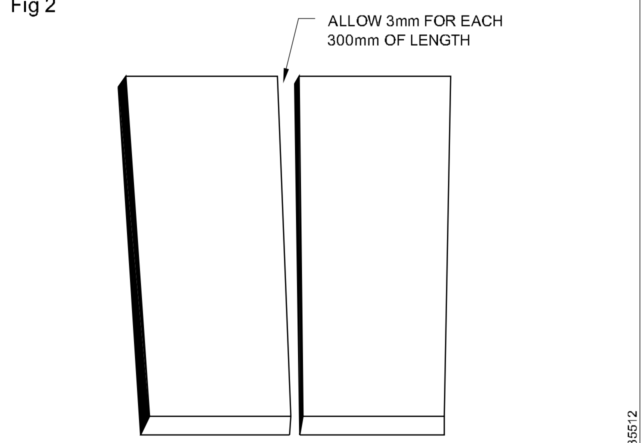
Too much oxygen will cause the formation of copper oxide and the weld will be brittle.

Too much acetylene will cause steam to form a porous weld.

Setting: 1.6 mm root gap between the sheets with a divergence allowance at the rate of 3-4 mm per 300 mm run. (Fig 2) Use wedge for welding long seam in copper. (Fig 3) No tacking is done.

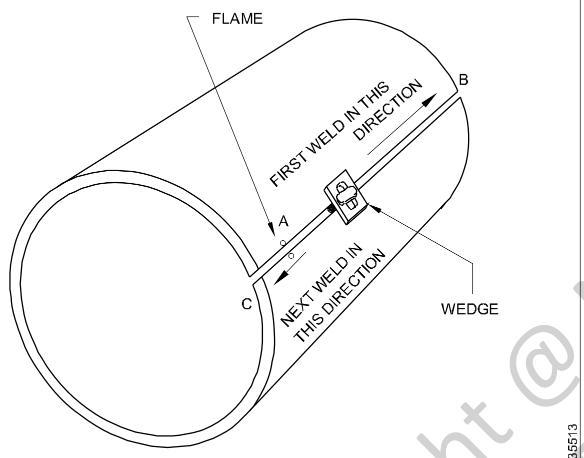
Preheat: Surface of the base metal is raised to a fairly high temperature 750°C (peacock neck blue colour) before the actual welding is started.

Fig 2



DIVERGENCE ALLOWANCE

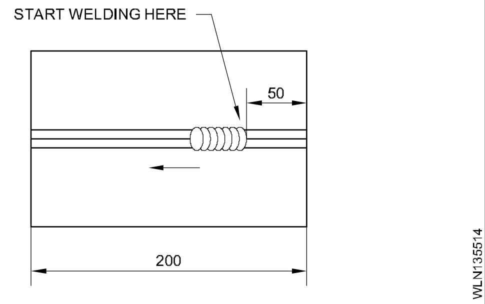
Fig 3



WELDING LONG SEAM IN COPPER

Welding technique: Adopt leftward technique up to 3.5 mm thickness and rightward technique for 4 mm thickness and above. Usually the welding starts from a point 40 to 50 mm away from the right end of the job and after welding till the left end turn the job by 180° and weld the balance unwelded portion. Always welding is done towards the open end of the joint. (Fig 4)

Fig 4



Control of distortion

Divergence allowance (as already stated in job setting) acts as an effective controlling distortion.

Chill plates or backing bar also prevents distortion.

After treatment

Peening is done in order to reduce the grain size and the locked up stresses. This is done when the metal is in hot condition.

Bronze welding of copper

Objectives: At the end of this lesson you shall be able to
- **explain the principle of bronze welding of copper**
- **describe the welding technique**
- **explain the advantages of bronze welding of copper**
- **describe the brazing problems and their remedies.**

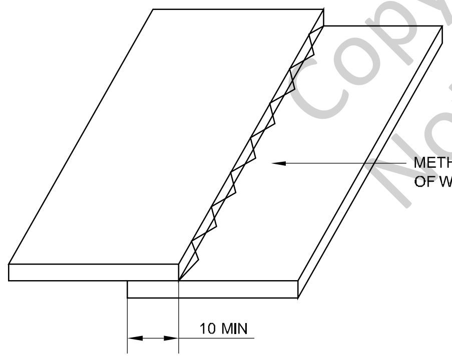
Principle of bronze welding of copper: Brazing is also a process of joining of similar or dissimilar metals together in a solid state by means of alloys (hard solder) which have a lower melting point than the metals to be joined. This process is used at a temperature above 452°C to 800°C depending upon the type of metal.

In bronze welding the base metal are not melted. Instead, they have been raised to a point which is above the melting point of the hard solder. The molten filler wets the surfaces to be joined, spreads over them, and solidifies, thereby forming the joint.

Technique: After the joint surfaces are perfectly cleaned the members of the joint should be clamped in a jig or in a fixture giving easy access for brazing the joint from all sides. The clearance should be set in advance.

Heating: Set a suitable oxidising flame. Heating should be done with the broad part of the flame. (Fig 1) When joining unequal sections of unequal thickness, the flame should be made to play on the thicker section.

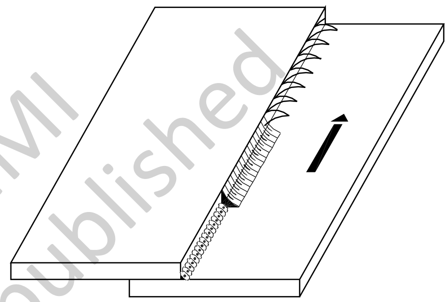
Fig 1



Flux: Brazing flux should be applied to the heated joint surfaces just before brazing. Some flux should also be applied to the filler rod which should be slightly heated.

Filler rod: The silicon-bronze filler rod should be melted by the heated members, as the filler rod is made to touch the edge of the member, and never melted directly by the flame. The method of depositing multiple pass on a fillet lap weld is shown in Fig 2. After the joint is completed, the bronze weld and the base metal should be allowed to cool slowly. Non-ferrous metals may be cooled in water also.

Fig 2



MAKING A MULTIPLE PASS FILLET WELD ON A LAP JOINT

Advantages

Dissimilar metals can be joined.

Assemblies can be 'bronzed' in a stress-free condition.

Complex assemblies can be bronzed in several steps by using filler metals at progressively lower melting temperatures.

Materials of different thickness can be joined.

Cast and wrought metals can be joined.

Metallurgical properties of the base materials are not seriously disturbed.

Brazed joints require little or no finishing.

Brazing problems and remedies

Problem	Remedy
The filler metal 'balls up' does not melt and flow into the joint.	Add more flux. Ensure pickling or additional mechanical cleaning to remove oxides, oils, or other surface coatings. Use fresh flux. Also check for contaminated pickling acid of 'dirty' grinder wheels that could spread impurities instead of removing them.
The filler metal melts but does not flow completely through the joint.	Increase the preheating period. The base metal may not be hot enough. Ensure thorough cleaning. Try a wider or narrower joint gap. Joint must not be too tight or too loose. Also check for gaps or spaces where capillarity is interrupted. Apply more flux to both filler rod and base metal. If not successful use a different flux compound. Improper flux may be breaking down due to too much heat.
The filler metal runs out instead of into the joint.	Reposition (tilt) the joint, so that gravity helps the filler joint. Make a small reservoir in the joint to start the capillary action. Feed the filler metal into the joint from above rather than horizontally or from below.
The filler metal melts but does not flow.	Ensure additional cleaning of the filler metal to remove the oxides. Use more flux on both the filler rod and the base metals.

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Welding of aluminium and its alloys

Objectives: At the end of this lesson you shall be able to
- **explain the properties of aluminium and its alloys**
- **state the difficulties in welding of aluminium by oxy-acetylene process**
- **describe the joint design, importance of flux and welding procedure**
- **state the various process of welding aluminium**
- **explain the advantages and disadvantages of welding of aluminium by oxy-acetylene process.**

Properties of aluminium and its alloys

Silvery white in colour.

Weighs only about one third as much as the commonly used low carbon steel.

Highly resistant to corrosion.

Possesses great electrical and thermal conductivity.

Very ductile, adaptable for forming and pressing operations.

Non-magnetic.

Melting point of pure aluminium is 659°C

Aluminium oxide has a higher melting point (1930°C) than aluminium.

Types

Aluminium is classified into three main groups.

– Commercially pure aluminium
– Wrought alloys
– Aluminium cast alloys

Commercially pure aluminium has a purity of atleast 99% the remaining 1% consisting of iron and silicon.

Difficulties in welding of aluminium by gas: Aluminium does not change in colour before it reaches the melting temperature. When the metal begins to melt, it collapses suddenly.

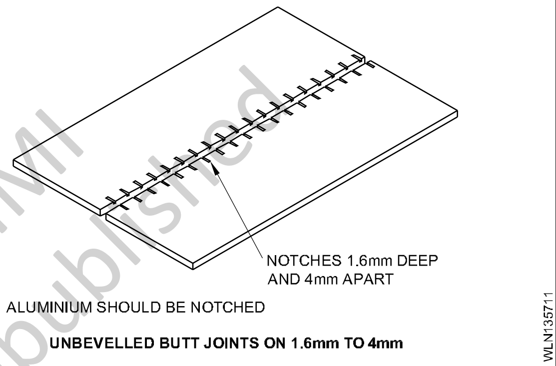
Molten aluminium oxidizes very rapidly form a heavy coating of aluminium oxide on the surface of the seam which has a higher melting point - 1930°C. This oxide must be thoroughly removed by using a good quality flux.

Aluminium, when hot, is very flimsy and weak. Care must be taken to support it adequately during the welding operation.

Joint design: Up to 1.6 mm, the edges should be formed to a 90° flange at a height equal to the thickness of the material.

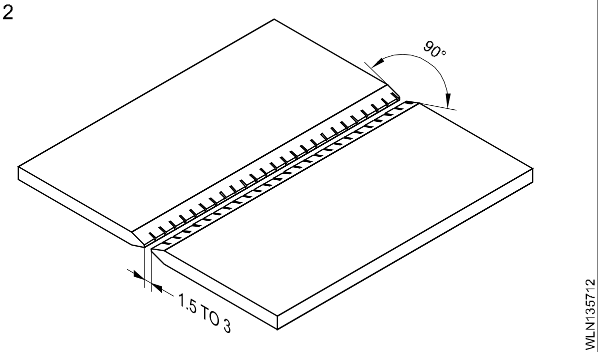
From 1.6 to 4 mm it can be butt-welded provided the edges are notched with a saw or cold chisel. (Fig 1)

Fig 1



For welding heavy aluminium plates, 4 mm or more in thickness, the edges should be bevelled to form 90° included angle with a root gap of 1.6 mm to 3 mm. (Fig 2)

Fig 2



Preparation, pitch of tack, nozzle, size, filler rod etc. are given in Table 1 for butt joints.

Importance of flux: Since aluminium oxidizes very rapidly, a layer of flux must be used to ensure a sound weld.

Aluminium flux powder is to be mixed with water (two parts of flux to one part of water).

The flux is applied to the joint by means of a brush. When a filler rod is used, the rod is also coated with flux.

On heavy sections, it is advisable to coat the metal as well as the rod for greater ease in securing better fusion.

Necessity of preheat: Aluminium and its alloys possess high thermal conductivity and high specific and latent heat. For this reason, a large amount of heat is required for fusion welding.

To ensure fusion and complete penetration to avoid cracking, and to reduce gas consumption, aluminium castings and assemblies in wrought alloys of above 0.8 mm are to be preheated.

Preheating temperature varies from 250°C to 400°C according to the size of the work, and can be done by using a torch or by keeping the job in the furnace where preheating is done.

Welding procedure: Please refer to Working Steps and Skill Information of Ex. No. 2.28/G-55.

Various processes of welding of aluminium

- Oxy-acetylene welding
- Manual metal arc welding
- TIG welding
- MIG welding
- Resistance welding
- Carbon arc welding
- Solid state welding:
  - cold welding
  - diffusion welding
  - explosive welding
  - ultrasonic welding.

Advantages of adopting oxy-acetylene process for welding of aluminium

Simple and low cost equipment

For welding thinner sheets, gas welding may prove to be economical.

Disadvantages

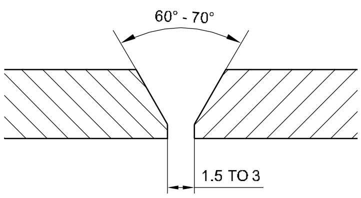
The flux residue, if not properly removed, may result in corrosion.

Distortion is greater than in arc welding.

Heat-affected zone is wider than in arc welding.

Welding speed is lower.

Table 1

Metal thickness	Preparation	Joint assembly	Pitch of tacks (mm)	Nozzle size	Filler rod
1	Square	No gap	25	1	2.5 mm
1.2	Square	No gap	40	2	2.5 mm
1.5	Square	No gap	40	2	2.5 mm
3		1.5 - 3 mm gap	75	5	3.15 mm

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Metallic arc cutting and gouging

Objectives: At the end of this lesson you shall be able to
- **state the different arc cutting and gouging processes**
- **state the equipments and accessories**
- **explain the different electrodes and their properties**
- **describe the current setting for different size electrodes**
- **describe the arc cutting and gouging procedures**
- **explain the advantages and applications.**

Different arc cutting and gouging processes

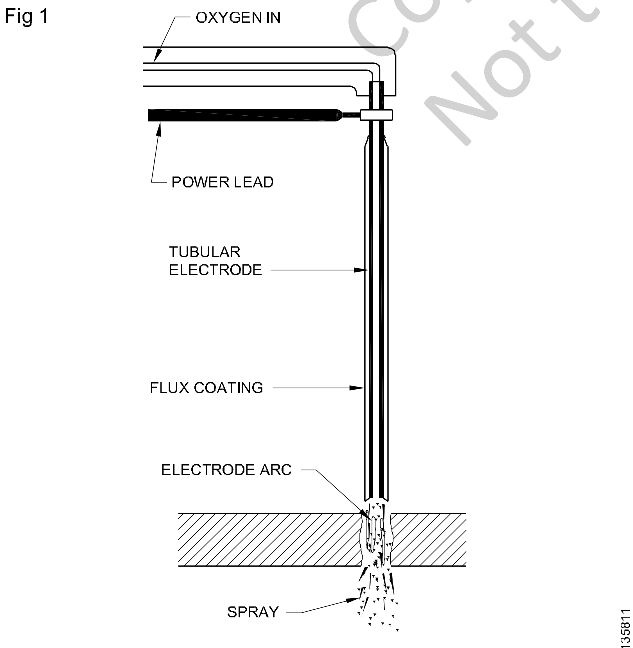
– Metallic arc cutting gouging process
– Carbon arc cutting process
– Air arc cutting process
– Plasma arc cutting process
– Oxy-arc cutting process
– Carbon arc gouging process

Metallic arc cutting - equipment and accessories

They are:

– AC or DC machines
– cables with lugs and earth clamp
– electrode holders
– shield or helmet with suitable glasses (Shade No. 14)
– chipper or chipping hammer
– apron, gloves, safety boots and white goggles.

Fig 1



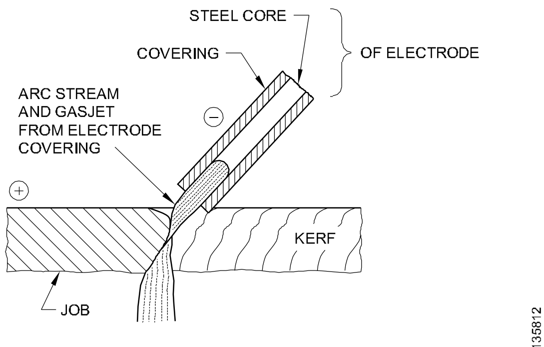
SCHEMATIC OF OXYGEN ARC CUTTING ELECTRODE IN OPERATION

ELECTRODES AND THEIR PROPERTIES

Oxy-arc cutting electrode: This electrode is similar to the manual arc welding electrode and is coated with a flux, whose function is to provide an insulated sleeve to stabilise the arc and to make the products of combustion more fluid. The core wire, however, is in the form of a hollow tube through which a stream of oxygen is passed and designed holder, capable of conveying electric current to the electrode as well as oxygen to the arc, is used. (Fig 1)

Metallic arc cutting and gouging electrodes: These electrodes are normally the same as welding electrodes or are sometime specially designed as cutting electrodes (Fig 2) at a current setting which is 20 to 50% higher than that normally used for a given size for welding. Although AC can be used, DC with electrode negative is preferred. Sometimes it helps to make the electrode slightly wet. Water in the coating reduces overheating of the electrode to some extent and disassociates in the arc to render it more penetrating.

Fig 2



METAL ARC CUTTING

Tungsten arc cutting electrode: This is an arc cutting electrode, which is used in TIG and plasma arc cutting processes.

CURRENT SETTING FOR DIFFERENT SIZE ELECTRODES

Metal thickness		Electrode diameter		AC Range amps	DC (DCEN) amps
in.	mm	in.	mm		
1/8	3.2	3/32	2.4	40-150	75 - 115
1/8 - 1	3.2 - 25.4	1/8	3.2	125-300	150 - 175
3/4 - 2	19.1 - 50.8	5/32	4.00	250-375	170 - 500
1 - 3	25.8 - 76.2	3/16	4.8	300-450	—
3 and over	76.2 and over	1/4	6.4	400-650	—

ARC CUTTING AND GOUGING PROCEDURE

Arc cutting procedure: Prepare the piece as per the requirements. Clean the surface to be cut. Mark and punch the line. Position the job in flat.

Choose the welding machine and set the polarity DCEN, if DC is used.

Select the electrode size according to the thickness of the material.

Set the current as per the requirements for the selected electrodes.

Strike the arc and move the electrodes up and down on the edge of the plate. As the metal melts brush it downwards with the arc. Feed the electrodes into the slot and make the molten metal to run away underneath. Use only half the electrode and keep it away to cool for use again.

Check the cut surface for its smoothness and uniformity.

Arc gouging procedure: Prepare the piece as per the requirements. Clean the surface to be gouged. Mark and punch the line. Position the job in flat.

Choose the machine and set the polarity DCEN if DC is used.

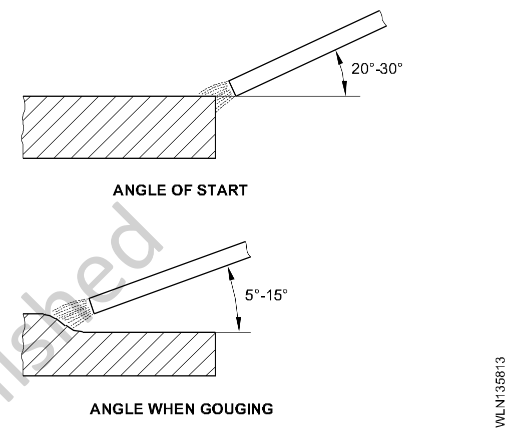
Select suitable sizes of electrodes and set the required current.

Strike the arc and as a molten pools is established, lower the electrode holder and reduce the angle between 5°-15° from 20°-30°. (Fig 3)

Move the electrode along the line of marking from the right to the left side of the plates and push the molten pool and slag away from the gouged groove.

Because of the rapid fusion due to the arc heat, move the electrode fast and control the gouging operation. Ensure that the angle of slope is not too steep, and avoid grooving too deeply. Maintain the angle of the electrode constant and the rate of travel uniform to obtain a groove of uniform width and depth.

Fig 3



Clean the surfaces.

Check the smoothness, depth and uniformity.

Advantages: Arc gouging procedure can be used when other cutting and gouging processes are not available.

In emergency it is more useful.

It can be used on metals which are difficult to cut by the oxy-acetylene cutting process.

(Cast iron, stainless steel, wrought iron, manganese steel and non-ferrous metals etc.)

Applications: Metallic arc cutting and gouging are used:

- to remove weld defects
- to make the groove on the root penetration for depositing sealing run
- to cut the scarp
- to remove rivets
- to pierce holes
- to remove casting defects and make grooves.

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Carbon Arc Cutting and Gouging

Objectives: At the end of this lesson you shall be able to
- **describe the machine used for carbon arc cutting**
- **explain the different sizes of electrodes and current setting**
- **describe the method of carbon arc cutting**
- **state the applications of this process**
- **explain the method of gouging by air carbon arc process**
- **explain the safety points to be observed while cutting.**

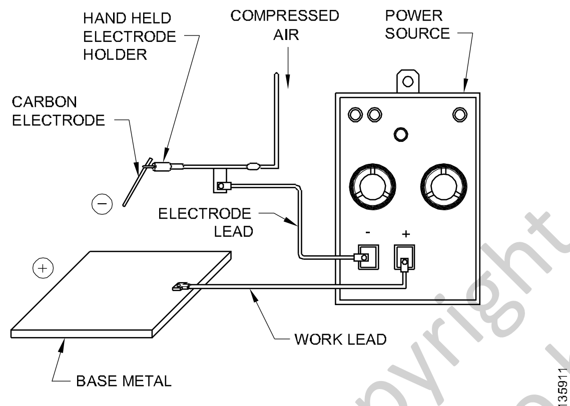
Carbon arc cutting is a process of cutting metals by melting with the heat of a carbon arc. It is melting process and as such does not produce smooth even edges. The actual cutting process is similar to that of metallic arc cutting.

The equipment consists of:

– an AC, DC or AC/DC (rectifier) welding machine (Fig 1)

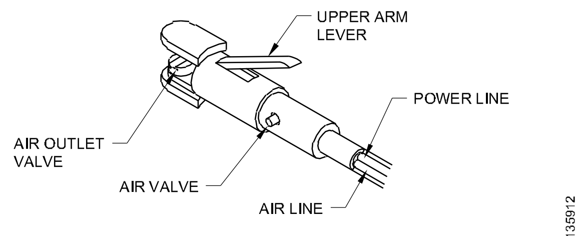
– a special carbon electrode holder (Fig 2)

Fig 1



CIRCUIT BLOCK DIAGRAM OF CARBON ARC CUTTING

Fig 2



ELECTRODE HOLDER FOR CARBON ARC CUTTING

– heavy duty gloves (asbestos).

Two types of electrodes are available i.e. AC electrodes (copper added electrodes) and DC electrodes. An AC machine is used when AC electrodes are used, and the DC electrodes (plain carbon electrodes) are connected to the negative side of the DC machine.

Carbon electrodes, used for cutting, come in sizes ranging from 12.2 mm to 25.4 mm. Rods are available in different lengths i.e. 305,457 and 610 mm (12, 18 and 24 inches).

A table of recommended electrode sizes, current settings, and speeds for carbon arc cutting various thickness of steel is given. (Table 1)

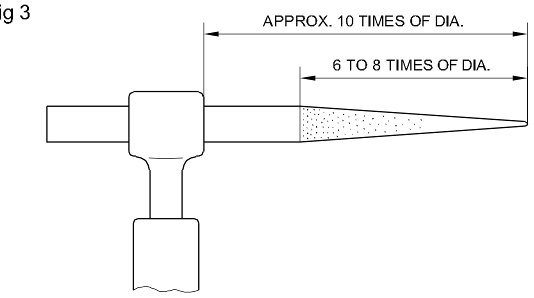
TABLE 1

Recommended electrode sizes, current settings, and speeds for carbon arc cutting of various thickness of steel

Thickness of plate		Current setting and carbon electrode diameter			
in.	mm	300 amps 1/2 in. dia. (12.2 mm)	500 amps 5/8 in. dia. (15.9 mm)	700 amps 3/4 in. dia. (19.1 mm)	1000 amps 1 in. dia. (25.4 mm)
		SPEED OF CUTTING IN MINUTES PER FOOT			
1/2	12.7	3.5	3.5	1.5	1.0
3/4	19.1	4.7	4.7	2.0	1.4
1	25.4	6.8	6.8	2.9	2.0
1 1/4	31.8	9.8	9.8	4.0	2.9
1 1/2	38.1	-	-	5.8	4.0
1 3/4	44.5	-	-	8.0	5.3
2	50.8	-	-	-	7.0

Prior to cutting, the carbon electrodes should be ground to a very sharp point. The length of taper should be 6-8 times the electrode diameter. (Fig 3)

Fig 3

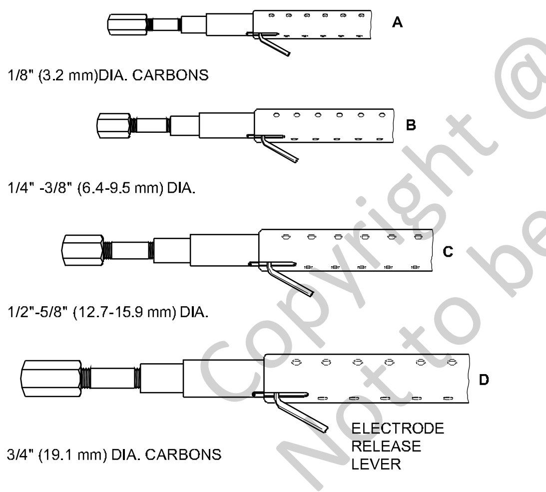


The electrode should stick out from the electrode holder to a distance equal to 10 times the electrode diameter.

(This is necessary to reduce electrical resistance and the heating effect on the electrodes. If carbon wears away too fast, shorten the electrode extension out of the electrode holder to as little as 7 cms.)

Carbon electrodes holders are designed for: A-3.2 mm (1/8 in.) carbon electrode B - 6.4 - 9.5 mm carbon electrode, C - 12.7 - 15.9 mm carbon electrode and D - 19.1 mm carbon electrode. (Fig 4)

Fig 4



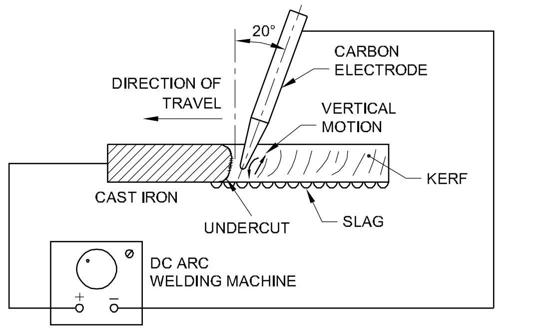
CARBON ELECTRODE HOLDERS

Procedure: Start the cutting at the bottom right hand edge of the plate and proceed towards the left end of the plate.

During the actual cutting, the carbon electrode should be manipulated in a vertical elliptical movement to cut the metal. This motion facilitates the removal of the molten metal. In addition to the vertical motion, a side-to-side crescent motion is recommended along the line of cut. For heavy plates the electrode angle is about 20° off from the vertical. (Fig 5)

Applications: The carbon arc method of cutting may be used successfully on cast iron because the temperature of the arc is sufficient to melt the iron oxides formed.

Fig 5



CARBON ARC CUTTING

NOTE THAT THE CARBON ELECTRODE IS CONNECTED TO ELECTRODE IS THE NEGATIVE TERMINAL OF THE WELDING MACHINE, AND THE WORK TO THE POSITIVE TERMINAL.

This method is used to cut:

- almost all types of steels
- light gauge to heavy gauges of metals.
- non-ferrous metals.

Safety precautions: In cutting operations a large amount of metal always falls on the floor. Therefore be sure there are no combustible materials nearby when excessive amount of cutting is to be done. It is a good idea to sprinkle sand over the concrete floor. This prevents the molten metal from heating the concrete and thus avoid cracks and particles to fly upward. Alternatively provide water/sand tray on the floor where cutting is to be done.

DIFFERENCES BETWEEN METAL ARC CUTTING AND CARBON ARC CUTTING

Metal arc cutting: The arc is struck between the consumable steel electrode and base.

AC and DC machines can be used.

The electrode used are of smaller diameters, say 4 mm ø.

Sheets and plates can be cut.

The cut face is not as fine when compared to the face produced by carbon arc cutting.

This process is more suitable for cutting scarps, rivets and for piercing holes.

Ordinary electrode holder is used.

Carbon arc cutting: A carbon arc is struck between the consumable carbon electrode and base metal.

Generally a DC machine is used.

A special type of holder is used.

The electrodes used are of a bigger diameter i.e. above 12 mm

A water cooling type holder is used when cutting with a higher current.

Generally heavy sections are cut by this process.

The cut face is more hard.

Good for cast iron and non-ferrous metal cuttings.

Gouging: Air-carbon arc method

Equipment: The equipment used for air-carbon arc cutting (ARC) consists of the following.

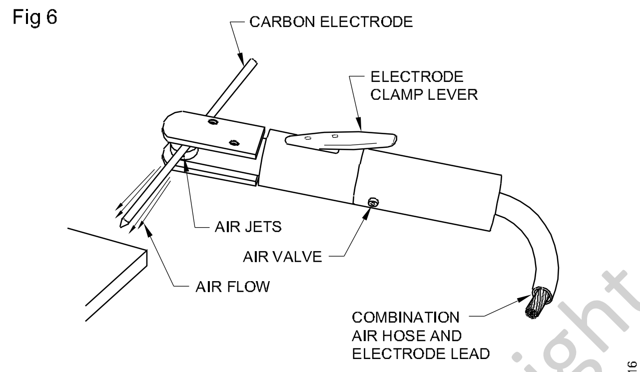
AC, DC or AC/DC welding machine.

An air compressor or compressed air cylinders.

A compressed air hose.

An air carbon arc torch equipment with an air jet device. (Fig 6)

Fig 6



AN AIR CARBON ARC ELECTRODE HOLDER WITH A CARBON ELECTRODE INSTALLED. NOTE THE AIR JET ORIFICES BEHIND THE ELECTRODE.

Electrodes: Electrodes may be of carbon form or graphite form or a mixture of carbon and graphite.

There are 3 basic types of air-carbon arc cutting electrodes. They are:

- CDEP, plain
- DCEP, copper coated
- AC, copper coated

The copper coating helps to reduce the oxidation of the electrode body. It also helps to keep the electrode cool.

Carbon electrodes for gouging come in sizes from 4 mm to 25.4 mm.

A table suggesting current settings for various diameters and types of air carbon arc electrodes is given. (Table 2)

Gouging procedure: In gouging, the amperage and electrode diameter are selected according to the width and depth of the desired groove.

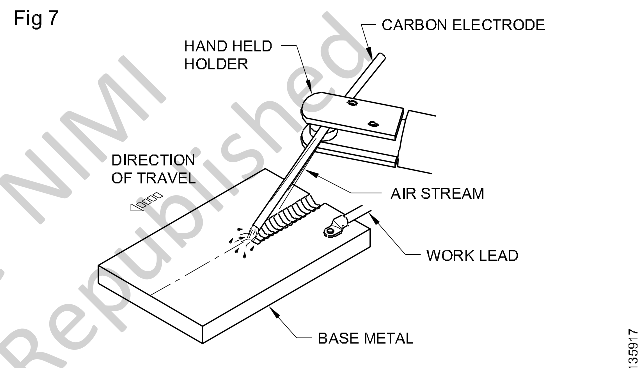
TABLE 2

Suggested current setting for various diameters and types of air carbon arc electrodes

Electrode diameter		Amperage with DCEP (D_{CRP}) electrode		Amperage with Ac electrode	
in.	mm	Min.	Max.	Min.	Max.
5/32	4.0	90	150	—	—
3/16	4.8	150	200	150	200
1/4	6.4	200	400	200	300
5/16	7.9	250	450	—	—
3/8	9.5	350	600	300	500
1/2	12.7	600	1000	400	600
5/8	15.9	800	1200	-	-
3/4	19.1	1200	1600	-	-
1	25.4	1800	2200	-	-

When gouging, the air stream must be turned on prior to striking the arc. The air stream must be directed from behind the carbon electrode. (Fig 7)

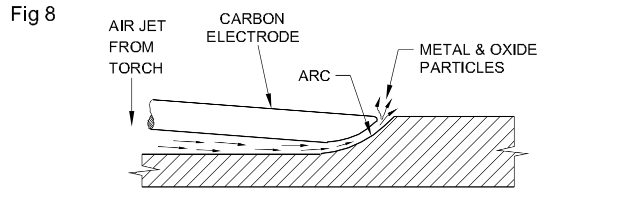
Fig 7



PROCESS DIAGRAM FOR AIR-CARBON ARC CUTTING OR GOUGING

This permits the metal to be blown out of the arc pool as shown in the Fig 8.

Fig 8



A SCHEMATIC DIAGRAM OF AN AIR-CARBON ARC GOUGING OPERATION IN PROGRESS. NOTE HOW THE COMPRESSED AIR BLOWS UNDER THE CARBON ELECTRODE TO REMOVE THE MOLTEN METAL.

In the vertical position, gouging should be done from the top to downwards. This permits gravity to help remove the molten metal from the arc groove. Gouging in horizontal position may be done from the right to the left.

When gouging overhead, the electrode should be placed in the electrode holder so that it is nearly parallel to the centre line of the holder.

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Cast Iron-Properties-Types and Weldability

Objectives: At the end of this lesson you shall be able to
- **explain the properties of cast iron and its types**
- **explain the method of edge preparation**
- **describe the cast iron welding technique**
- **select filler rods for the jobs to be welded by gas.**

Cast iron is widely used in the manufacture of machine parts, since it has a good compressive strength and easy to make the castings. There are different problems in the welding of cast iron in comparison to mild steel, even though this is also in the group of ferrous metals.

Types of cast iron

There are four basic types of cast iron available.

– Grey cast iron
– White cast iron
– Malleable cast iron
– Nodular cast iron (or) spheroidal graphite iron

Grey cast iron: Grey cast iron is soft and tougher than the white cast iron which is hard and brittle. The good mechanical properties of grey cast iron are due to the presence of particles of free state carbon or graphite, which separate out during slow cooling. Grey cast iron is of a weldable type. It contains 3 to 4% of carbon.

White cast iron: White cast iron is produced from pig iron by causing the casting to cool very rapidly. The rate of cooling is too rapid and this does not allow the carbon to separate from the iron carbide compound. Consequently the carbon found in white cast iron exists in the combined form. This type of cast iron is very hard and brittle and is not weldable and also not easily machinable.

Malleable cast iron: Malleable cast iron is obtained by annealing white cast iron over a prolonged period of time, and then allowing it to cool slowly. This heat treatment results in greater resistance to impact and shock.

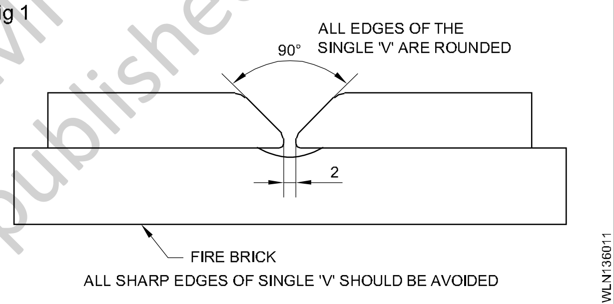
Nodular cast iron: It is also known as spheroidal graphite iron (SG iron). It is obtained by adding magnesium to the molten grey cast iron. The tensile strength and elongation of nodular iron is similar to that of steels which makes this iron a ductile material.

Properties of grey cast iron: Grey cast iron is mostly used in the manufacture of machine components. It has got good mechanical properties due to the free state carbon/graphite. The other constituents are silicon, sulphur, manganese and phosphorous. The grey cast iron has a much higher compressive strength than steel but has low ductility and tensile strength.

Since the carbon is in free graphite form it gives a grey colour to the fractured structure.

Method and types edge preparation: The edges of grey cast iron can be prepared by different methods such as chipping, grinding, machine and filing. The above methods are used according to the condition and type of the job. Usually it is required to weld, a cracked casting or a butt joint. Also the thickness of the casting to be welded or repaired will be 6 mm and above. So usually a single V butt joint is prepared as shown in Fig 1.

Fig 1



Method of cleaning

There are two methods used for cleaning cast iron jobs.

– Mechanical cleaning
– Chemical cleaning

Mechanical cleaning is mostly used to clean the surface of the cast iron jobs.

In this method grinding, filing and wire brushing tec. are done.

The chemical cleaning process is applied to remove oil, grease and any other substances which cannot be removed by mechanical cleaning.

Flame (strict neutral flame): Nozzle no. 10 is used in the blow pipe and a strict neutral flame should be adjusted. Care should be taken that there is not even the slightest trace of oxygen which would cause a weak weld through oxidation.

Filler rod: A 5 mm size round or square high (super) silicon cast iron filler rods containing 2.8 - 3.5 percentage silicon are used for cast iron welding. The weld metal by this rod is easily machinable. (The S-CI 1 as per IS 1278 - 1972).

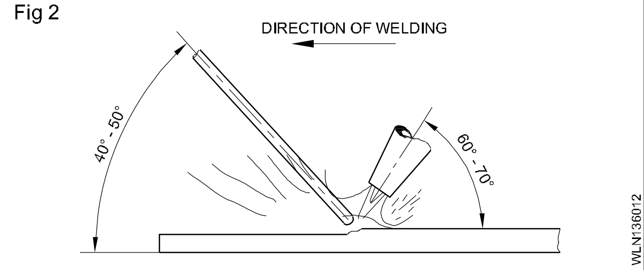
Flux: The flux should be of good quality to dissolve the oxides and prevent oxidation.

Cast iron flux is composed of borax, sodium carbonate, potassium carbonate, sodium nitrate and sodium bicarbonate. This is in a powder form.

Technique of cast iron welding: The welding operations should be performed on the preheated, dull red hot, cast iron piece. The preheating temperature for C.I welding varies from 200°C to 310°C.

The blowpipe angle should be 60° to 70° and the filler rod angle 40° to 50° to the line of weld. (Fig 2)

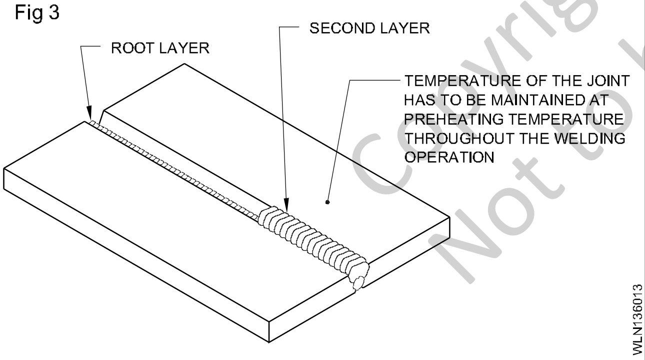
Fig 2



Using the leftward or forehead technique, the first layer should be complete by giving a slight weaving motion to the blowpipe but not to the filler rod. The hot rod end should be dipped into the powdered flux at intervals.

After the completion of the first layer, play the flame on the job so as to heat evenly and then deposit the second layer with a slight reinforcement of weld metal from the surface of the job. (Fig 3)

Fig 3



The technique of welding the second layer is the same as that for the first layer.

After completion of the second layer, play the flame again on the whole job for getting an even heat. This is called 'post heating'.

Then allow the job to cool slowly by covering with a heap of lime or ash or dry sand.

Selection of filler rod

Filler rod should be selected according to the:

- kind or type of metal to be welded, i.e. ferrous, non-ferrous, hard facing (Table 1).

  thickness of metal to be welded (including joint edge preparation) (Table 2)
- nature of joint to be made (i.e.), fusion welding or braze welding (non-fusion)
- welding technique to be used (leftward or rightward).

Table 1

Metals	Filler rods
Mild steel and wrought iron	Copper coated mild steel (C.C.M.S)
High carbon and alloy steel	High Carbon steel Silicon-manganese steel Wear-resisting alloy steel 3.5% Nickel steel
Stainless steel	Columbium stainless steel
Cast iron	Super silicon cast iron Ferrotectic cast iron Nicotectic cast iron
Copper and its alloys (brass, bronze)	Copper-silver alloy Silicon-brass, silicon-bronze Nickel bronze Manganese bronze
Aluminium and its alloys	Pure aluminium 5% Silicon aluminium alloy 10-13% Silicon aluminium alloy

Table 2

Thick-ness mm	Edge preparation mm	Root gap	Dia. of filler rod mm
0.8	Square	-	1.6
1.6	Square	2.4	1.6
2.4	Square	3.2	1.6
3.2	80° Vee	3.2	2.4
4.0	80° Vee	3.2	3.2
5.0	80° Vee	3.2	4.0

More the thickness of the metal welded, more the diameter of the filler rod used. Less the number of weld runs deposited, less the distortion and faster the welding.

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Bronze welding of cast iron

Objectives: At the end of this lesson you shall be able to
- **describe the principle of bronze welding and its application**
- **explain the functions of bronze filler rods and flux**
- **describe the advantage and limitations of bronze welds of C.I**
- **state the various types and composition of bronze welding filler rods and function of each element in it.**

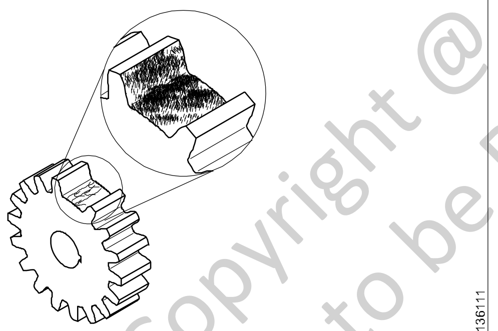
Bronze welding

Bronze welding is a process in which the joint is produced by heating the metal to suitable temperatures above 425°C (800°F) and depositing filler metal into a groove of the joint by using a non-ferrous filler rod having a melting point below that of the base metal.

When the filler metal is made of copper-zinc alloy, the process is referred to as bronze welding.

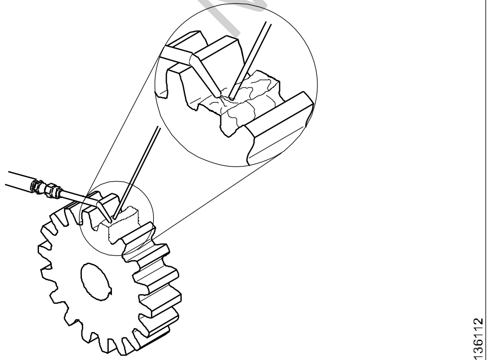
Applications of bronze welding: Bronze welding is particularly adoptable for joining or repairing such metals as cast iron, malleable iron, copper, brass and various dissimilar sections such as worn out of gear teeth. (Figs 1, 2, 3 & 4)

Fig 1



THE FIRST STAGE OF REPAIR-PREPARATION

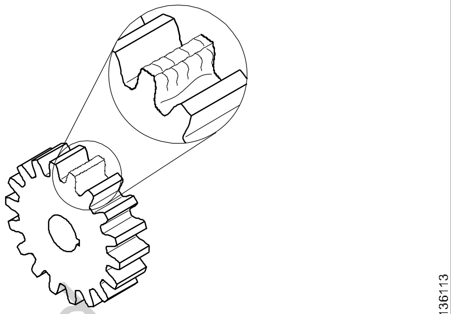
Fig 2



BRAZING

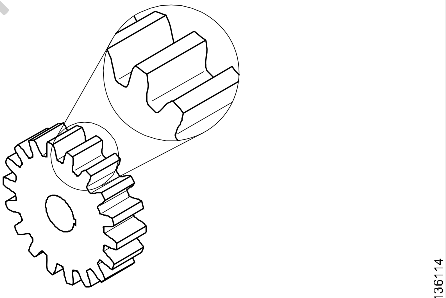
Characteristics of bronze filler rod: The main elements of a bronze filler rod used in bronze welding are copper and zinc which produce high tensile strength and ductility.

Fig 3



SLOW COOLING

Fig 4



FINISHED TOOTH

The elements like tin, manganese and silicon contained in the filler rod help to deoxidize the weld metal, decrease the tendency of zinc to fume, and increase the free-flowing action of the molten metal.

Hardness and wear-resistance is improved.

Flowing and wetting properties are improved.

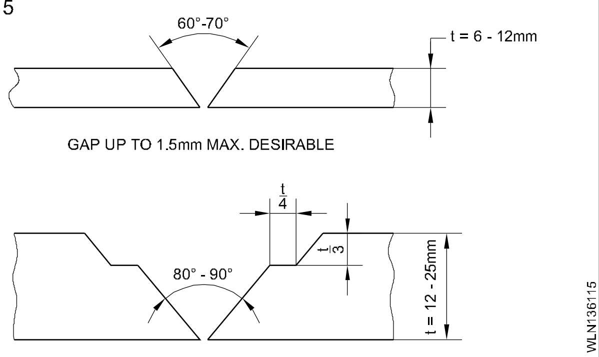
A bronze filler rod generally contains 60% copper and 40% zinc. A small percentage of other metals such as manganese, tin, nickel and silicon is added in the filler rod.

Importance of flux for bronze welding: Adhesion of the molten bronze to the base metal will take place only if the surface is chemically clean. Good surface cleaning action will be obtained by applying good quality flux which also prevents oxidation during welding.

Type of flame: A slightly oxidising flame is a suitable one. Since the melting point of zinc is 540°C and that of copper is 1083°C, before copper starts melting the zinc will evaporate as white fumes. Excess oxygen in the oxidising flame will convert zinc into zinc oxide and arrest the evaporation of zinc due to the higher melting pint of zinc oxide. While solidifying the flux will remove the oxide and maintain the bronze deposit.

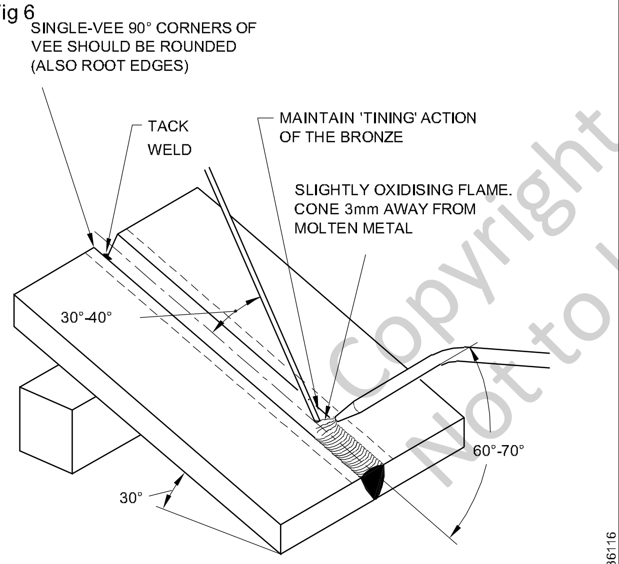
Welding technique: The edges are prepared as shown in Fig 5. All the edges of the joint are to be rounded off to avoid sharp edges.

Fig 5



Use leftward welding technique and keep the joint inclined at 30°. (Fig 6)

Fig 6



BRONZE WELDING CAST IRON

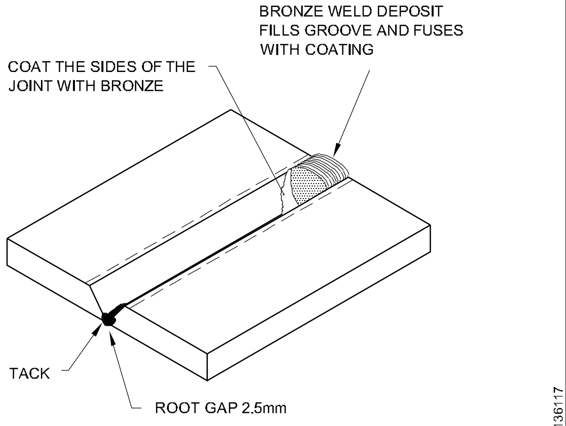
Ensure the job is preheated to 200°C to 300°C and the weld face is properly wetted/tinned before depositing the bronze filler metal. (Fig 7)

Use No. 10 nozzle on the blowpipe and 3 mm bronze filler rod dipped in powdered flux.

Cool the joint slowly by covering the job with asbestos powder or dry sand.

Remove the flux residue from the joint and clean the joint.

Fig 7



BRONZE WELDING CAST IRON

Advantages of bronze welding

Bronze welding is done at low temperature

Bronze welding can be done faster than fusion welding.

The base metal need not be heated to a molten condition. So there is less possibility of destroying the main characteristics of the base metal. This results in lower fuel consumption.

The low degree of heat in bronze welding reduces to a minimum the expansion and contraction forces and thereby reduces distortion.

Machining the welded portion is possible.

Limitations of bronze welding

Bronze welding is not useful to weld a metal that will be subjected to a high temperature in service, since bronze loses its strength when heated to (500°F) 260°C or more.

Bronze welding should not be used on steel parts that must withstand unusually high stresses.

Colour match will not be there with ferrous metals.

The filler metal costs more than the super silicon cast iron or steel filler metals used for full fusion welding.

In certain chemical processes, some materials that have almost no effect on cast iron but will react with the bronze filler metal.

Filler rods for bronze welding of cast iron

Types of filler rods

S-C4

S-C5

S-C6

S-C8

S-C9

S-C10

COMPOSITION OF EACH TYPE

S-C4

Copper 57 to 63%
Silicon 0.15 to 0.3%
Manganese 0.05 to 0.25%
Iron 0.1 to 0.5 %
Balance % zinc

Melting point of this filler rod is 870° to 900°C

S-C Fabrication : Welder - Exercise 1.1.01
Fabrication : Welder - Exercise 1.1.015

Tin 0.5% max
Manganese 0.5% max
Iron 0.5% max
Copper 45 to 53%
Melting point 970° to 980°C
Silicon 0.15 to 0.5%
Nickel 8 to 11%

S-C6

Copper 41 to 45%
Silicon 0.2 to 0.5%
Nickel 14 to 16%
Tin 1.00% max
Manganese 0.2 % max }
} Optional
Iron - 0.3% max }
Zinc balance

S-C8

Manganese bronze or high tensile brass.

S-C9

High nickel bronze (High tensile nickel brass)

S-C10

High nickel bronze (High tensile nickel brass)

FUNCTIONS OF EACH ELEMENT

Phosphorus

De-oxidiser

Tin

Improves the strength and corrosion resistance and wear resistance.

Nickel

Improves corrosion resistance, ductility.

Manganese

De-oxidiser, improves wear resistance.

Silicon

Improves fluidity.

Removes impurities.

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