SPINNING TECHNICIAN

1st Semester

TRADE THEORY

SECTOR: Textile & Apparel

GOVERNMENT OF INDIA
MINISTRY OF LABOUR & EMPLOYMENT
DIRECTORATE GENERAL OF EMPLOYMENT & TRAINING

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

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

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Duration : 2 - Years

Trade : Spinning Technician - Trade Theory

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FOREWORD

The National Instructional Media Institute (NIMI) is an autonomous body under the Directorate General of Employment and Training (DGE&T) Ministry of Labour and Employment has been developing, producing and disseminating Instructional Media Packages (IMPs are extensively used in the Industrial Training Institutes/Training centres in Industries to impart practical training and develop work-skills for the trainees and the trainers

The Ministry of Labour & Employment constituted Mentor Councils (MCs) to revampcourses run / to be run under National Council of Vocational Training (NCVT) in 25 sectors. The MCs have representatives from thought leaders among various stakeholders viz. one of the top ten industries in the sector innovative entrepreneurs who have proved to be game-changers, academic/professional institutions (IITs etc.), experts from field institutes of DGE &T, champion ITIs for each of the sectors and experts in delivering education and training through modern methods like through use of IT, distance education etc. The technical support to the MCs is provided by Central Staff Training and Research Institute (CSTARI), Kolkata and National Instructional Media Institute (NIMI), Chennai. Some of the MCs are also supported by sector-wise Core Groups which were created internally in the Ministry (in 11 sectors).

A Steering Committee to provide overall coordination and guidance to Mentor Councils has also been constituted and has representation from the MCs, Chair positions to be endowed by the Ministry, trade unions, and experts on distance education and training. The MCs are mandated to work towards revamping/ suggesting new courses, improving assessment systems, overall learning etc. for subjects under the purview of the NCVT.

Accordingly NIMI with the support and assistance of MC has developed **Spinning Technician Trade Theory 1st Semester** in **Textile and Apparel sector** to enhance the employability of ITI trainees across the country and also to meet the industry requirement.

I have no doubt that the trainees and trainers of ITIs & Training centres in industries will derive maximum benefit from these books and that NIMI's effort will go a long way in improvement of Vocational Training.

I complement Director, Mentor Council members, Media Development Committee (MDC) members and staff of NIMI for their dedicated and invaluable contribution in bringing out this publication.

ALOK KUMAR, I.A.S.,
Director General of Employment &
Training/ Joint Secretary
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PREFACE

This National Instructional Media Institute (NIMI) was set up at Chennai by the Directorate General of Employment and Training (DGE&T) Ministry of Labour and Employment, 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 disseminate instructional materials for various trades as per the prescribed syllabi under the Craftsmen and Apprenticeship Training Schemes.

The instructional materials are developed and produced in the form of Instructional Media Packages (IMPs). An IMP consists of Trade Theory book, Trade Practical book, Test and Assignment book, Instructor guide, Wall Charts and Transparencies.

Hon'ble Union Minister of Finance during the budget speech 2014-2015 mentioned about developing **Skill India** and made the following announcement

"A national multi-skill programme called Skill India is proposed to be launched. It would skill the youth with an emphasis on employability and entrepreneur skills. It will also provide training and support for traditional professions like welders, carpenters, cobblers, masons, blacksmiths, weavers etc. Convergence of various schemes to attain this objective is also proposed."

The Ministry of Labour & Employment constituted Mentor Councils (MCs) to revamp courses run / to be run under National Council of Vocational Training (NCVT) in 25 sectors which will give a sustained skill based employability to the ITI trainees as the main objective of Vocational training. The ultimate approach of NIMI is to prepare the validated IMPs based on the exercises to be done during the course of study. As the skill development is progressive the theoretical content on a particular topic is limited to the requirement in every stage. Hence the reader will find a topic spread over a number of units. The test and assignment will enable the instructor to give assignments and evaluate the performance of a trainee. If a trainee possesses the same it helps the trainee to do assignment on his own and also to evaluate himself. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also helps the trainees to grasp the technical topic quickly. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirement ,

Thus the availability of a complete Instructional Media Package in an institute helps the trainer and management to impart an effective training. Hence it is strongly recommended that the Training Institutes/Establishments should provide at least **one IMP** per unit. This will be small, one time investment but the benefits will be long lasting.

The **Spinning Technician Trade Theory 1st semester in Textile and Apparel sector** is one of the book develop by the core group members of the Mentor Councils (MCs). The 1st semester book includes **Module 1 - Fitting, Module 2 - Turning, Module 3 - Sheet metal, Module 4 - Welding, Module 5 - Carpenter, Module 6 - Basic electrical, Module 7 - Basic electronics.**

The **Spinning TechnicianTrade Theory 1st semester** is the outcome of the collective efforts of Members of Mentor Council which includes academic/professional institutions (IITs etc.) , experts from field institutes of DGE&T, champion ITIs for each of the sectors, and also Media Development Committee (MDC) members and staff of NIMI.

NIMI wishes that the above material (Trade Practical & Trade Theory) will fulfil to satisfy the long needs of the Trainees and Instructor and helps the trainees for their employability in vocational training.

NIMI would like to take this opportunity to convey sincere thanks to all the Mentor Council members and Media Development Committee (MDC) members.

A. MAHENDIRAN
Director, NIMI

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 organisation to bring out this IMP **(Trade Theory)** for the trade of **S[inning Technician** under **Textile and Apparel** Sector for Craftsmen Training Scheme. This Book is prepared as per Revised Syllabus.

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

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

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

INTRODUCTION

This manual of Trade Theory consists of related theoretical information for the first semester course of the **Spinning Technician** trades. This manual is divided into 7 modules as given below

Module 1	Fitting
Module 2	Turning
Module 3	Sheet Metal
Module 4	Welding
Module 5	Carpenter
Module 6	Basic Electrical
Module 7	Basic Electronics

The Trade Theory has to be taught and learnt along with the corresponding exercises contained in the manual - Trade practical. The correlation between practical exercises and theory lesson information is indicated by the semester/module number and exercise/theory information number. For example, theory lesson No.1.1.05 indicates that it relates to Exercise 5 of first module of first semester

In the case of Module 2 - Turning, first digit of exercise number corresponds to the semester, the second digit refers module and third digit refers exercise number.

It is preferable to teach/learn the trade theory connected to each exercise in advance before performing the related practicals in the shop floor. The trade theory is to be treated as an integral part of each exercise.The material is not a selflearning text and should be considered as supplementary to the classroom instructions.

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

CONTENTS

Lesson No.	Title of the Lesson	Page No.
	Module 1 : Fitting	
1.1.01	Safety practice - elements of files	1
1.1.02	Length measurement	8
1.1.03	Marking media	10
1.1.04	Shapes of files	15
1.1.05	Hacksaw frame and blade	21
1.1.06	Chisel	23
1.1.07	Off-hand grinding with bench and pedestal grinders	26
1.1.08	Drilling machines	27
1.1.09	Drilling defects and causes	33
1.1.10	Identification of Metals	37
1.1.11	Originating of reference surfaces	55
	Module 2 : Turning	
1.2.01	Centre lathe-parts and specification	66
1.2.02	Lathe parts - carriage	72
1.2.03	Cutting tool materials	76
1.2.04	Alignment of lathe centres	84
1.2.05	Lathe carriers	91
1.2.06	Lathe operation - taper turning	94
	Module 3 : Sheet Metal	
1.3.01	Tools and Equipment used in oxy-acetylene gas welding	98
1.3.02	Gases used in gas welding	104
1.3.03	Method of cleaning before welding	108
1.3.04	Filler rods for gas welding	110
1.3.05	Leftward and Rightward welding techniques	113
1.3.06	Gases used for welding and gas flame combinations	116
1.3.07	Soft soldering, brazing and silver brazing	112

Lesson No.	Title of the Lesson	Page No.
1.3.08	Material preparation method	127
1.3.09	Metal transfer across the arc (Characteristics of arc)	132
1.3.10	Systems of oxy-acetylene welding	135
	Module 4 : Maintenance	
1.4.01	Belt tension	119
1.4.02	Lubricating machines	141
1.4.03	Belt drives - creep & slip	145
1.4.04	Gears - types - care & maintenance	150
1.4.05	Mounting the bearing	154\
	Module 5 : Basic Electrical	
1.5.01	Conductors - insulators - wires, cables types - measurement of wire size voltage grading	156
1.5.02&1.5.03	Electrical soldering practice - types of solders, flux and methods	170
1.5.04	DC series circuit	177
1.5.05	DC Parallel circuit	180
1.5.06	Measurement of energy in single phase circuits	184
1.5.07	Multimeter	186
1.5.08-1.5.10& 1.5.13	Conduit wiring - batten wiring and earthing	191
1.5.11	Heating appliances	210
1.5.12	Thermostat heat controls in automatic electric iron	211
1.5.14	Magnetic circuit paramenter	214
1.5.15&1.5.16	Dynamically induced EMF	219
1.5.17	Armature circuit resistance and its relation with different types of windings and brush resistance	228
1.5.18	Building up of voltage and magnetization characteristic of DC shunt generator	231
1.5.19	Continuity testing and insulation resistance in D.C. machine	235
1.5.20	Measurement of Power	237
1.5.21	Measurement of Energy	242

Lesson No.	Title of the Lesson	Page No.
	Module 6 : Basic Electronics	
1.6.01	Passive electronic components	244
1.6.02	Semi conductors - atomic structure - active components	246
1.6.03	Polarity test in DC supply	251
1.6.04	Alternating current (A.C)	253

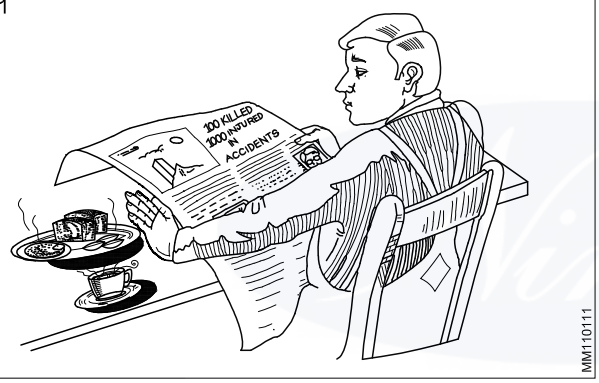
Safety practice - elements of files

Objectives: At the end of this lesson you shall be able to
- **state what an accident is**
- **state the causes for accidents in general terms**
- **state what is safety attitude**
- **identify the four basic categories of safety signs.**

What is an accident?

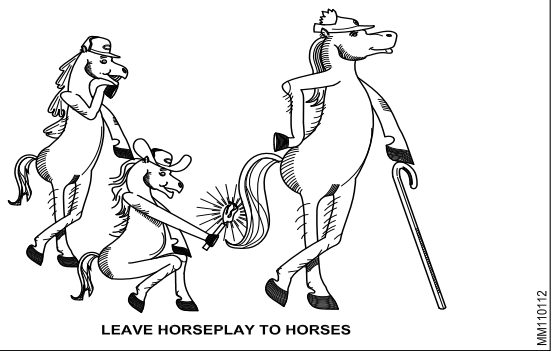
Nobody deliberately has an accident; accidents occur due to causes which are not foreseen. Sometimes nothing can be done to prevent them from happening. For example, a part of a machine fails when nobody has any reason to think there is anything wrong with it, or the driver of a vehicle collapses at the wheel. Most accidents however occur as a result of human error of ignorance or neglect, forgetfulness or recklessness. These accidents can be prevented, if people had acted differently at some point, the event which we call an 'accident' would not have occurred. (Fig. 1)

Fig 1



Lot of accidents still happen every year killing lot of people. Although most people are alarmed and horrified by this state of affairs, accidents continue to happen, costing the industry millions of rupees every year. Older workers who have come to terms with the dangers, young workers who may be reckless, employers who turn a blind eye to the possibility of things going wrong - because they want to get the job done, all these factors contribute to this senseless waste. Fortunately there are many who do not take this view. They have a different attitude to safety - and 'attitude' is an important factor in the chain of events which leads to someone causing, being involved in, or becoming the victim of an 'accident'. (Fig. 2)

Fig 2



Causes for accidents

ACCIDENTS DO NOT JUST

HAPPEN. THEY ARE CAUSED!

LEAVE HORSEPLAY TO HORSES.

Normally accidents do not just happen. They are caused.

Causes for accidents are many. Some of the important causes are listed below.

– Unawareness of danger
– Disregard for safety
– Negligence
– Lack of understanding of proper safety procedures
– Untidy condition of work place
– Inadequate light and ventilation
– Improper use of tools
– Unsafe condition

Fig 3



Safety attitudes: People's attitudes govern what they do or fail to do. In most cases where someone is working with unsafe equipment or in an unsafe situation, somebody has allowed that state of affairs to come about by something they have done or failed to do. (Fig. 3)

Most accidents don't just happen; they are caused by people who (for example) damage equipment or see it is faulty but don't report it, or leave tools and equipment lying about for other people to trip over. Anybody who sees a hazard and does nothing about it is contributing to the possibility of an accident. A worker doesn't necessarily need to do anything to help bring about an accident; just going mindlessly about his work may be enough to ensure a workmate being crippled for life. He didn't do it - but by proper and timely thinking and acting, he could have prevented it.

Fig 4



Safety doesn't just happen - it has to be organised and achieved like the work-process of which it forms a part. The law states that both an employer and his employees have a responsibility in this behalf. (Fig. 4)

Employer's responsibilities: The effort a firm puts into planning and organising work, training people, engaging skilled and competent workers, maintaining plant and equipment, checking, inspecting and keeping records - all of this contributes to the safety in the workplace.

The employer will be responsible for the equipment provided, the working conditions, what the employees are asked to do, and the training given.

Employee's responsibilities: You will be responsible for the way you use the equipment, how you do your job, how best you make use of your training, and your general attitude to safety.

A great deal is done by employers and other people to make your working life safer; but always remember you are responsible for your own actions and the effect they have on others. You must not take that responsibility lightly.

Rules and procedures at work: What you must do, by law, is often included in the various rules and procedures laid down by your employer. They may be written down, but more often than not, are just the way a firm does things - you will learn these from other workers as you do your job. They may govern the issue and use of tools, protective clothing and equipment, reporting procedures, emergency drills, access to restricted areas, and many other matters. Such rules are essential; they contribute to the efficiency and safety of the job.

Safety signs: As you go about your work on a construction site you will see a variety of signs and notices. Some of these will be familiar to you - a 'no smoking' sign for example; others you may not have seen before. It is up to you to learn what they mean - and to take notice of them. They warn of the possible danger, and must not be ignored.

Safety signs fall into four separate categories. These can be recognised by their shape and colour. Sometimes they may be just a symbol; other signs may include letters of figures and provide extra information such as the clearance height of an obstacle or the safe working load of a crane.

The four basic categories of signs are as follows:

– prohibition signs
– mandatory signs
– warning signs
– information signs.

Prohibition signs (Fig 5)

Shape Circular

Colour Red border and cross bar. Black symbol on white background.

Meaning Shows it must not be done.

Example No smoking.

Fig 5



Mandatory signs (Fig 6)

Shape Circular.

Colour White symbol on blue background.

Meaning Shows what must be done.

Example Wear hand protection.

Fig 6



Warning signs (Fig 7)

Shape Triangular.

Colour Yellow background with black border and symbol.

Meaning Warns of hazard or danger.

Example Caution, risk of electric shock.

Fig 7



Information signs (Fig 8)

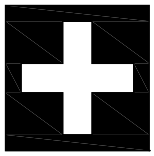
Shape Square or oblong.

Colour White symbols on green background.

Meaning Indicates or gives information of safety provision.

Example First aid point.

Fig 8



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Questions about your safety (Figs 9, 10 & 11)

Do you know the general safety rules that cover your place of work?

Are you familiar with the safety laws that govern your particular job?

Do you know how to do your wok without causing danger to yourself, your workmates and the general public?

Are the plant, machinery and tools that you use really safe? Do you know how to use them safely and keep them in a safe condition?

Do you wear all the right protective clothing, and have you been provided with all the necessary safety equipment?

Have you been given all the necessary safety information about the materials used?

Have you been given training and instruction to enable you to do your job safely?

Do you know who is responsible for safety at your place of work?

Do you know who are the appointed 'Safety Representatives'?

Fig 9



SMOKING AND NAKED FLAMES PROHIBITED

DO NOT EXTINGUISH WITH WATER

PEDESTRAINS PROHIBITED

MM110119

Fig 10



MANDATORY SIGNS

MM11011A

Fig 11



WARNING SIGNS

MM11011B

Safety on shop-floor

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

- **state the importance of safety**
- **list out the safety precautions to be observed in a machine shop**
- **list out the personal safety precautions to be observed**
- **list out the safety precautions to be observed while working on the machines.**

Generally accidents do not happen; they are caused. Most accidents are avoidable. A good craftsman, having a knowledge of various safety precautions, can avoid accidents to himself and to his fellow workers and protect the equipment from any damage. To achieve this, it is essential that every person should follow safety procedures.

Safety in a workshop can be broadly classified into 3 categories.

– General safety
– Personal safety
– Machine safety

General safety

Keep the floor and gangways clean and clear.

Move with care in the workshop, do not run.

Don't leave the machine which is in motion.

Don't touch or handle any equipment/machine unless authorised to do so.

Don't walk under suspended loads.

Don't cut practical jokes while on work.

Use the correct tools for the job.

Keep the tools at their proper place.

Wipe out spilt oil immediately.

Replace worn out or damaged tools immediately.

Never direct compressed air at yourself or at your co-worker.

Ensure adequate light in the workshop.

Clean the machine only when it is not in motion.

Sweep away the metal cuttings.

Know everything about the machine before you start it.

Personal safety (Fig 1)

Wear a one piece overall or boiler suit.

Keep the overall buttons fastened.

Don't use ties and scarves.

Roll up the sleeves tightly above the elbow.

Wear safety shoes or boots and goggles.

Cut the hair short

Don't wear a ring, watch or chain.

Never lean on the machine.

Don't clean hands in the coolant fluid.

Don't remove guards when the machine is in motion.

Don't use cracked or chipped tools.

Don't start the machine until:

– the workpiece is securely mounted
– the feed machinery is in the neutral
– the work area is clear.

Don't adjust clamps or holding devices while the machine is in motion.

Never touch the electrical equipment with wet hands.

Don't use any faulty electrical equipment.

Ensure that electrical connections are made by an authorised electrician only.

Concentrate on your work.

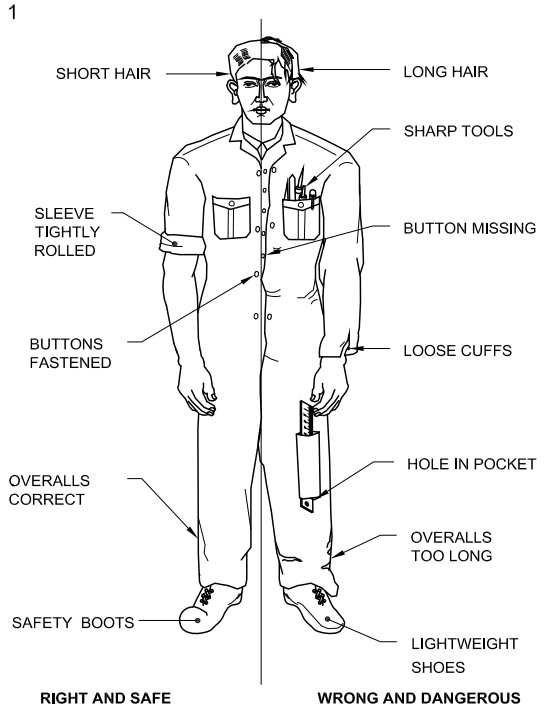
Have a calm attitude.

Do things in a methodical way.

Don't engage yourself in conversation with others while concentrating on your job.

Don't distract the attention of others.

Fig 1



Don't try to stop a running machine with hands.

Machine safety

Switch off the machine immediately if something goes wrong.

Keep the machine clean.

Replace any worn out or damaged accessories, holding devices, nuts, bolts etc as soon as possible.

Do not attempt operating the machine until you know how to operate it properly.

Do not adjust the stroke, tool or the workpiece unless the power is off.

Stop the machine before changing the speed.

Disengage the automatic feeds before switching off.

Check the oil level before starting the machine.

Before starting the machine, move the ram by hand to ensure that the ram or tool-holder does not strike the workpiece or table.

Never start a machine unless all the safety guards are in position.

Take measurements only after stopping the machine.

Use wooden planks over the bed while loading and unloading heavy jobs.

Do not stop the machine before the finish of the cutting stroke.

Safety is a concept, understand it.

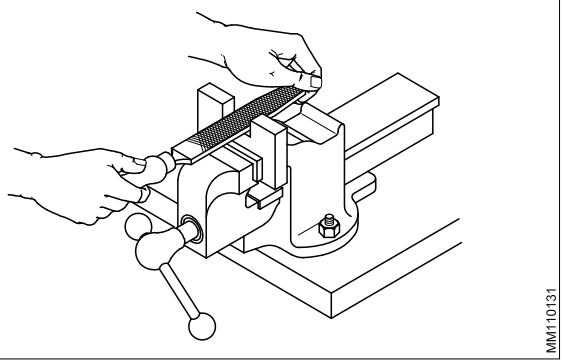
Safety is a habit, cultivate it.

Elements of a files

Objectives: At the end of this lesson you shall be able to
- **identify the parts of a file**
- **name and state the uses of each grade of file**
- **list and state the uses of different cuts of files**
- **state the specification of a file.**

Filing is a method of removing excess material from a workpiece by using a file. (Fig 1)

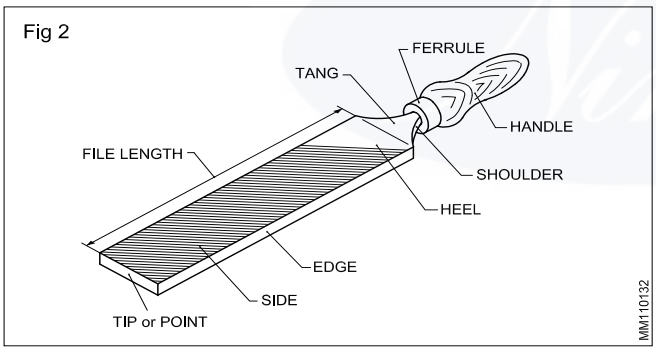
Fig 1



Files are available in many shapes and sizes. They are made of high carbon or high grade cast steel. The teeth portion of the file (body) alone is hardened and tempered.

Parts of a file (Fig 2): The illustration above will help you in learning the parts of a file.

Fig 2



Files are specified according to their (1) length (2) grade (3) cut and (4) shape.

Eg. File flat 300 mm bastard double cut.

The length of a file is the distance from the tip to the heel.

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 (Fig 3A) and fins-burrs on forged components.

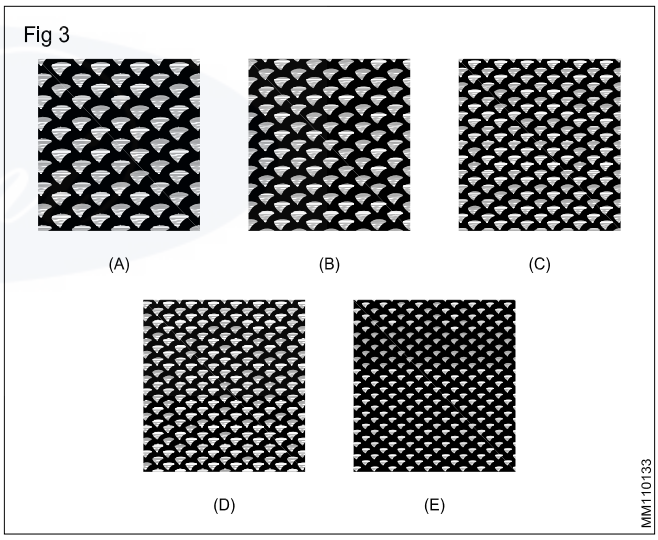
A bastard file is used in cases where a heavy reduction of material is required. (Fig 3B)

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. (Fig 3C)

A smooth file is used to remove small quantities of material and to give a good finish. (Fig 3D)

A dead smooth file is used to bring the material to accurate size with a high degree of finish. (Fig 3E)

Fig 3



Flat file & hand file

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**
- **list different cuts and their uses.**

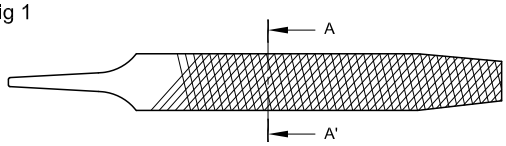
Files are made in different shapes so as to able to file and finish components to different shapes.

The shape of files is usually specified by their cross-section.

The files useful for this exercise are flat files and hand files.

Flat files (Fig 1)**:** These files are of 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 files are used for general purposes work. They are useful for filing and finishing external and internal surfaces.

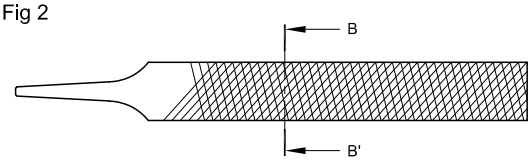
Fig 1



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

Fig 2



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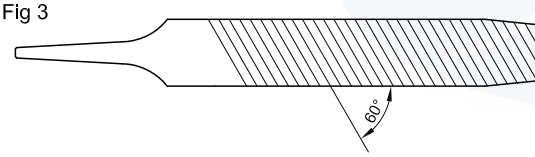
The most used grades of files are bastard, second cut, smooth and dead smooth. These are the grades recommended by the Bureau of Indian Standards. (BIS)

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

The uses of the different cuts of files are as follows.

Single cut files are useful for filing soft metals like brass, aluminium, bronze and copper and also used for deburring the job on lathe. (Fig 3)

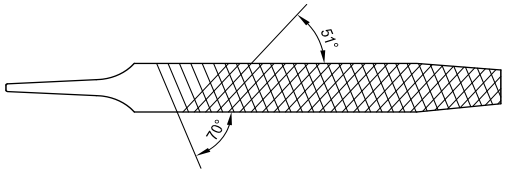
Fig 3



MM110143

Double cut files remove material faster than the single cut files. (Fig 4)

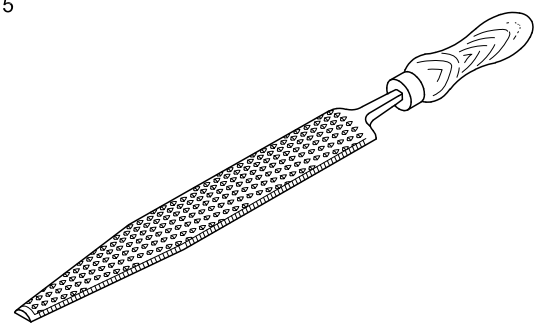
Fig 4



MM110144

Rasp cut files are useful for filing wood, leather and other soft materials and are available only in half round shape. (Fig 5)

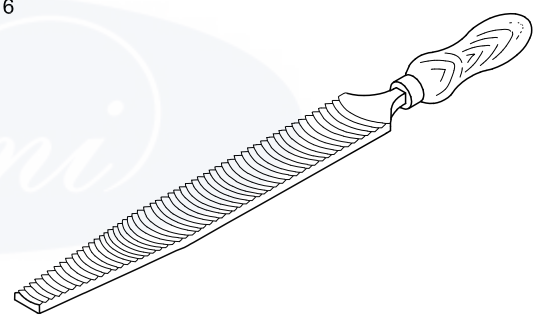
Fig 5



MM110145

Curved cut files have deeper cutting action and are useful for filing soft materials like aluminium, tin, copper and plastic. (Fig 6)

Fig 6



MM110146

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.**

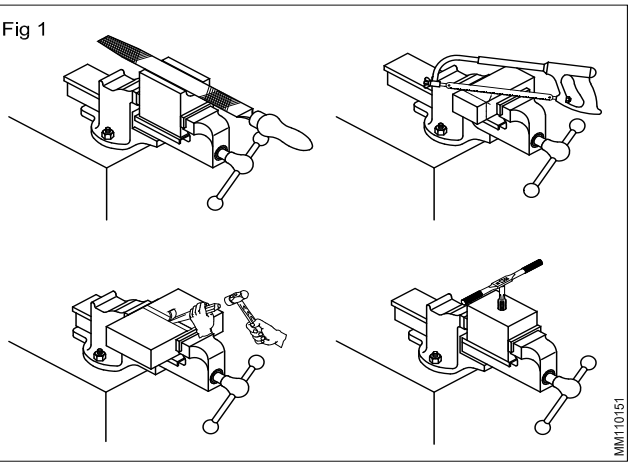
Vices are used for holding workpieces. They are available in different types. The vice used for bench work is the bench vice or called Engineer's vice.

A 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.

eg. 150mm parallel jaw bench vice

Fig 1



MM110151

Parts of a bench vice (Fig 2)

The following are the parts of a vice.

Fixed jaw, movable jaw, hard jaws, spindle, handle, box-nut and spring are the parts of a file.

The box-nut and the spring are the internal parts.

Vice clamps or soft jaws (Fig 3)

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

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

Fig 2

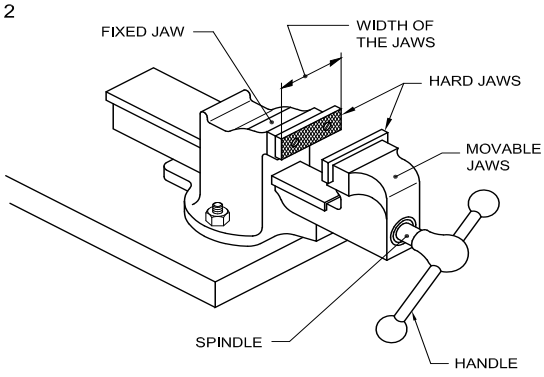
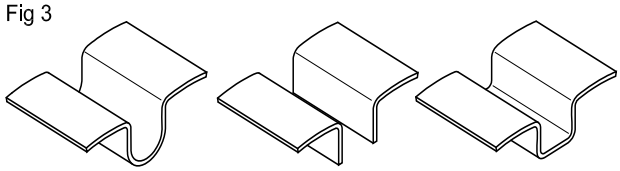


Fig 3

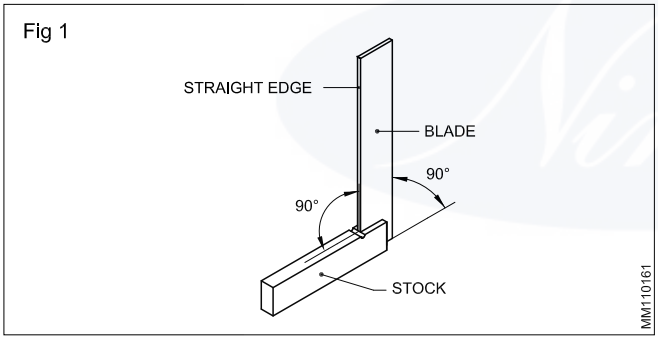


Try square

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

The try square (Fig 1) is an instrument which is used to check squareness (angles of 90°) of a surface.

Fig 1

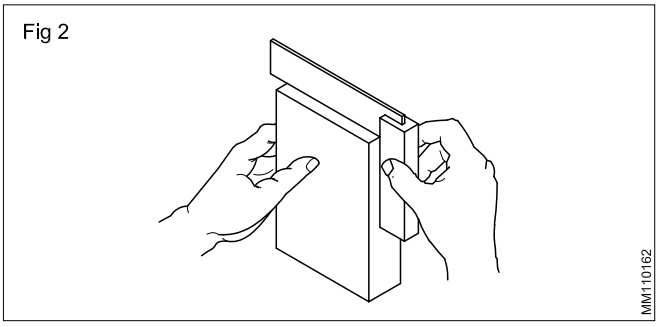


The accuracy of measurement by a try square is about 0.002 mm per 10 mm length, which is accurate enough for most workshop purposes. The try square has a blade with parallel surfaces. The blade is fixed to the stock at 90°.

Try squares are made of hardened steel.

Try squares are specified according to the length of the blade i.e. 100mm, 150, 200mm.

Fig 2



Uses: The try-square is used to:

– check the squareness (Fig 2)
– check the flatness (Fig 3)
– mark lines at 90° to the edges of workpieces (Fig 4)
– set workpieces at right angles. (Fig 5)

Fig 3

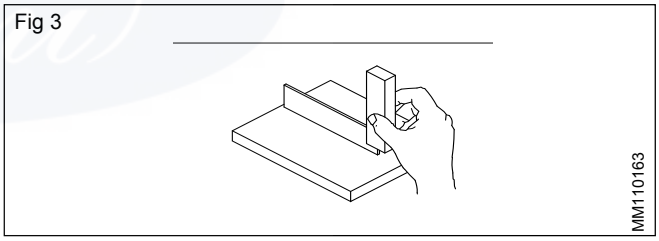


Fig 4

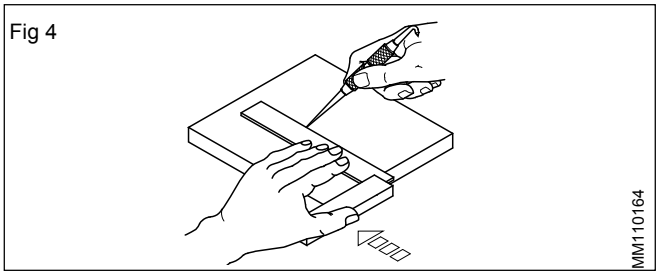
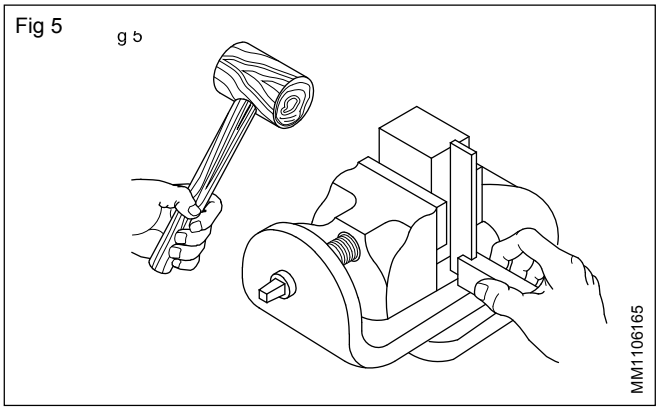


Fig 5



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 metre 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 metre. The table given below lists some multiples of a metre.

METRE(m) = 1000 mm
CENTIMETRE (cm) = 10 mm
MILLIMETRE (mm) = 1000µ
MICROMETRE (µ)µm = 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

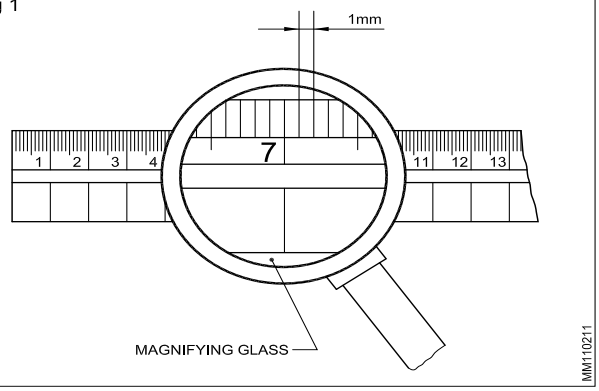
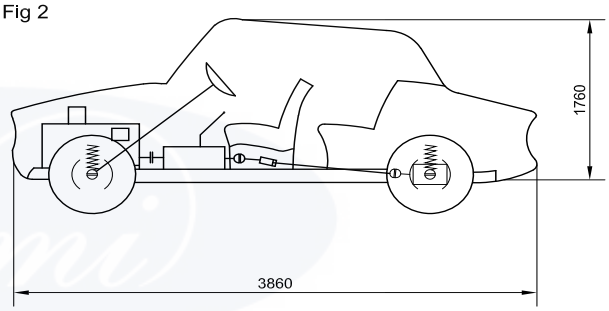


Fig 2

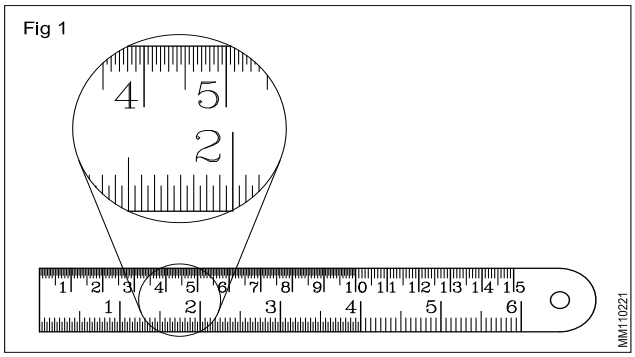


Steel rule

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) are used to measure the dimensions of work pieces.

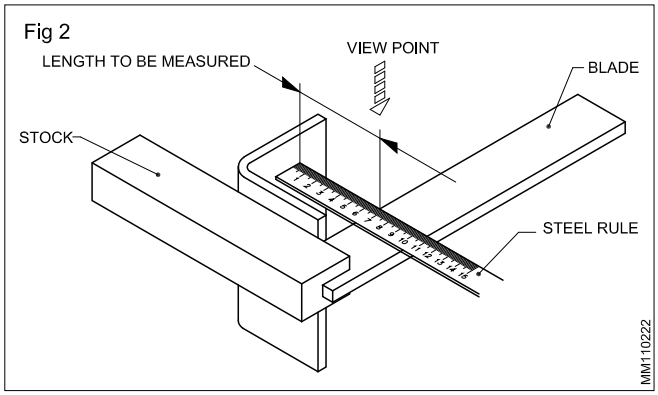
Fig 1



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 0.5mm and 1/64 inch.

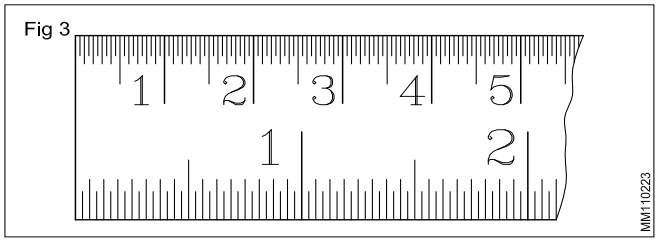
For accurate reading it is necessary to read vertically to avoid errors arising out of parallax. (Fig 2)

Fig 2



Steel rule in English measure, they can also be furnished with metric and English graduation in a complete range of sizes 150, 300, 500 and 1000 mm. (Fig 3)

Fig 3

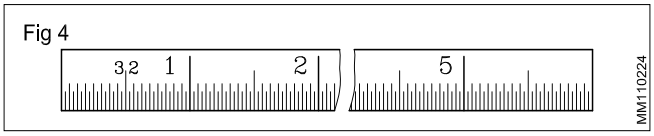


Other types of rule

– narrow steel rules
– short steel rules
– full flexible steel rule with tapered end.

Narrow steel rule: Narrow steel rule are 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 approximately 5mm thickness 2mm. (Fig 4)

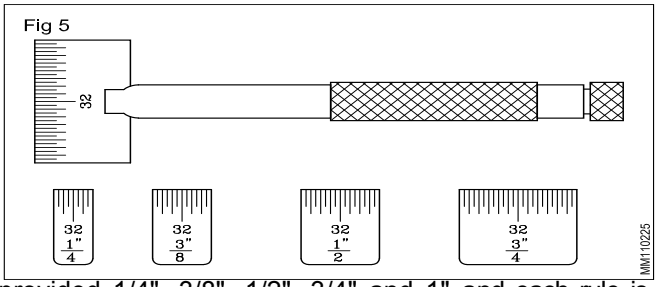
Fig 4



Short steel rule (Fig 5): 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 knurled nut at the end of the handle. Five rule lengths are

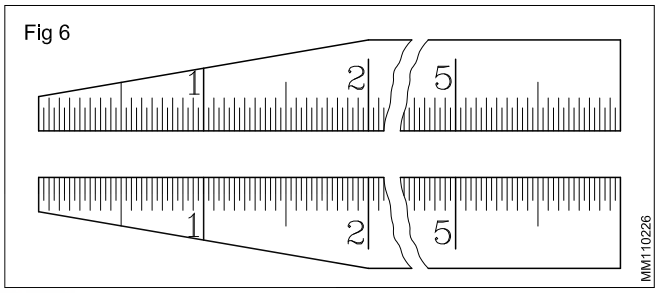
Fig 5



provided 1/4", 3/8", 1/2", 3/4" and 1" and each rule is graduated in 32nds on one side and 64ths 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 slots, 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)

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.**

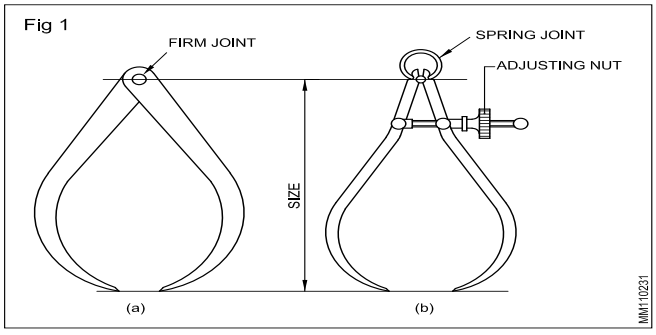
Calipers are indirect measuring instruments used for transferring measurements from a steel rule to a job, and vice versa.

Calipers are classified according to their joints and their legs.

Joint

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

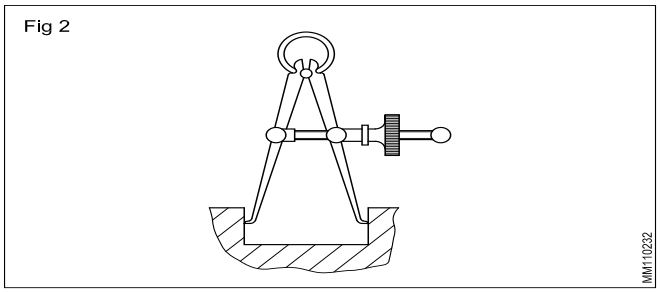
Fig 1



Legs

– Outside caliper for external measurement. (Figs 1a & b)
– Inside caliper for internal measurement. (Fig 2)

Fig 2



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 types of marking media**
- **select the correct marking media for different applications.**

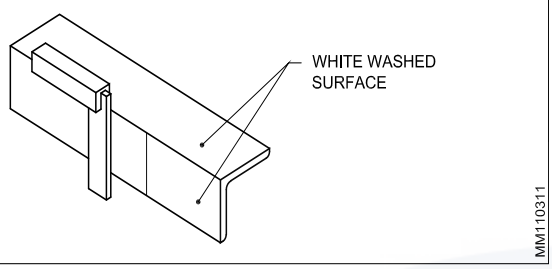
Different Marking Media: The different marking media are Whitewash, Prussian Blue, Copper Sulphate and Cellulose Lacquer.

Whitewash: White wash is prepared in many ways

Chalk powder mixed with water

Chalk mixed with methylated spirit
White lead powder mixed with turpentine.

Fig 1

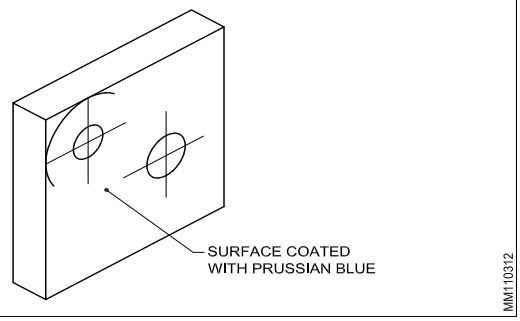


Whitewash is applied to rough forgings and castings with oxidised surfaces. (Fig 1)

Whitewash is not recommended for workpieces of high accuracy.

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

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.

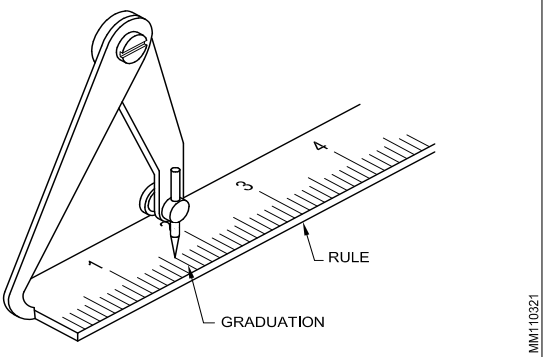
The selection of marking medium for a particular job depends on the surface roughness and the accuracy of the workpiece.

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 of 150mm, 200mm, 250mm and 300mm.

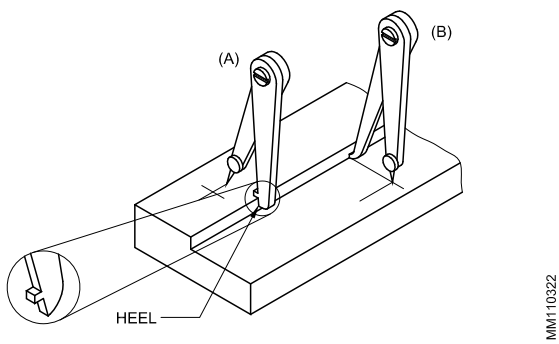
Fig 1



Jenny calipers are used:

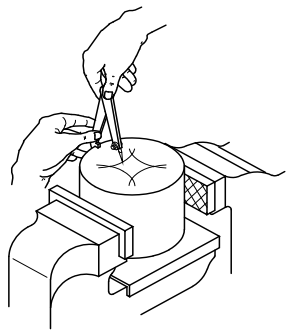
– for marking lines parallel to the inside and outside edges (Fig 2)

Fig 2



– for finding the centre of round bars. (Fig 3)

Fig 3



MM110323

These calipers are available 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 caliper are:

– hermaphrodite calipers
– leg and point calipers
– odd leg caliper

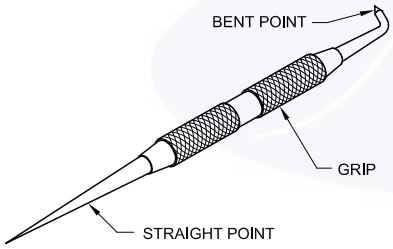
Scribers

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 honed frequently for maintaining its sharpness.

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

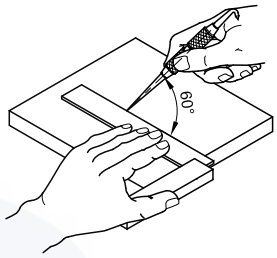
Fig 1



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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



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

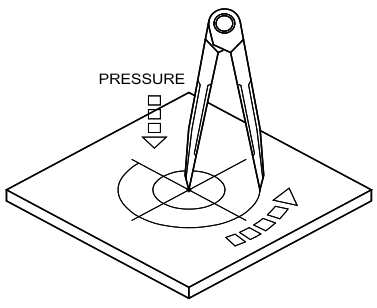
Place a cork on the point when not in use to prevent accidents.

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, arcs and for transferring and stepping off distances. (Fig 1,2 and 3)

Fig 1

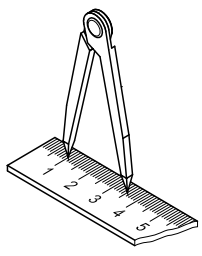


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FIRM JOINT DIVIDER

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

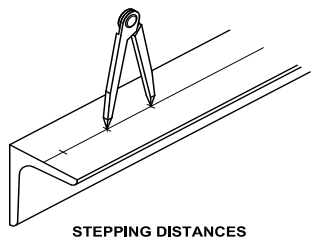
Fig 2



MM110342

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

Fig 3



STEPPING DISTANCES

MM110343

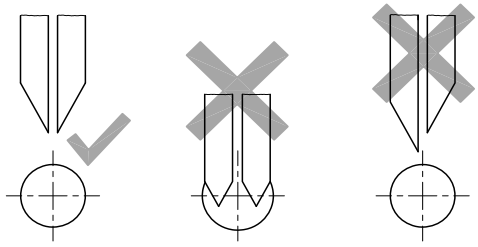
The distance from the point to the centre of the fulcrum roller (pivot) is the size of the divider. (Fig 4)

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.

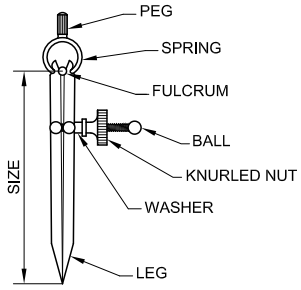
The divider point should be kept sharp in order to produce fine lines. Frequent sharpening with an oilstone is better than sharpening by grinding. Sharpening by grinding will make the points soft.

Fig 5



MM110345

Fig 4



SPRING JOINT DIVIDER

MM110344

Surface gauges

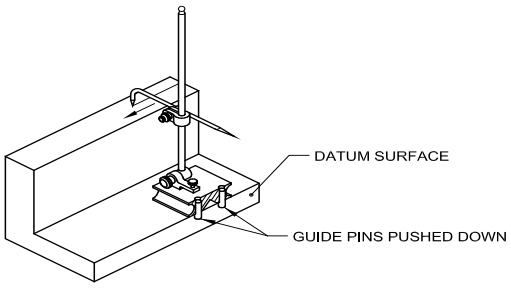
Objectives: At the end of this lesson you shall be able to

- **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:-

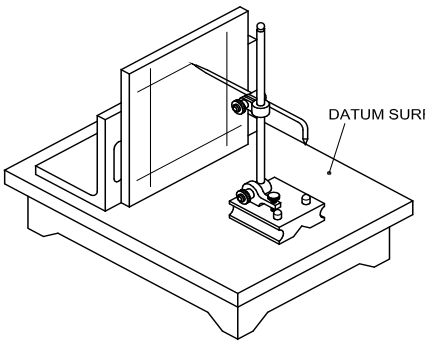
– scribing lines parallel to a datum surface. (Figs 1 & 2)

Fig 1



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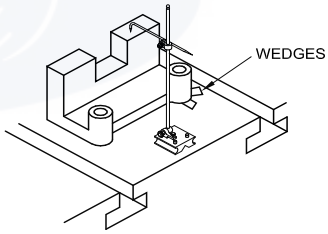
Fig 2



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

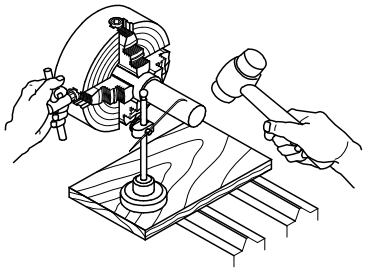
Fig 3



MM110353

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

Fig 4



MM110354

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

– fixed and universal.

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

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

Fig 5

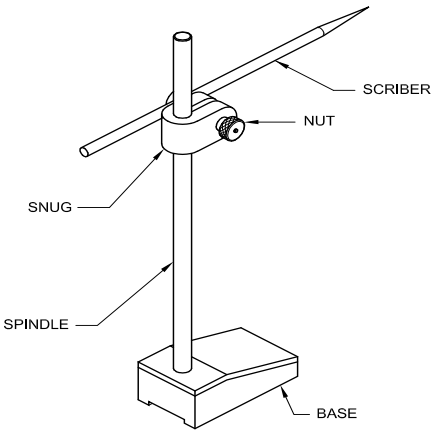
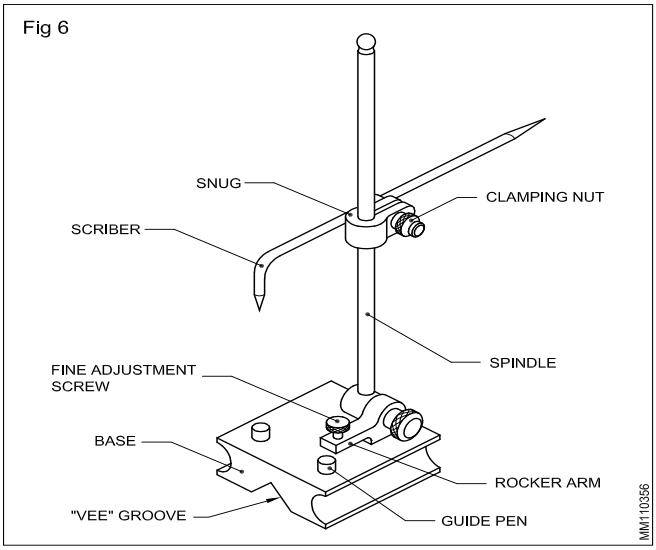


Fig 6



– The spindle can be set to any position.
– Fine adjustments can be made quickly.
– Can also be used on cylindrical datum surfaces.

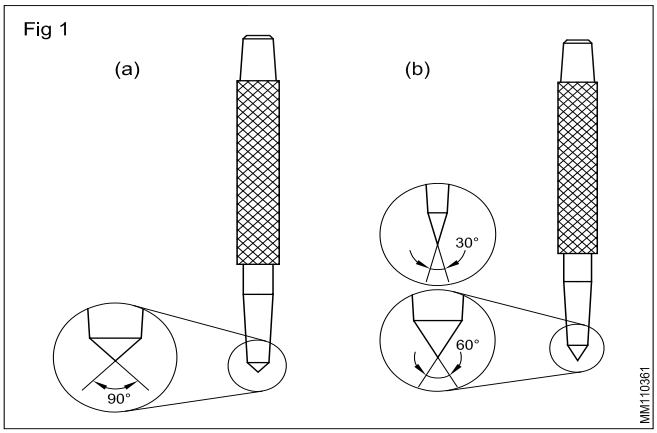
Types of marking punches

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 permanent. There are two types of punches. They are centre punch and prick punch made up of high carbon steel, hardened and ground.

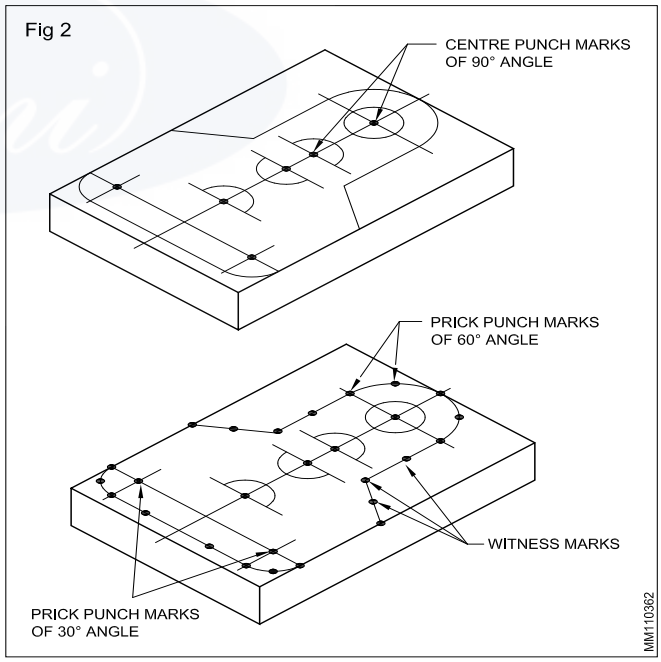
Centre Punch: The angle of the point is 90° in a centre punch. The punch mark made by this is wide and not very deep. This punch is used for locating centre of the holes. The wide punch mark gives a good seating for starting the drill. (Fig 1a)

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 making 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 witness marks and called as dot punch. (Fig 2)

Fig 2



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

Angular measuring instruments (Semi-precision)

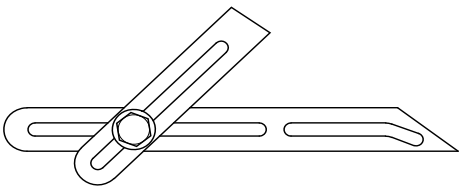
Objectives: At the end of this lesson you shall be able to
- **state the names of semi-precision angular measuring instruments**
- **differentiate between bevel and universal bevel gauges**
- **state the features of bevel protractors.**

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 angles directly. They are, therefore, indirect angular measuring instruments. The angles can be set and measured with bevel protractors.

Fig 1



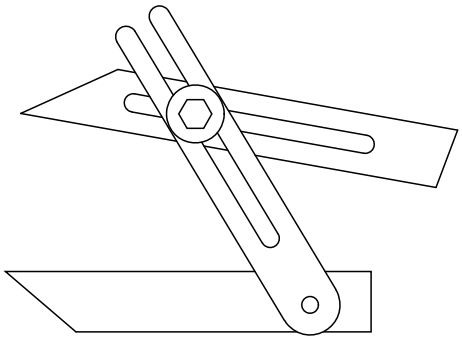
BEVEL

MM110371

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 angles within an accuracy of ±1°.

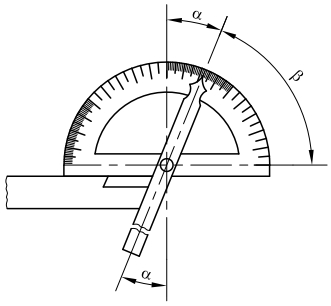
Fig 2



UNIVERSAL BEVEL

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Fig 3



BEVEL PROTRACTOR

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Datum

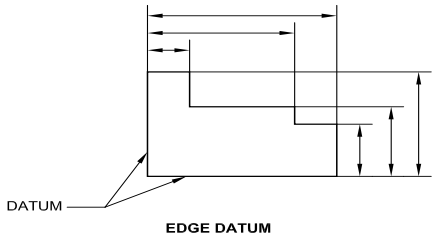
Objectives: **At the end of this lesson you shall be able to**

- **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 or the common basis for measurement.

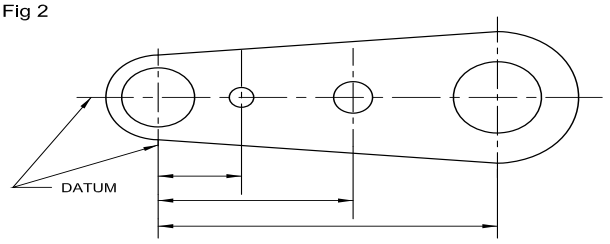
A datum is a reference surface, line or point, and its purpose is to provide a common position from which measurements may be taken. The datum may be an edge or centre line depending on the shape of the work. For positioning a point, two datum references are required. (Fig 1,2 and 3)

Fig 1



EDGE DATUM

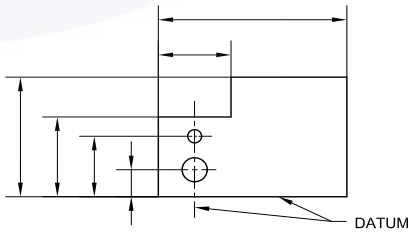
Fig 2



CENTRE LINE DATUM

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Fig 3

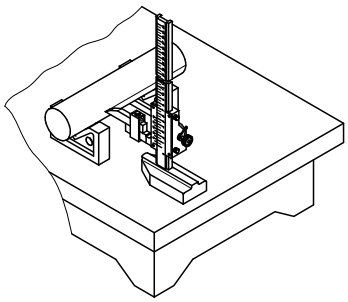


EDGE DATUM AND CENTRE LINE DATUM

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Marking tables, surface plates, angle plates, 'V' blocks, and parallel blocks serve as a datum. (Fig 4) Marking tables aremade up of cast iron since they are i) self lubricating ii) easy to cast and iii) cheaper.

Fig 4



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Shapes of files

Objectives: At the end of this lesson you shall be able to
- **identify the different shapes of files**
- **state the uses of Square, Round, Half Round, Triangular and Knife-edge files**
- **state the correct shape of files for filing different profiles.**

For filing and finishing different profiles, files of different shapes are used.

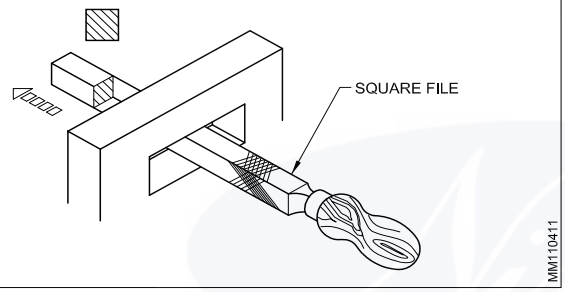
The shape of files is stated by its cross section.

Common files of different shapes: Flat file, Hand file, Square file, Round file, Half round file, Triangular file and Knife-edge file.

(Flat and hand files have already been discussed).

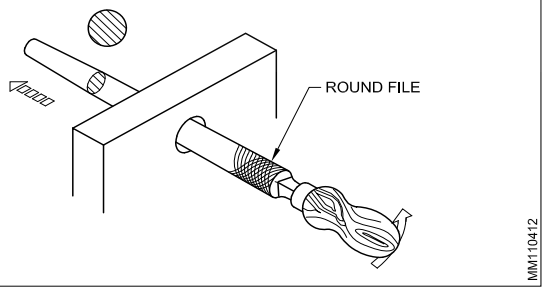
Square File: The square file is square in its cross section. It is used for filing square holes, internal square corners, rectangular openings, keyways and splines. (Fig 1)

Fig 1



Round file: A round file is circular in its cross section. It is used for enlarging the circular holes and filing profiles with fillets. (Fig 2)

Fig 2



Half round file: A half round file is in the shape of a segment of a circle. It is used for filing internal curved surfaces. (Fig3)

Triangular file: A triangular file is of a triangular cross section. It is used for filing corners and angles which are more than 60°. (Fig 4)

Fig 3

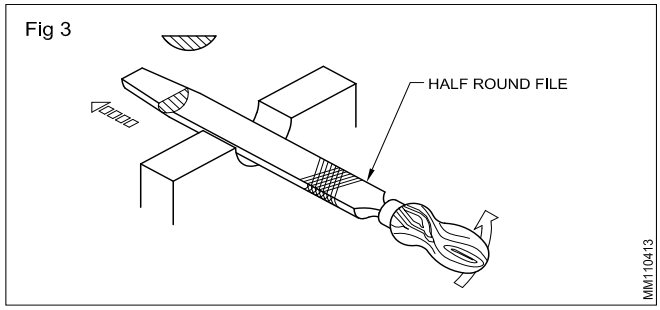
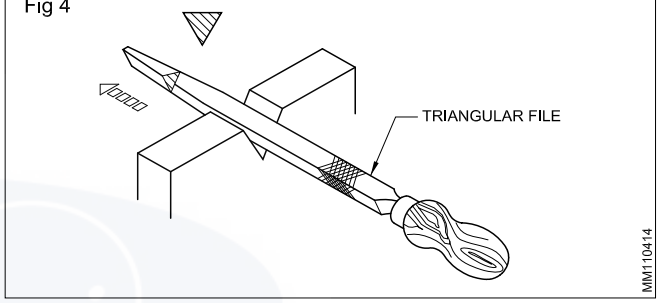
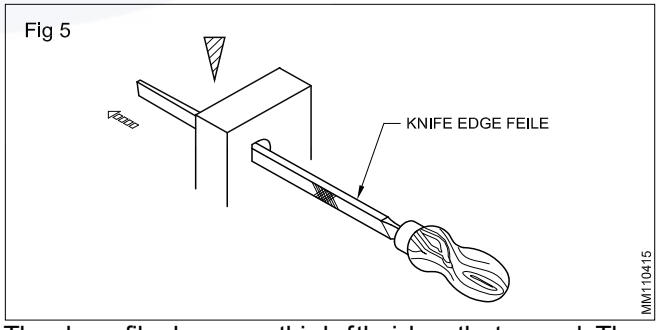


Fig 4



Knife-edge file: A knife-edge file has the cross section of a sharp triangle. It is used for filing narrow grooves and angles above 10°. (Fig 5)

Fig 5



The above files have one third of their lengths tapered. They are available both in single and double cuts.

Square, round, half-round and triangular files are available in lengths of 100, 150, 200, 250, 300 and 400 mm. These files are made in bastard, second cut and smooth grades.

Convexity of files

Objective: At the end of this lesson you shall be able to
- **list the reasons for convexity on files.**

Most files have the faces slightly bellied lengthwise. This is known as convexity of a file. This should not be confused with the taper of a file. A flat file has faces which are convex and it also tapers slightly in width and thickness.

Purpose: If the file is parallel in thickness, all the teeth on the surface of the work will cut. This would require more downward pressure to make the file 'bite' and also more forward pressure to make the file to cut.

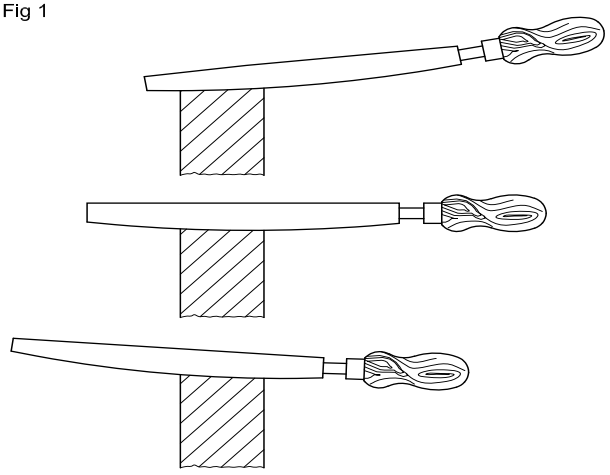
It is more difficult to control a file of uniform thickness.

To produce a flat surface with a file of parallel thickness, every stroke should be straight. But it is not possible due to the see-saw action of the hand.

If the file is made with parallel faces, while giving heat treatment, one face may warp and become concave, and the file will be useless for flat filing.

Excessive chip removal at the front or rear workpiece edge is prevented and filing of the flat surface is made easier because of the convexity on the cutting faces. (Fig 1)

Fig 1



Pinning of files

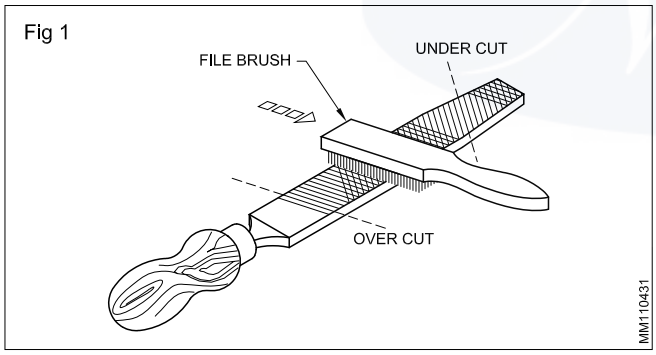
Objective: At the end of this lesson you shall be able to
- **clean the files.**

During filing, sometimes the metal chips (filings) will clog between the teeth of files. This is known as 'pinning' of files.

Files which are pinned will produce scratches on the surface being filed, and also will not bite well.

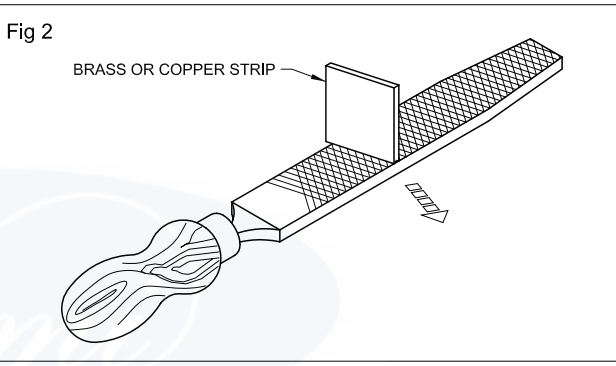
Pinning of the files is removed by using a file brush also called a file card, (Fig 1) with either forward or backward stroke.

Fig 1



Filings which do not come out easily by the file card should be taken out with a brass or copper strip. (Fig 2)

Fig 2



For new files, use only soft metal strips (brass or copper) for cleaning. The sharp cutting edges of the files will wear out quickly if a steel file card is used.

When filing a workpiece to a smooth finish more 'pinning' will take place because the pitch and depth of the teeth are less.

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.

Needle files

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

- **identify the different shapes of needle files**
- **designate needle files as per BIS.**

Needle files are usually available in sets with assorted shapes. These types of files are used for delicate, light kinds of work. These files are available in bastard and smooth grade.

Shapes: The common shapes of needle files are shown in figure 1. The shapes are round edge, flat edge, flat taper, half round, triangular, square, round, knife, feather edge, crossing, barret and marking. (Fig 1)

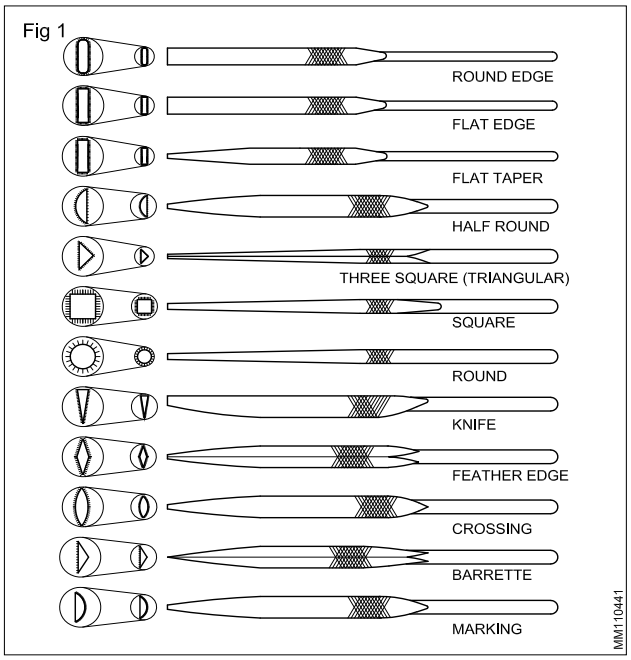
Nomenclature of needle files (Fig 2)

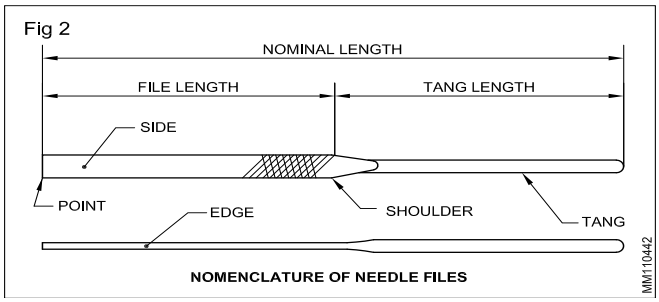
Length: These files are available in a nominal length of 120mm to 180mm.

Grades: The grades of cut may be identified by the cut number as follows-

– bastard - Cut 0.

– smooth - Cut 2.





Designation of needle files: The needle files are designated by their names

– grade of cut
– nominal length
– BIS number.

Example

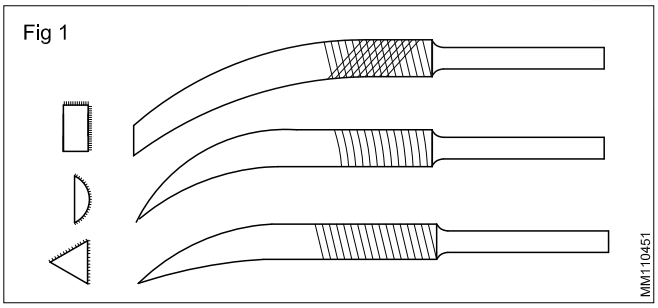
A flat edge needle file with grade of cut bastard, having a nominal length of 160mm shall be designated as flat edge needle file bastard, 160 IS 3152.

Special files

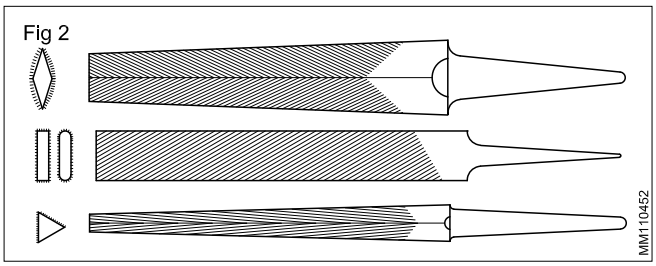
Objectives: At the end of this lesson you shall be able to
- **identify the different types of special files**
- **state the uses of each type of special files.**

In addition to the common type of files, files are also available in a variety of shapes for 'special' applications. These are as follows.

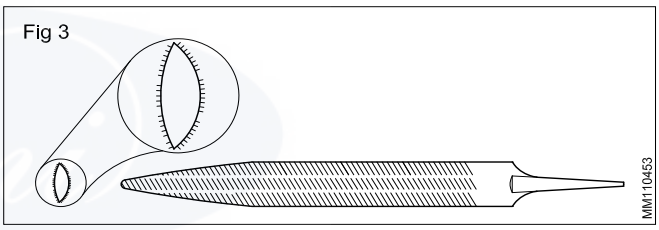
Riffler files (Fig 1)**:** These files are used for die-sinking, engraving and in silversmith's work. They are made in different shapes and sizes and are made with standard cuts of teeth.



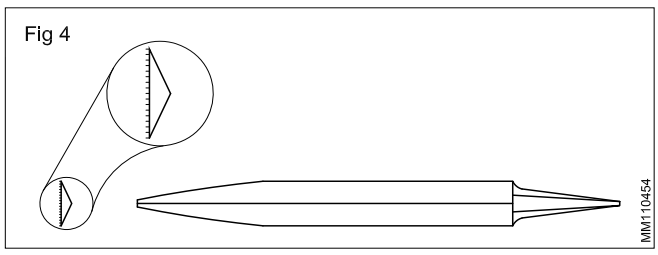
Mill saw files (Fig 2)**:** Mill saw files are usually flat and have square or rounded edges. These are used for sharpening teeth of wood-working saws, and are available in single cut.



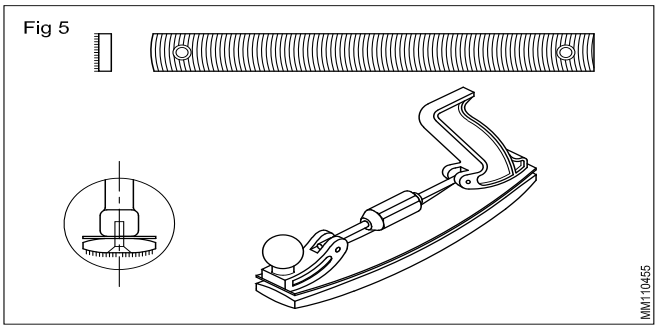
Crossing file (Fig 3)**:** This file is used in the place of a half round file. Each side of the file has different curves. It is also known as 'fish back' file.



Barrette file (Fig 4)**:** This file has a flat, triangular face with teeth on the wide face only. It is used for finishing sharp corners.



Tinker's file (Fig 5)**:** This file has a rectangular shape with teeth only at the bottom face. A handle is provided on the top. This file is used for finishing automobile bodies after tinkering.



Rotary files (Fig 6)**:** These files are available with a round shank. They are driven by a special machine with a portable motor and flexible shaft. These are used in diesinking and mould-making work.

Machine files for hand filing machine (Fig 7)**:** Machine files are of double cut, having holes or projections to fix to the holder of the filing machine. The length and shape will vary according to the machine capacity. These files are suitable for filing the inner and outer surfaces, and are ideal for diesinking and other tool-room work.

Fig 6

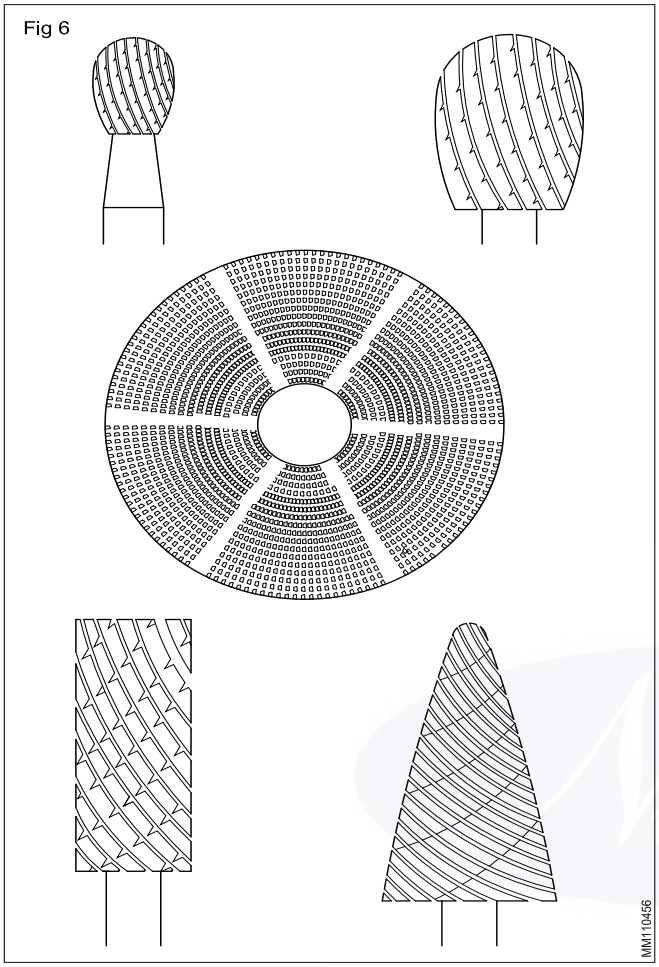
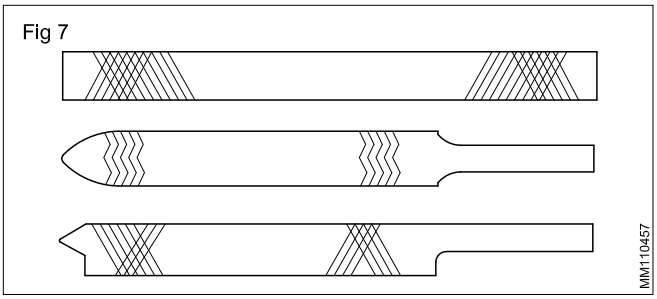


Fig 7



Types of vices

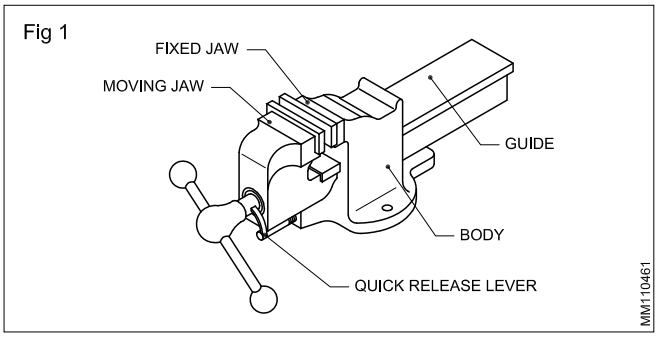
Objectives: At the end of this lesson you shall be able to
- **state the construction and advantages of a quick releasing vice**
- **state the uses of pipe vice, toolmakers vice, hand vice and pin vice.**

There are different types of vices used for holding work-pieces. They are quick releasing vice, pipe vice, hand vice, pin vice and toolmaker's vice.

Quick releasing vice (Fig 1)**:** A quick releasing vice is similar to an ordinary bench vice but the opening of the movable jaw is done by using a trigger (lever). If the trigger at the front of the movable jaw is pressed, the nut disengages the screw and the movable jaw can be set in any desired place quickly.

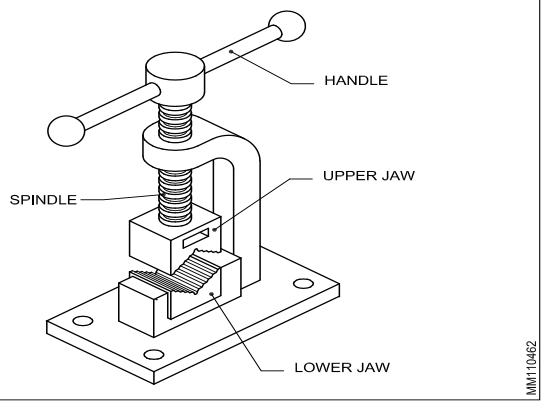
Pipe vice (Fig 2)**:** A pipe vice is used for holding round sections of metal, tubes and pipes. In the vice, the screw is vertical and movable. The jaw works vertically.

Fig 1



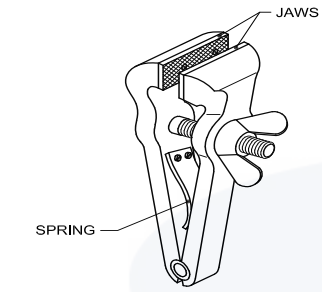
The pipe vice grips the work at four points on its surface. The parts of a pipe vice are shown in Fig 2.

Fig 2



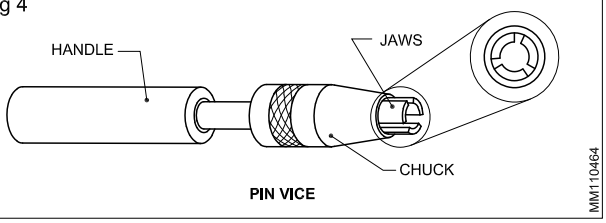
Hand vice (Fig 3)**:** Hand vices are used for gripping screws, rivets, keys, small drills and other similar objects which are too small to be conveniently held in the bench vice. A hand vice is made in various shapes and sizes. The length varies from 125 to 150 mm and the jaw width from 40 to 44 mm. The jaws can be opened and closed using the wing nut on the screw that is fastened to one leg, and passes through the other.

Fig 3



Pin vice (Fig 4)**:** The pin vice is used for holding small diameter jobs. It consists of a handle and a small collet chuck at one end. The chuck carries a set of jaws which are operated by turning the handle.

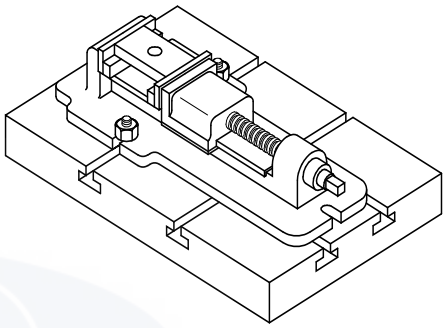
Fig 4



Toolmaker's vice (Fig 5)**:** The toolmaker's vice is used for holding small work which requires filling or drilling and for marking of small jobs on the surface plate. This vice is made of mild steel.

Toolmaker's vice is accurately machined.

Fig 5

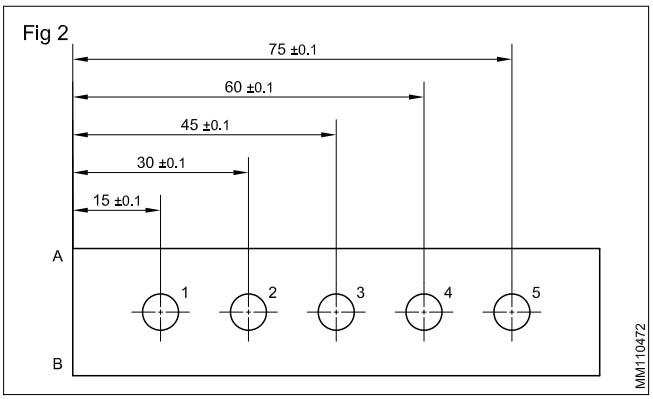


Datum line and cumulative error

Objectives: At the end of this lesson you shall be able to
- **state the reason for cumulative error in marking**
- **state the application of datum line and datum surface in marking out**
- **name the different types of datum.**

When the marking is done progressively as shown in Fig 1 the maximum distance from the datum line AB to the 5th hole is 75.5 mm. The minimum distance from the datum line AB is 74.5 mm.

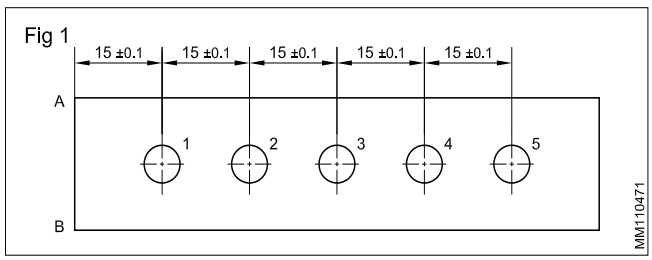
Fig 2



There is a tolerance of 1 mm in size. Assembly of matching parts and the interchangeability may not be possible in such cases.

To avoid this error, each feature of the component should be marked out individually from the edge AB, as shown in Fig 2. In this case no hole will be more than the specified deviation of ± 0.1 mm and there is no possibility of build up or cumulative error.

Fig 1

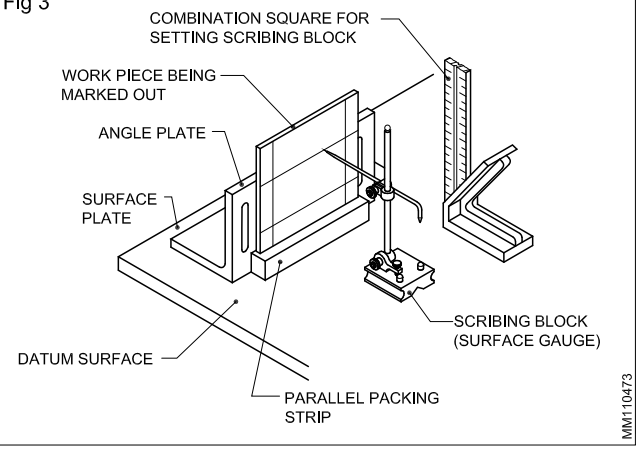


Datum line and datum surface: Datum line is a reference line from which all other lines are marked.

This can be also a reference surface or plane for marking or measurement.

For most components two datum lines are required, one horizontal, and the other vertical; the intersecting point provides the common position. (Fig 3)

Fig 3

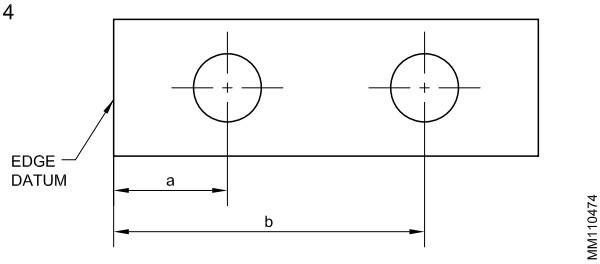


The surface plate or marking table top surface provides the datum surface. All measurements are made from this surface. All lines scribed by the scribing block or vernier height gauge will be parallel to this surface.

Types of reference

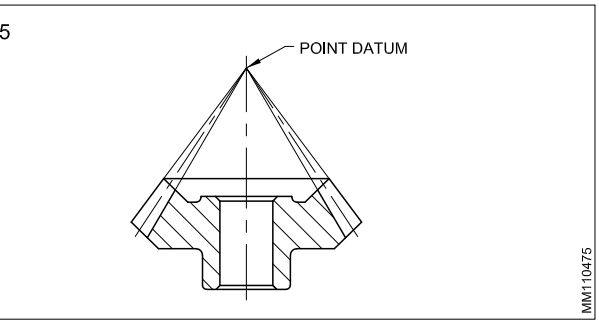
Edge datum: The datum surface in this case is the edge of a work. All markings and measurements are carried out using the edge as the basis. (Fig 4)

Fig 4



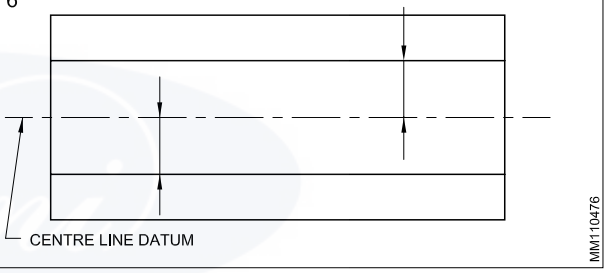
Point datum: In this case, the reference is a point for marking and measuring. (Fig 5)

Fig 5



Line datum: Use of a centre line as a datum is an example of this. (Fig 6)

Fig 6



Hacksaw frame and blade

Objectives: At the end of this lesson you shall be able to
- **name the different types of hacksaw frames**
- **specify hacksaw blades.**

Hacksaw frame: A hacksaw frame is used along with a blade to cut metals of different sections, and is specified by the type and maximum length of the blade that can be fixed.

Example

Adjustable hacksaw frame - tubular - 250 - 300 or 8" - 12"

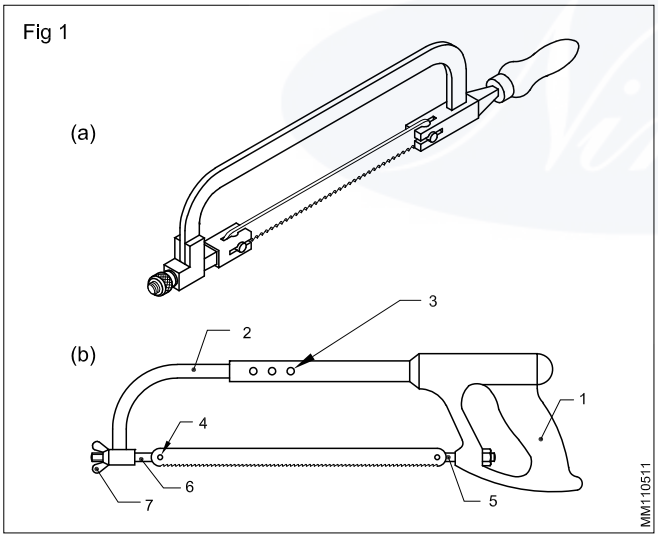
Types of Hacksaw Frames

Solid frame (Fig 1a)**:** Only a blade of a particular standard length can be fitted to this frame. e.g 300 mm or 250 mm.

Adjustable frame (flat type)**:** Different standard lengths of blades can be fitted to this frame i.e. 250 mm and 300 mm.

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

Fig 1



Parts of a hacksaw frame

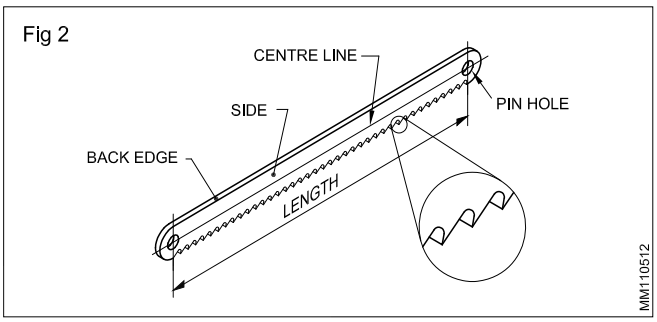
1 Handle
2 Frame
3 Tubular frame with holes for length adjustment
4 Retaining pins
5 Fixed blade-holder
6 Adjustable blade-holder
7 Wing-nut

A hacksaw blade is made of either low alloy steel (LA) or high speed steel (HSS), and is available in standard lengths of 250 mm and 300 mm. (Fig 2)

Parts of a hacksaw blade (Fig 2)

1 Back edge
2 Side
3 Centre line
4 Pin holes

Fig 2



Type of Hacksaw Blades

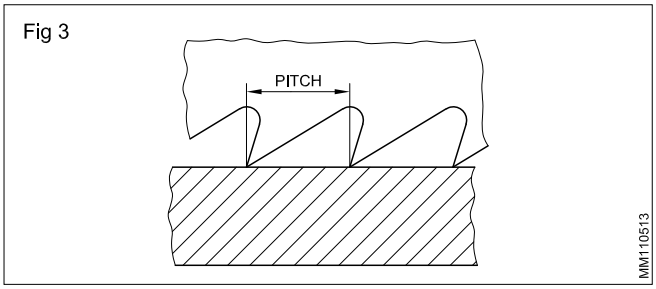
All-hard blade: The full length of the blade between the pins is hardened and it is used for harder metals such as tool steel, die steel and HCS.

Flexible blade: Only the teeth are hardened. Because of their flexibility these blades are useful for cutting along curved lines. Flexible blades should be thinner than all-hard blades.

Pitch of the 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

Fig 3



Specification: Hacksaw blades are specified by the length, pitch and type of material. (The width and thickness of blade is standardised)

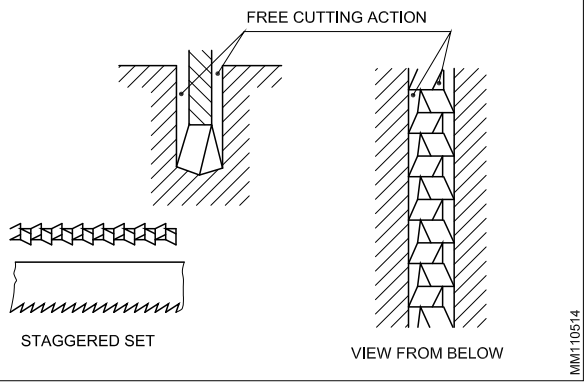
Example

300 x 1.8 mm, pitches LA all-hard blade.

To prevent the hacksaw blade binding when penetrating into the material, and to allow free movement of the blade, the cut is to be broader than the thickness of the hacksaw blade. This is achieved by the setting of the hacksaw teeth. There are two types of hacksaw teeth settings.

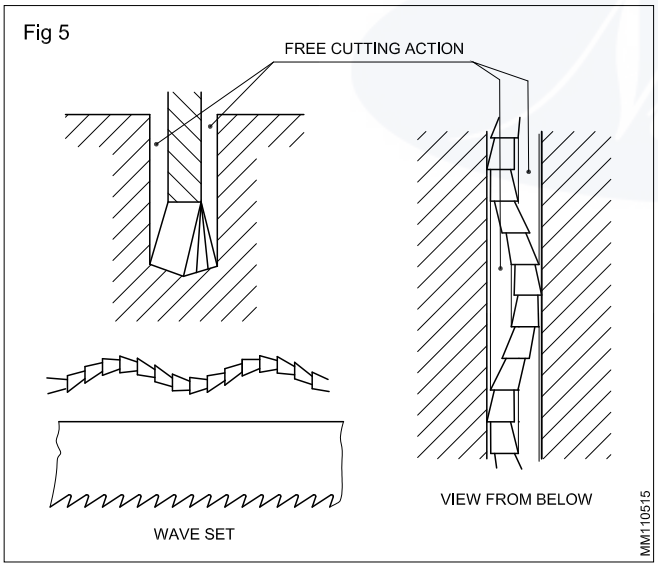
Staggered set (Fig 4)**:** Alternate teeth or groups of teeth are staggered. This arrangement helps for free cutting, and provides for good chip clearance.

Fig 4



Wave set (Fig 5)**:** In this, the teeth of the blade are arranged in a wave-form. The types of sets for different pictures are as follows:

Fig 5

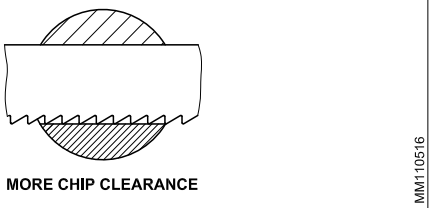


Pitch	Type of set
0.8 mm	Wave-set
1.0 mm	Wave-set or staggered
Over 1.0 mm	Staggered

For the best results, the blade with the right pitch should be selected and fitted correctly.

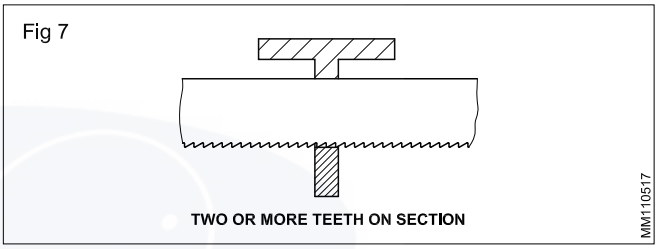
Selection of blade: The selection of the blade depends on the shape and hardness of the material to be cut.

Fig 6



Pitch selection (Fig 6)**:** For soft materials such as bronze, brass, soft steel, cast iron, heavy angles etc. use a 1.8 mm pitch blade.

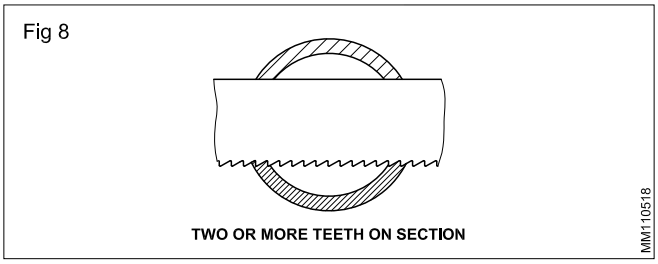
Fig 7



For tool steel, high carbon, high speed steel etc. use a 1.4 mm pitch. For angle iron, brass tubing, copper, iron pipe etc. use a 1 mm pitch blade. (Fig 7)

For conduit and other thin tubing, sheet metal work etc. use a 0.8 mm pitch. (Fig 8)

Fig 8

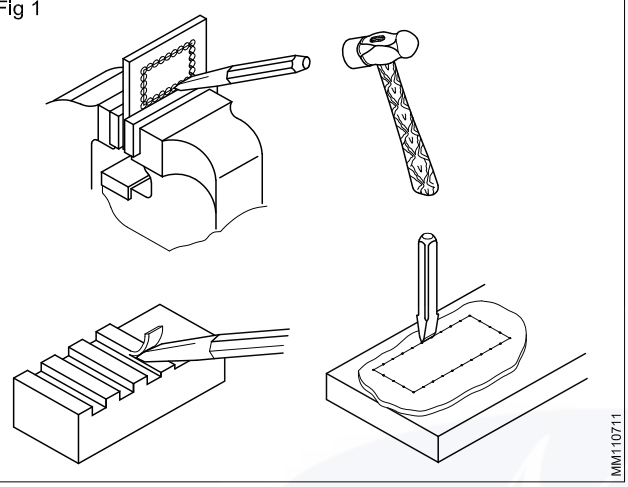


Chisel

Objectives: At the end of this lesson you shall be able to
- **list the uses of a cold chisel**
- **name the parts of a cold chisel**
- **state the different types of chisels**
- **state the safety measures.**

The cold chisel is a hand cutting tool used by fitters for chipping and cutting off operations. (Fig 1)

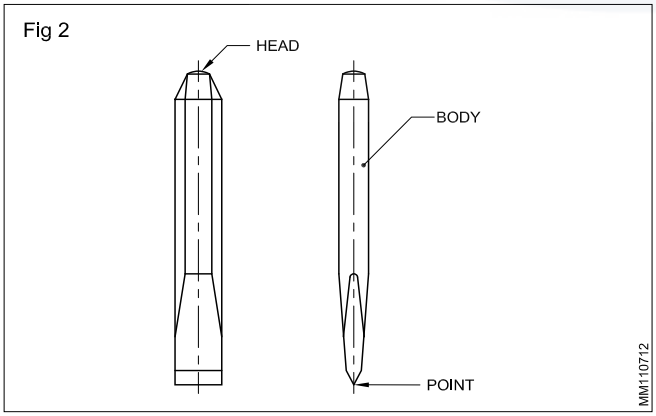
Fig 1



Chipping is an operation of removing excess metal with the help of a chisel and hammer. Chipped surfaces being rough, they should be finished by filing.

Parts of a Chisel (Fig 2)**:** A chisel has the following parts.

Fig 2



Head, body, point or cutting edge

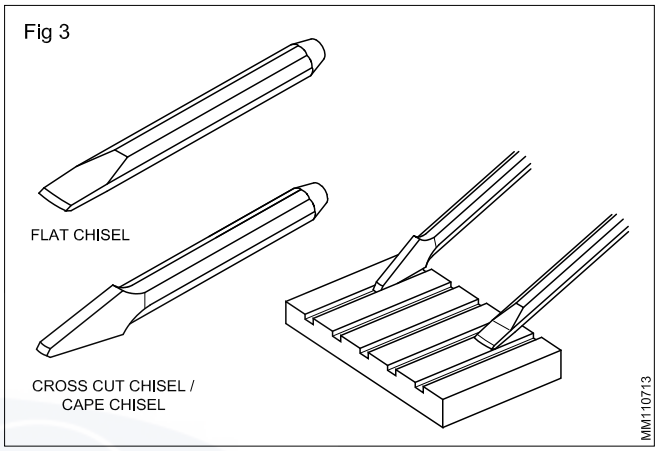
Chisels are made from high carbon steel or chrome vanadium steel. The cross-section of chisels is usually hexagonal or octagonal. The cutting edge is hardened and tempered.

Common types of chisels: There are five common types of chisels.

– Flat chisel
– Cross-cut chisel
– Half-round nose chisel
– Diamond point chisel
– Web chisel

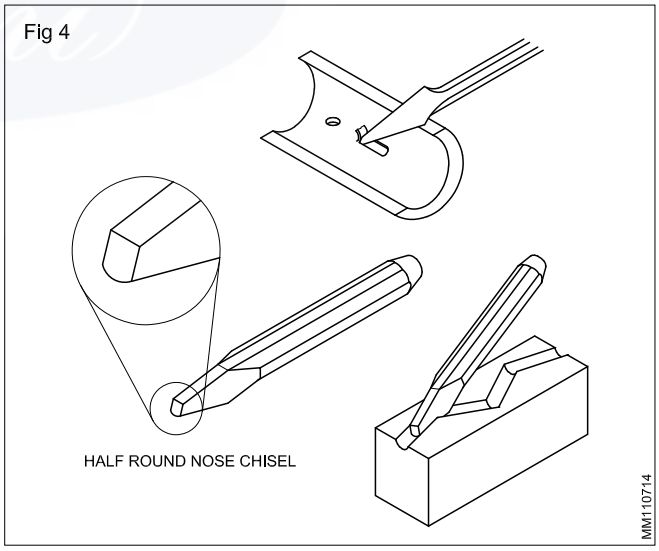
Flat chisels (Fig 3)**:** They are used to remove metal from large flat surfaces and chip-off excess metal of welded joints and castings.

Fig 3



Cross-cut or cape chisels (Fig 3)**:** These are used for cutting keyways, grooves and slots.

Fig 4



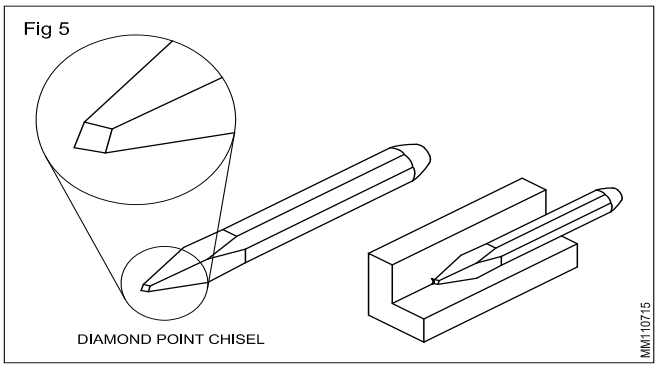
Half-round nose chisels (Fig 4)**:** They are used for cutting curved grooves (oil grooves).

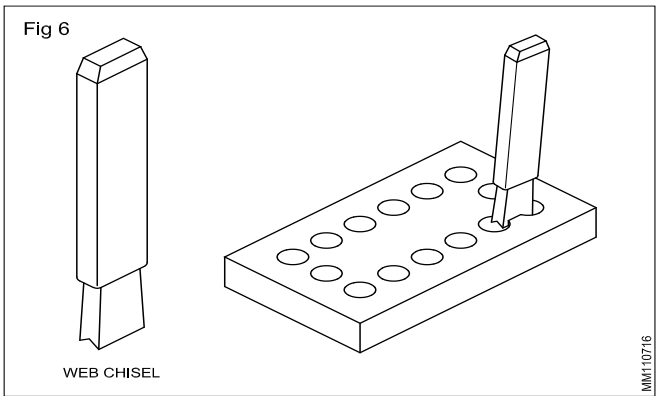
Diamond point chisels (Fig 5)**:** These are used for squaring materials at the corners, joints.

Web chisels/punching chisels (Fig 6)**:** These chisels are used for separating metals after chain drilling.

Chisels are specified according to their

– length
– width of the cutting edge
– type
– cross-section of the body.





The length of the chisels ranges from 100 mm to 200 mm.

The width of the cutting edge varies according to the type of chisels.

Hammer

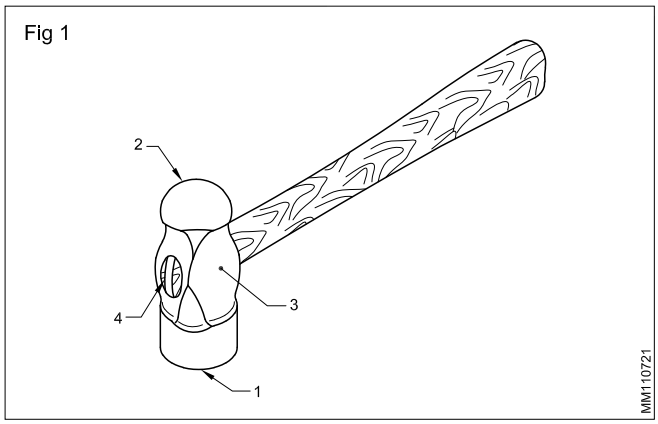
Objectives: At the end of this lesson you shall be able to
- **state the uses of an engineer's hammer**
- **identify the parts of an engineer's hammer**
- **name the types of engineer's hammer**
- **specify the engineer's hammer.**

An engineer's hammer is a hand tool used for striking purposes while punching, bending, straightening, chipping, forging or riveting.

Major parts of a hammer: The major parts of a hammer are the head and the handle.

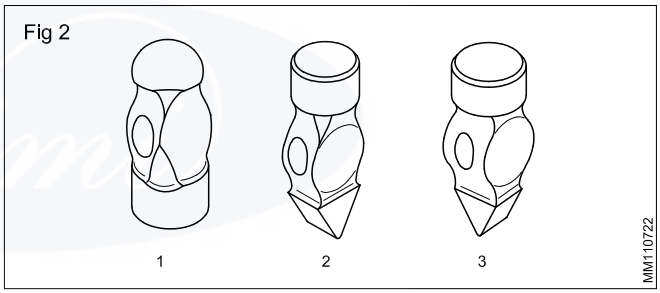
The head is made of drop-forged carbon steel, while the wooden handle must be capable of absorbing shock.

The parts of a hammer-head (Fig 1) are the face(1), pein(2) cheek (3) and the eyehole (4).



Face: The face is the striking portion. A slight convexity is given to it to avoid digging of the edge. It is used for striking while chipping, bending, punching, etc.

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 such as:



– ball pein
– cross-pein
– straight pein. (Fig 2)

The face and the pein are case hardened.

Cheek: The cheek is the middle portion of the hammer-head. The weight of the hammer is stamped here.

This portion of the hammer-head is left soft.

Eyehole: The eyehole is meant for fixing the handle. It is shaped to fit the handle rigidly. The wedges fix the handle in the eyehole. (Figs 3 and 4)

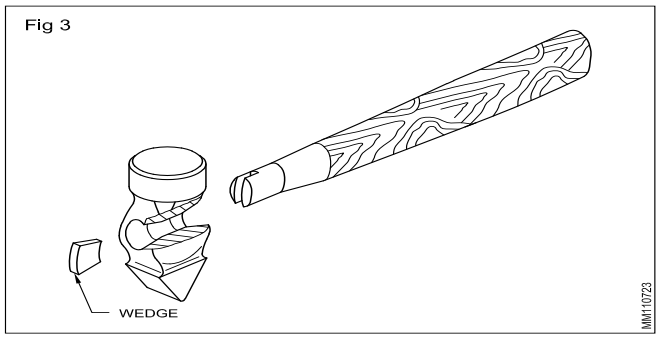
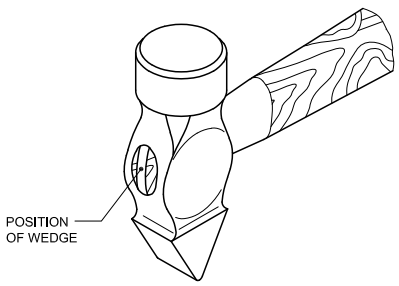


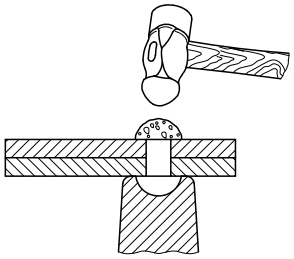
Fig 4



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Application of hammer pein: The ball pein is used for riveting. (Fig 5)

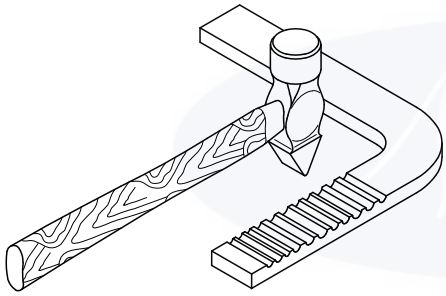
Fig 5



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The cross-pein is used for spreading the metal in one direction. (Fig 6)

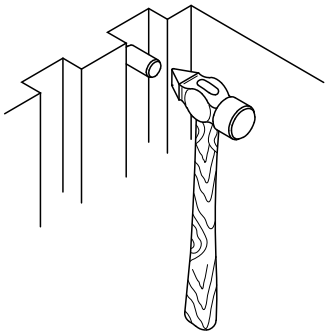
Fig 6



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The straight pein is used at the corners. (Fig 7)

Fig 7



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Specification: An engineer's hammers are specified by their weight and the shape of the pein. Their weight varies from 125 gms to 750 gms.

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/fitting shop.

Before using a hammer:

- makes sure the handle is properly fitted
- select a hammer with the correct weight suitable for the job
- check the hammer head and handle whether any crack is there
- ensure that the face of the hammer is free from oil or grease.

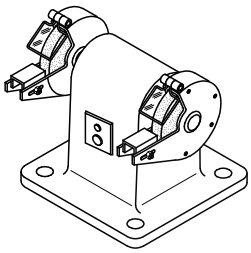
Off-hand grinding with bench and pedestal grinders

Objectives: At the end of this lesson you shall be able to
- **state the purposes of off-hand grinding**
- **name the machines with which off-hand grinding is done**
- **state the features of bench and pedestal grinders.**

Off-hand grinding is the operation of removing material which does not require great accuracy in size or shape. This is carried out by pressing the workpiece by hand against a rotating grinding wheel.

Off-hand grinding is performed for rough grinding of jobs and resharpening of scribers, punches, chisels, twist drills, single point cutting tools etc.

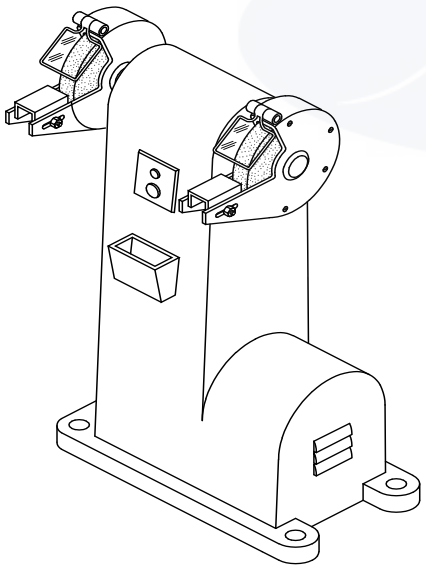
Fig 1



BENCH GRINDER

MM111211

Fig 2



PEDESTAL GRINDER

MM111212

Off-hand grinders are fitted to a bench or a pedestal (Figs 1 and 2)

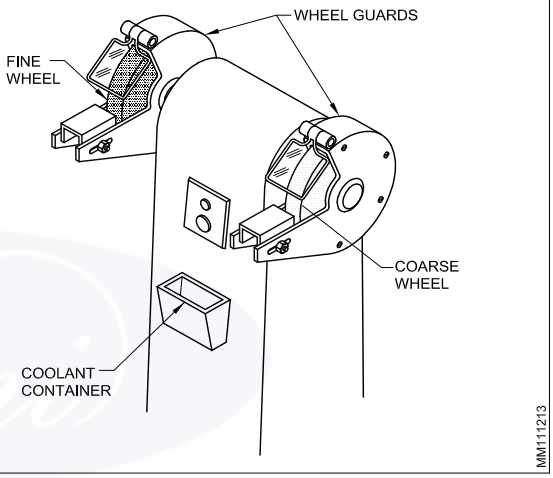
Bench grinders: Bench grinders are fitted to a bench or table, and are useful for light duty work.

Pedestal grinders: Pedestal grinders are mounted on a base (pedestal), which is fastened to the floor. They are used for heavy duty work.

These grinders consist of an electric motor and the spindle for mounting the grinding wheels. On one end of the spindle a coarse-grained wheel is fitted, and on the other end, a fine-grained wheel. For safety while working, wheel guards are provided.

A coolant container (Fig 3) is provided for frequent cooling of the work.

Fig 3

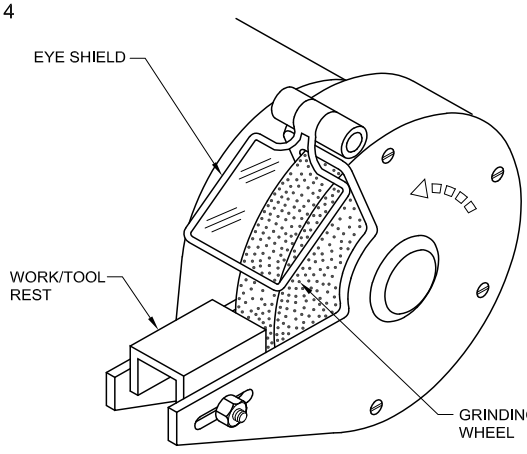


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Adjustable work-rests are provided for both the wheels to support the work while grinding. These work-rests must be set very close to the wheels. (Fig 4)

Extra eyeshields are also provided for the protection of the eyes. (Fig 4)

Fig 4



MM111214

Drilling machines

Objectives: At the end of this lesson you shall be able to
- **name the various types of drilling machines**
- **identify the parts of the bench and pillar type drilling machines**
- **compare the features of the bench and pillar type drilling machines.**

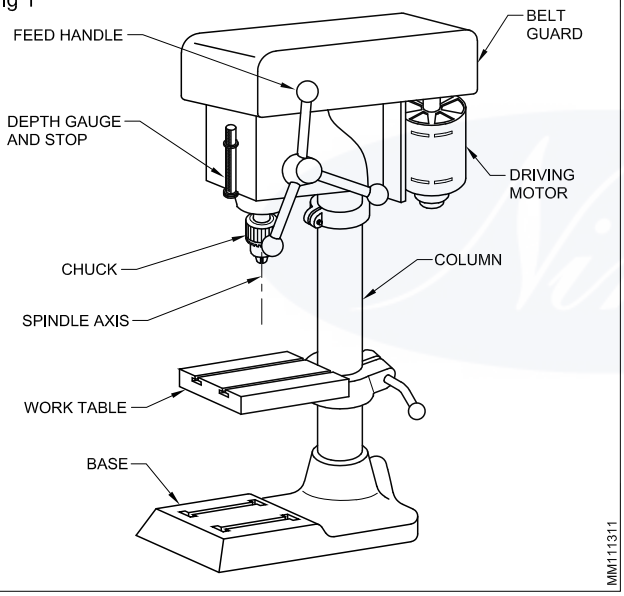
The principal types of drilling machines are:

– the sensitive bench drilling machine
– the pillar drilling machine
– the column drilling machine
– the radial arm drilling machine (radial drilling machine).

(You are not likely to use the column and radial type of drilling machines now. Therefore, only the sensitive and pillar type machines are explained here.)

The sensitive bench drilling machine (Fig 1)

Fig 1



The simplest type of the sensitive drilling machine is shown in the figure with its various parts marked. This is used for light duty work.

This machine is capable of drilling holes up to 12.5 mm diameter. The drills are fitted in the chuck or directly in the tapered hole of the machine spindle.

For normal drilling, the work-surface is kept horizontal. If the holes are to be drilled at an angle, the table can be tilted. (Tilting arrangement not shown in Fig 1.)

Different spindle speeds are achieved by changing the belt position in the stepped pulleys. (Fig 2)

The pillar drilling machine (Fig 3)**:** This is an enlarged version of the sensitive bench drilling machine. These drilling machines are mounted on the floor and driven by more powerful electric motors. They are also used for light duty work. Pillar drilling machines are available in different sizes.

The larger machines are provided with a rack and pinion mechanism to raise the table for setting the work.

Fig 2

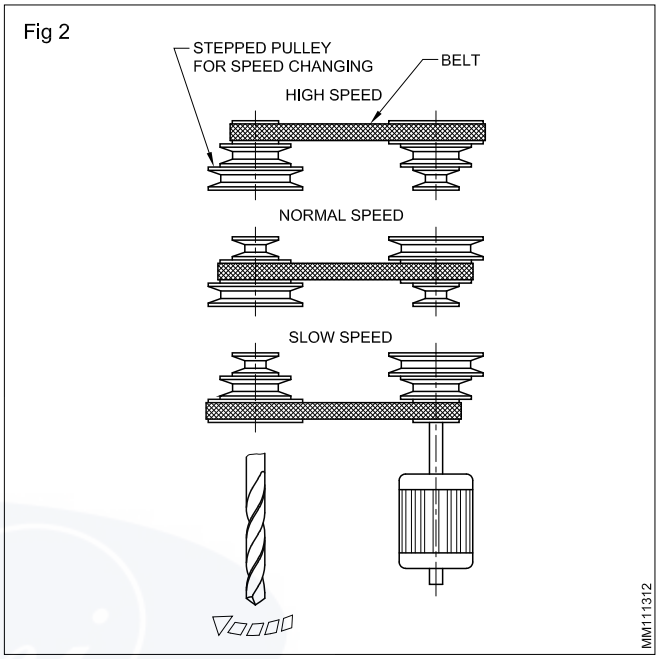
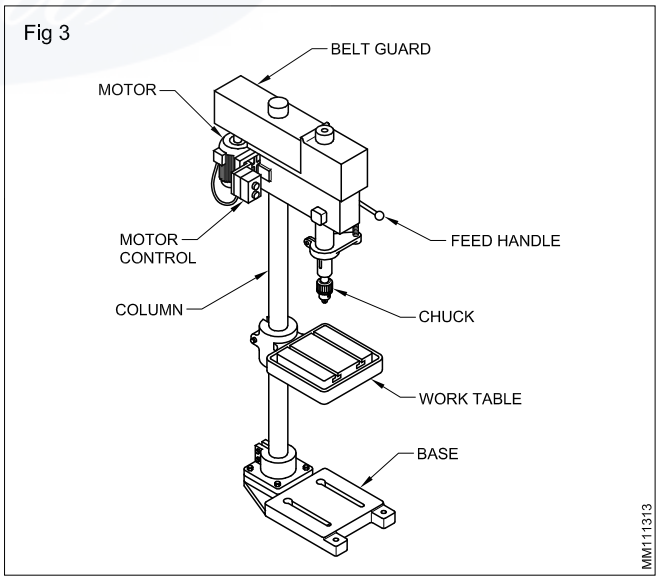


Fig 3



Drill-holding devices

Objectives: At the end of this lesson you shall be able to
- **name the different types of drill-holding devices**
- **state the features of drill chucks**
- **state the functions of drill sleeves**
- **state the function of drift.**

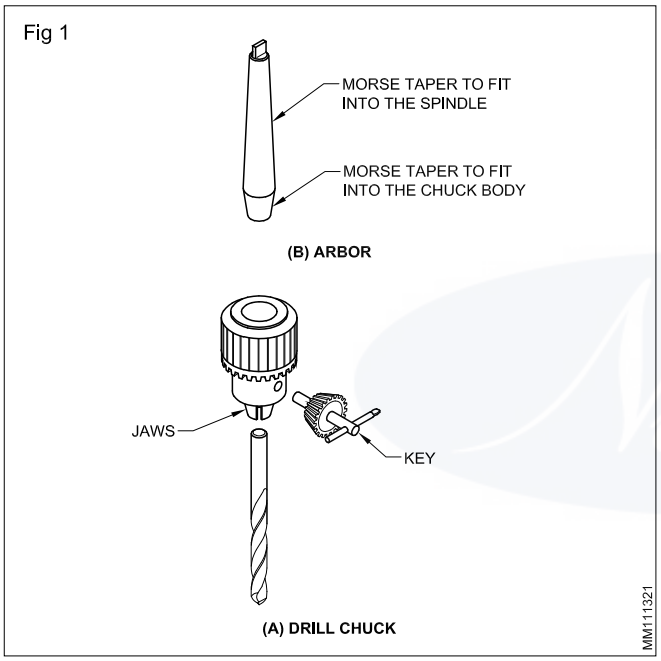
For drilling holes on materials, the drills are to be held accurately and rigidly on the machines.

The common drill-holding devices are drill chucks, sleeves and sockets.

Drill chucks: Straight shank drills are held in drill chucks. (Fig 1A) For fixing and removing drills, the chucks are provided either with a pinion and key or a knurled ring.

The drill chucks are held on the machine spindle by means of an arbor (Fig 1B) fitted on the drill chuck.

Fig 1



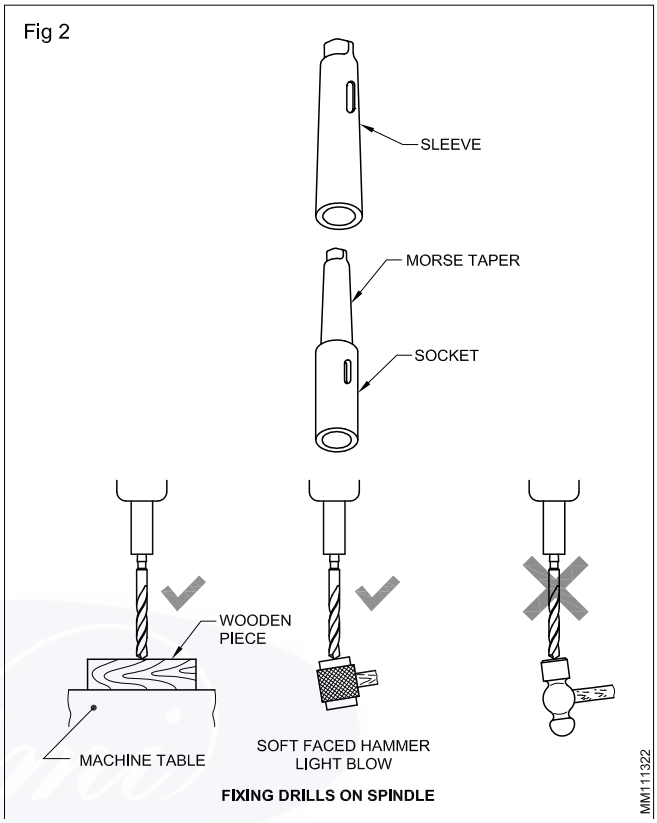
Taper sleeves and sockets (Fig 2): Taper shank drills have a Morse taper.

Sleeves and sockets are made with the same taper so that the taper shank of the drill, when engaged, will give a good wedging action. Due to this reason Morse tapers are called self-holding tapers.

The drills are provided with five different sizes of Morse tapers, and are numbered from MT 1 to MT 5.

In order to make up the difference in sizes between the shanks of the drills and the bore of machine spindles, sleeves of different sizes are used. When the drill taper shank is bigger than the machine spindle, taper sockets are used. (Fig 2)

Fig 2

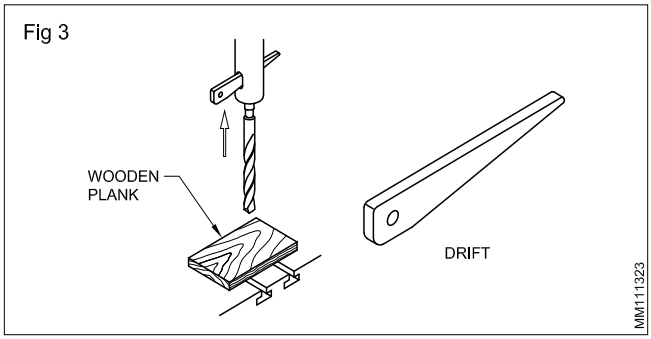


While fixing the drill in a socket or sleeve, the tang portion should align in the slot. This will facilitate the removal of the drill or sleeve from the machine spindle.

Use a drift to remove drills and sockets from the machine spindle. (Fig 3)

While removing the drill from the sockets/sleeves don't allow it to fall on the table or jobs.

Fig 3



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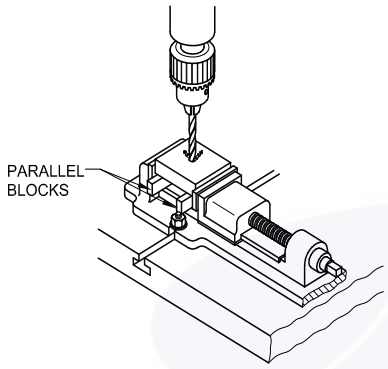
Work-holding devices

Objectives: At the end of this lesson you shall be able to
- **state the purpose of work-holding devices**
- **name the devices used for holding work**
- **state the precautions to be observed while using work-holding devices.**

Workpieces to be drilled should be properly held or clamped to prevent them from rotating along with the drill. Improperly secured work is not only a danger to the operator but can also cause inaccurate work, and breakage of the drill. Various devices are used to ensure proper holding.

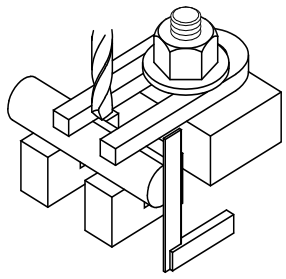
The machine vice: Most of the drilling work can be held in a machine vice. Ensure that the drill does not pass through the vice after it has passed through the work. For this purpose, the work can be lifted up and secured on parallel blocks providing a gap between the work and the bottom of the vice (Fig 1)

Fig 1



Clamps and bolts: Drilling machine tables are provided with T-slots for fitting bolt heads. Using clamps and bolts, the workpieces can be held very rigidly. (Fig 2)

Fig 2



While using this method, (Fig 2) the packing should be, as far as possible, of the same height as the work, and the bolt nearer to the work. (Fig 3)

There are many types of clamps, and it is necessary to determine the clamping method according to the work. (Figs 4 & 5)

Fig 3

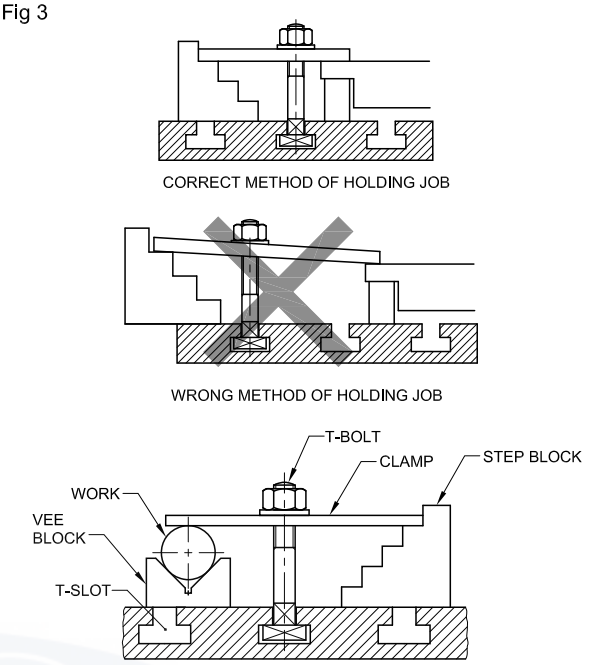


Fig 4

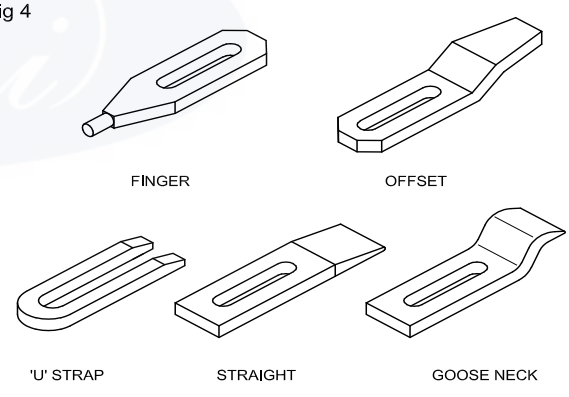
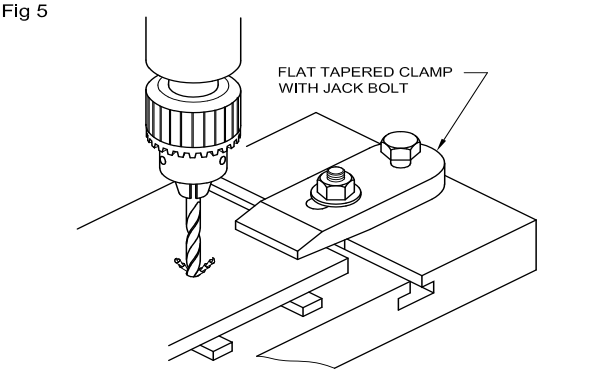


Fig 5



'Vee' threads

Objectives: At the end of this lesson you shall be able to
- **name the various types of 'Vee' threads used for thread fastening**
- **distinguish between the features of different 'Vee' thread forms**
- **designate the different types of 'Vee' threads.**

Types of 'Vee' threads: 'Vee' threads are available in different standards. The types of 'Vee' threads used for general engineering threaded fasteners are the:

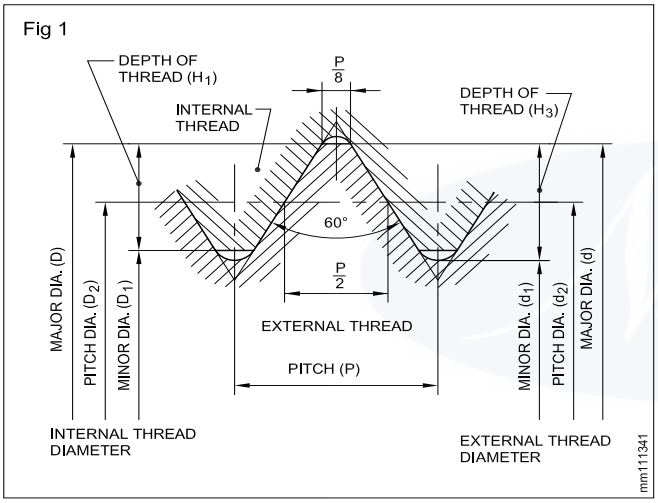
– ISO metric thread (International system organisation)
– ISO inch (unified thread)
– British Standard Whitworth thread (BSW)
– British Standard fine thread (BSF)
– British Association Thread (BA) (will be dealt-with later exercises)

ISO metric thread (Fig 1): This is the form of thread approved by B.I.S for threaded fastening. Two series of threads have been identified by them. They are:

ISO metric: coarse

ISO metric: fine

Fig 1



The thread angle is 60°. The root of the external thread is rounded. The crest of the external thread is flat, but sometimes it is rounded depending on the type of the manufacturing process. The root of the internal thread is cleared beyond the width equal to one eighth of the pitch, and is rounded. The crest of the internal threads is left flat.

Designation of ISO metric thread: ISO metric coarse thread is designated as M12 and fine thread as M12 x 1.25 etc. in the job drawing.

Example M12

The symbol M indicates that it is ISO metric thread and 12 indicates the diameter of the thread. For the coarse series the pitch of the threads is standardized for each diameter.

ISO Metric fine threads are designated as,

M12 x 1.25

The addition of 1.25 in this case indicates the pitch of the thread.

ISO inch (unified) **thread:** The ISO inch system (unified) is a recognized standard for interchangeability with the American National Thread.

These threads are used for general purpose engineering fastening, and are of two types.

– Unified National Coarse (UNC)

– Unified National Fine (UNF)

For unified threads the angle is 60°. The thread profile is similar to that of the ISO metric thread.

Designation of ISO inch (unified) **threads**

Examples

a) 1/4 20 UNC

b) 1/4 28 UNF

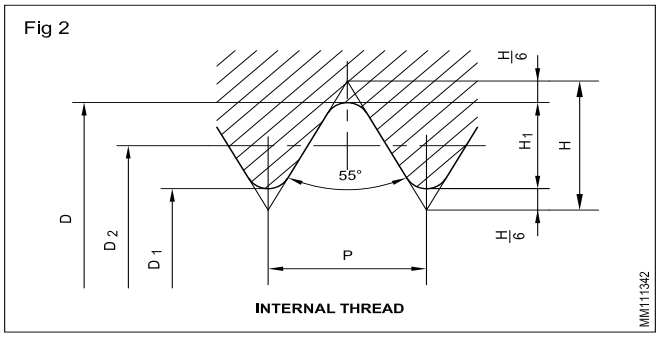
Example(a) indicates that the diameter of the thread is 1/4", it has 20 threads per inch (TPI) and the ISO thread series is UNC (unified coarse). Example (b) has 28 TPI and is of UNF series.

British Standard Whitworth (BSW) thread (Fig 2): This thread is gradually being replaced by ISO metric thread. However, the application of this thread is still being continued in a limited manner, particularly in the production of spare parts and repair works.

These threads have a 55° angle, and are rounded at the crest and the root. There are a definite number of threads per inch for a particular diameter.

These threads are designated by the diameter in inches followed by the abbreviation of the thread series.

Fig 2



Example - 1/2" BSW

British Standard fine (BSF) thread: This thread has the same form as BSW, but with fine pitches.

The threads are designated by the diameter in inches followed by the thread standard.

Example - 3/8" BSF.

Hand taps and wrenches

Objectives: At the end of this lesson you shall be able to
- **state the uses of hand taps**
- **state the features of hand taps**
- **distinguish between the different taps in a set**
- **name the different types of tap wrenches**
- **state the uses of the different types of wrenches.**

Use of hand taps: Hand taps are used for internal threading of components.

Features (Fig 1): They are made from high carbon steel or high speed steel, hardened and ground.

The threads are cut on the periphery and are accurately finished.

To form the cutting edges, flutes are cut across the thread.

The end of the shank of the tap is made of square shape for the purpose of holding and turning the taps.

The end of the taps are chamfered (taper lead) for assisting, aligning and starting of the thread.

The size of the taps, the thread standard, the pitch of the thread, the dia. of the tapping hole are usually marked on the shank.

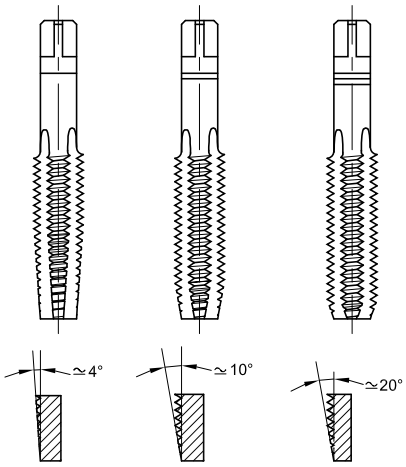
Marking on the shank are also made to indicate the type of tap i.e. first, second and plug.

Types of taps in a set: Hand taps for a particular thread are available as a set consisting of three pieces. (Fig 2)

These are:

– first tap or taper tap
– second tap or intermediate tap
– plug or bottoming tap

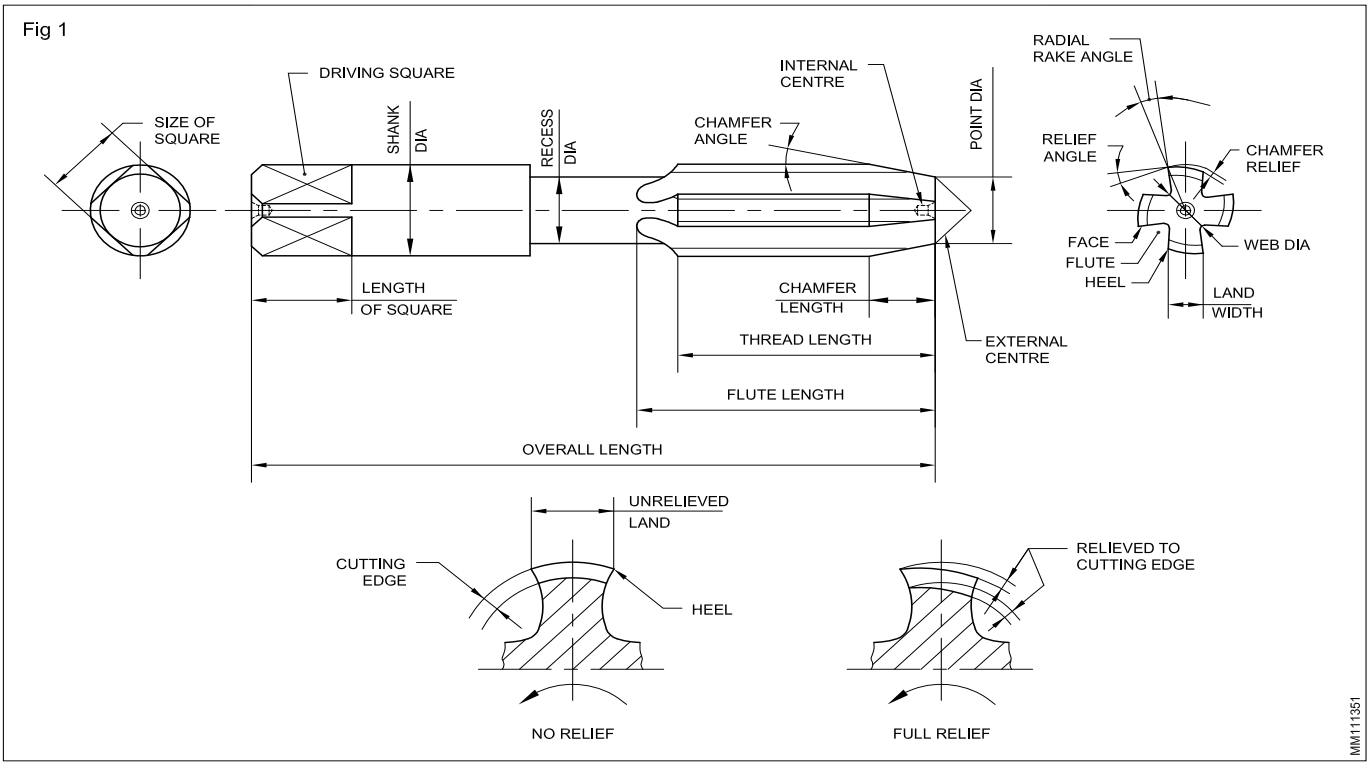
Fig 2



These taps are identical in all features except in the taper lead.

The taper tap is to start the thread. It is possible to form full threads by the taper tap in through holes which are not deep.

Fig 1



The bottoming tap (plug) is used to finish the threads of a blind hole to the correct depth.

For identifying the type of taps quickly - the taps are either numbered 1,2 and 3 or rings are marked on the shank.

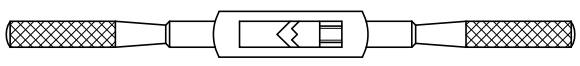
The taper tap has one ring, the intermediate tap has two and the bottoming tap has three rings. (Fig 2)

Tap wrenches: Tap wrenches are used to align and drive the hand taps correctly into the hole to be threaded.

Tap wrenches are of different types, such as double-ended adjustable wrench, T-handle tap wrench, solid type tap wrench etc.

Double-ended adjustable tap wrench or bar type tap wrench (Fig 3)**:** This is the most commonly used type of

Fig 3



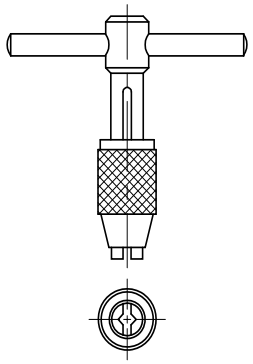
MM111353

tap wrench. It is available in various sizes - 175, 250, 350 mm long. These tap wrenches are more suitable for large diameter taps, and can be used in open places where there is no obstruction to turn the tap.

It is important to select the correct size of wrench.

T-handle tap wrench (Fig 4)**:** These are small, adjustable chucks with two jaws and a handle to turn the wrench.

Fig 4

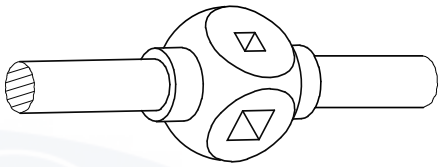


MM111354

This tap wrench is useful to work in restricted places, and is turned with one hand only. Most suitable for smaller sizes of taps.

Solid type tap wrench (Fig 5)**:** These wrenches are not adjustable.

Fig 5



MM111355

They can take only certain sizes of taps. This eliminates the use of wrong length of the tap wrenches, and thus prevents damage to the taps.

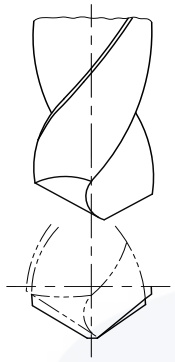
Drilling defects and causes

Objectives: At the end of this lesson you shall be able to
- **state the common drilling defects**
- **identify the causes of drilling defects**
- **suggest remedial steps for preventing drill failures.**

The common defects in drilling are listed below:

– Oversized holes
– Overheated drills
– Rough holes
– Unequal and interrupted flow of chips
– Split webs or broken drills.

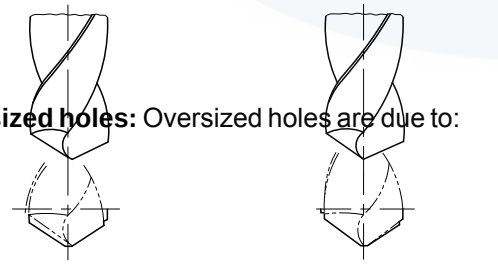
Fig 1



UNEQUAL LIP LENGTH

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Fig 2



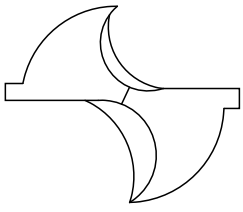
UNEQUAL ANGLE UNEQUALE ANGLE AND LENGTH

MM111912

Oversized holes: Oversized holes are due to:

– the unequal length of the cutting edges (Fig 1)
– the unequal angle of the cutting edges (Fig 2)
– the unequal thinning of the point (Fig 3)
– the spindle running out of centre
– the drill point not being in the centre. (Fig 4)

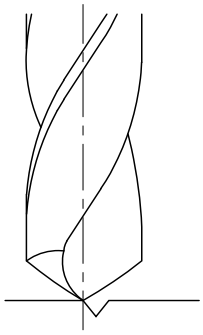
Fig 3



UNEQUAL POINT THINNING

MM111913

Fig 4



DRILL POINT NOT IN THE CENTRE OF THE JOB

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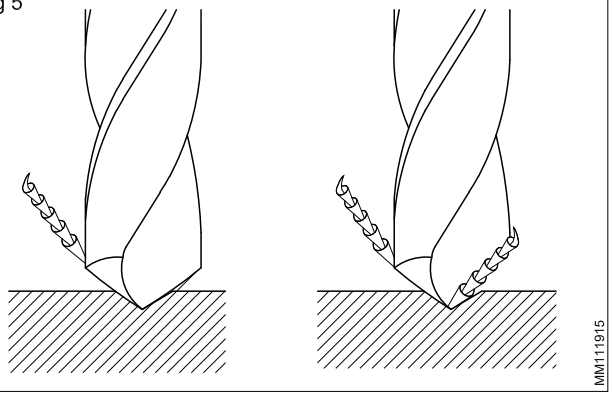
Overheated drills: The drills may get overheated if the:

– cutting speed is too high
– feed rate is too high
– clearance angle is incorrect
– cooling is ineffective
– point angle is incorrect
– drill is not sharp.

Rough holes: Rough holes are caused if the:

– feed rate is too much
– drill cutting edges are not sharp
– cooling is ineffective.

Fig 5



MM111915

Unequal flow of chips (Fig 5): Unequal flow of chips is caused if the cutting edges are not equal and the point angle is not in the centre of the drill.

Broken drill or split web: Broken drill or split web occurs when the:

– cutting speed is too high
– feed rate is too high
– work is not held rigidly
– drill is not held correctly
– drill is not sharp
– point angle is incorrect
– cooling is insufficient
– flutes are clogged with chips.

When we start drilling, after re-sharpening the drill bit the following faults or defects are noticed.

– It is difficult to start the hole on the centre
– Inefficient cutting during starting
– The drill cuts poorly or it grabs.

The causes for the above defects, and the suggested remedies are given in the following charts.

Fault : It is difficult to start the hole on a centre.

Indoication : Drill point tends to wander around centre punch impression.

Cause of fault	Remedy for fault	Results if the faults are ignored
Drill axis not aligned with centre punched mark.	Re-align the drill	Hole may be off centre
Surface irregularity around centre punch impression or inadequate centre punch impression.	File or scrap surface flat and level. Punch centre again.	Hole may be off centre
Point angle too great	Have drill point re-ground	Hole may be off centre. Drill will vibrate severely. Drilling machine may be damaged.
Web is too thick	Have web thinning by grinding.	Excessive pressure required to make the drill cut. May cause the drill to break.
Improper penetration	Check the direction of the spindle	Drill point is offset from the centre. Chisel edge centre wears off fast.

Fault : Inefficient cutting during starting

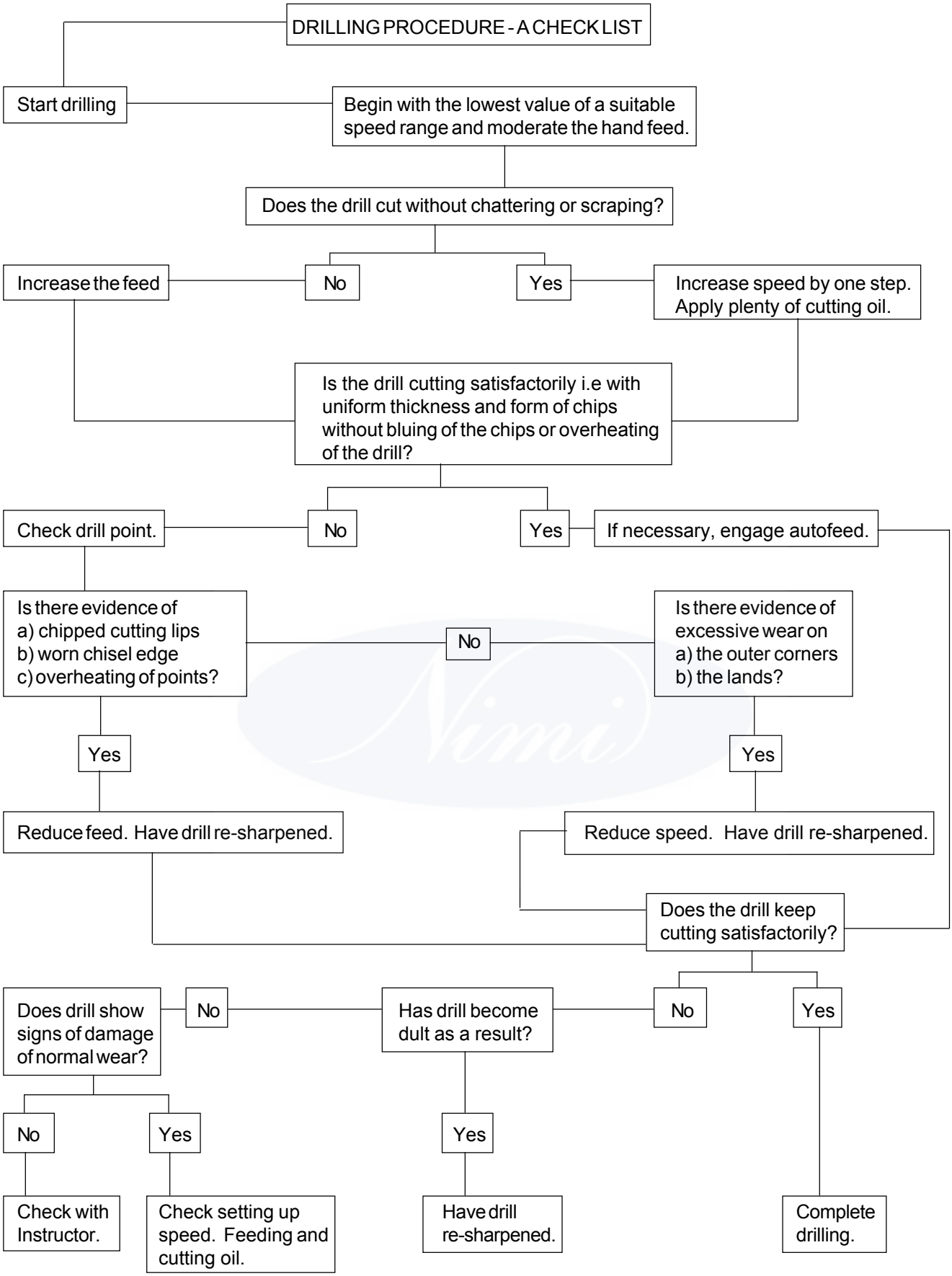
Indication : See table below. Each set of indications is listed in the order in which it should be noted.

Indication of faults	Causes of faults	Results of ignoring indication of faults
Flat at the bottom of the conical depression is large or has raised pip at centre or the drill point appears to wobble or the drilling chips come out unevenly or from one lip only.	Chisel edge not central with the axis of the drill, due to cutting lips having unequal length, and/or unequal angles with the axis	Drilling machine may vibrate severely. Work may become loose. Drill may break. Hole will be rough and/or stepped and of oval size.
Drilling chips come out from one lip only. Penetration is slow.	Cutting lips ground with unequal length and angles, but with chisel edge centre. Or in-sufficient lip clearance ground behind one lip.	The one lip doing all the cutting wears rapidly. Hole will be rough and or oversize.
The drill produces an unusual sound. Penetration is slow.	Insufficient clearance or web is too thick.	Drill will overheat. Drill may break if the feed is increased.

Fault : Drill cuts poorly or grabs

Indication : See table below

Indication of faults	Causes of faults	Remedies of faults
Penetration if slow. Drill emits unusual and or erratic sound.	Cutting edges dull or lands near point are worn out so that the un-worn lands rub.	Grind drill point back to un-worn land.
Drill grabs	Point angle is too sharp so that the drill point digs in.	Re-grind the drill point
Drill grabs or changes in the appearance of the swarf	Lip clearance too great so that lips chip and outer corners break off	Re-grind drill point
Change in appearance of the swarf or over-heating of the drill.	Excess speed that leads to excessive wear of the outer corners and the lands.	Reduce speed. Re-grind the drill.
Change in appearance of the swarf over-heating of the drill.	Excessive feed that leads to chipped cutting lips and a worn out chisel edge.	Reduce feed. Re-grind the drill.


DRILLING PROCEDURE - A CHECK LIST
Start drilling
Begin with the lowest value of a suitable speed range and moderate the hand feed.
Does the drill cut without chattering or scraping?
No
Yes
Increase the feed
Increase speed by one step. Apply plenty of cutting oil.
Is the drill cutting satisfactorily i.e with uniform thickness and form of chips without bluing of the chips or overheating of the drill?
No
Yes
Check drill point.
If necessary, engage autofeed.
Is there evidence of a) chipped cutting lips b) worn chisel edge c) overheating of points?
No
Is there evidence of excessive wear on a) the outer corners b) the lands?
Yes
Yes
Reduce feed. Have drill re-sharpened.
Reduce speed. Have drill re-sharpened.
Does the drill keep cutting satisfactorily?
Does drill show signs of damage of normal wear?
No
Has drill become dult as a result?
No
Yes
No
Yes
Yes
Check with Instructor.
Check setting up speed. Feeding and cutting oil.
Have drill re-sharpened.
Complete drilling.

— — — — — — — — —

Identification of metals

Objectives: At the end of this lesson you shall be able to
- **state the different methods of identifying ferrous metals and alloys**
- **state how non-ferrous metals and alloys are identified.**

A fitter has to handle different types of metals in his work. A knowledge about how to recognise and differentiate the commonly used metals will help him in many ways.

Ferrous metals and alloys can be identified by

their appearance (colour, texture etc)
their weight (light or heavy)
the sound
cold hammering
the spark test (grinding).

The above characteristics of different ferrous metals and alloys are given in Table 1. Apart from the above tests, steel bars are also identified by the code colours painted on them.

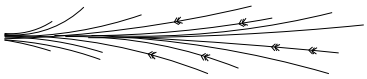
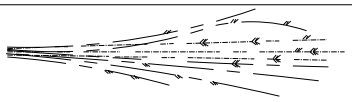
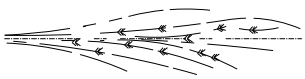
Different colours are marked, based on the different composition of materials and grade. Colour charts are available to determine the different metals.

Most non-ferrous metals and alloys can be identified by their colour. (Table 2)

TABLE 2

Metal/Alloy	Colour
Copper	Distinctive red colour
Aluminium	Dull white
Lead	Bluish-grey colour
Tin	Silvery white, with a slightly yellowish tinge
Brass (Alloy) (free cutting)	Distinctive yellow colour
Bronze (alloy)	Colour between copper and brass

TABLE 1

Ferrous Metals & alloys	Appearance	Density/ weight	Sound (Drop a ø 15 bar 25 cm long, on to the ground)	Cold hammering	Spark test	
Low carbon steel	Smooth scale with blue/ black sheen/ silver grey	7.85 medium weight	Medium metallic sound	Flattens easily	Stream of yellow white sparks varying in length slightly `fiery`.	
Medium carbon steel	Smooth scale black sheen	7.85 medium weight	Higher note than than of low carbon steel	Fairly difficult to flatten	Yellow sparks shorter than those of low carbon steel, finer and more feathery.	
High carbon steel	Rougher scale black	7.85 medium weight	Good ringing sound	Difficult to flatten	Sparkless bright, starting near grinding wheel and more feathery with secondary branching.	
High speed steel	Roughness scale black with reddish tint	9 compara tively heavy	Lower ringing more like low carbon steel	Very difficult to flatten Tends to crack easily.	Faint red streak ending in fork.	

The british system of measurement

Objectives: At the end of this lesson you shall be able to
- **name the different units and multiples of linear measurements in the British System**
- **state the metric equivalent of the unit in the inch system.**

The metric system for measurement is most widely used for industrial measurements. But in certain industries, the British system of measurement is still being used.

In this system of measurement, the inch, its multiples and sub-divisions are used to represent length measurements.

36 inches or 3 feet make 1 yard. 5280 feet or 1760 yards make 1 mile.

Conversions from inch to metric and vice versa

CONVERSION FACTORS		
1"	=	25.4 mm or 2.54 cm
1 yard	=	36" or 0.9144 m
1 mm	=	0.03937"
1 metre	=	1000 mm or 39.37"

FRACTIONS/DECIMALS EQUIVALENT

1/64"	=	0.015625"
1/32"	=	0.03125"
1/16"	=	0.0625"
1/8"	=	0.125"
1/4"	=	0.25"
1/2"	=	0.5"

1.00 unit inch
0.1 one tenth
0.01 one hundredth
0.001 one thousandth
0.0001 one ten thousandth
0.00001 one hundred thousandth
0.000001 one millionth (one micro inch)

Example of conversion (Metric to Inch)

1) .05 mm = .00196 inch (.05 x 03937 = 0.0019685 inch)
2) 1.25 m = 49.2125 inch (1.25x 39.37 = 49.2125 inches)

Example of conversion (Inch to Metric)

1) 3/4" = .75" = 19.05 mm (.75 x 25.4 = 19.05 mm)
2) 1/1000" = 0.001 = .0254 mm (.001 x 25.4 = 0.0254 mm)

(One thousandth of an inch = 25 micrometre approx)

ASSIGNMENT

Convert the following.

1) 38.1 mm = _____ inches
2) 300 mm = _____ inches
3) 8" = _____ mm
4) 40" = _____ mm.

5) Express the tolerance ±.05" in metric terms to the nearest mm. _____

6) Express the tolerance ± .02 mm in terms of inches to the nearest 1/10,000". _____

— — — — — — — — —

Reading vernier caliper & micromieter with inch gadutions

Objectives: At the end of this lesson you shall be able to
- **state the graduation of vernier calipers in the inch system**
- **state the graduation of micrometers in the inch system**
- **read the measurement of vernier calipers and micrometers with inch graduations.**

Reading vernier caliper and micrometer

The universal vernier calipers generally used in machine shop will have graduations in both metric units and inches.

The vernier caliper with inch graduation will have a least count of 0.001".

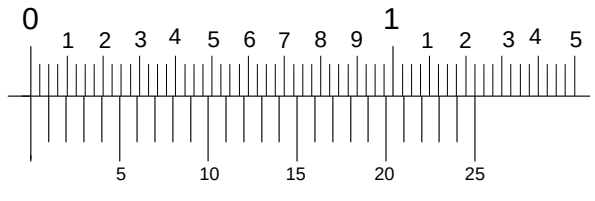
The vernier scales for these calipers have graduation with 25 divisions or 50 divisions.

Vernier caliper with 25 divisions in vernier scale.

(Fig 1)

One inch of the mainscale is divided into 10 major

Fig 1



divisions, and each of these is further divided into 4 equal parts. The value of each sub-division is 0.025 inch. Such 49 divisions of the main scale are equal to 25 divisions of the vernier scale.

Least count

25 vernier scale divisions = 49 x 0.025 = 1.225"

Value of vernier scale division = ⊠ = 0.49"

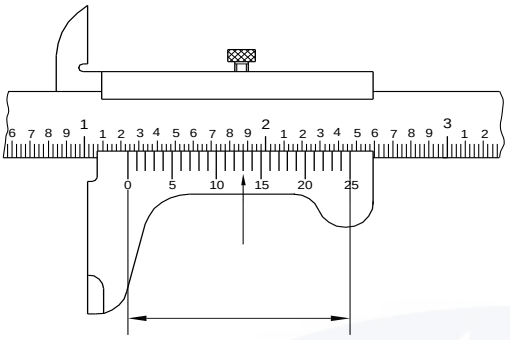
Value of 2 main scale divisions = 0.025 x 2 = 0.50"

Least count = Value of main scale division – value of 1 vernier scale division

= 0.05" – 0.49" = 0.001" or ⊠

Example of Reading (Fig 2)

Fig 2

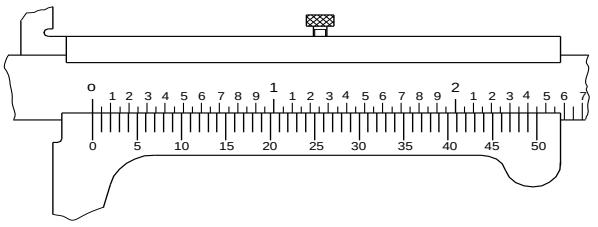


In Figure 2 the vernier '0' line is after 1" on the main scale

Full inch		= 1.000"
2 main scale divisions		= .200"
Value of 1 subdivision		= .025"
Value of the13th Vernier division coinciding	(13 x 001")	= .013"
	Reading	1.238"

In the vernier caliper given in fig 3 (50 divisions vernier scale), each inch of the main scale is divided into 10 major divisions, and they are further subdivided into two equal parts. The value of each subdivision is 0.05". 50 divisions of the vernier scale are equal to 49 sub divisions of the main scale.

Fig 3



Least count

Value of 50 V.S.D. = 49 X 0.05 = 2.45"

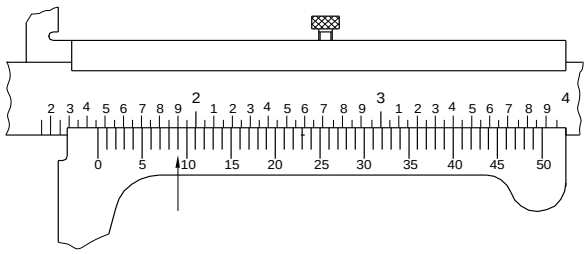
1 V.S.D. = 2.45"/50 = 0.049"

Lease count = Value of MSD – Value of 1 VSD

= 0.05" – 0.049 = 0.001"

Example of reading (Fig 4)

Fig 4



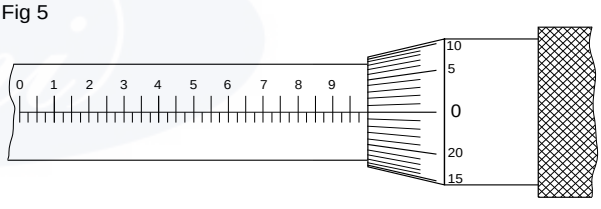
Vernier '0' line is after 1" on the main scale

Full inch		= 1.000"
The value of 4 major divisions	(4 x 0.1")	= .400"
The value of 1 subdivision	(1 x 0.05")	= .050"
The value of 9th vernier division coinciding	(9 x .001")	= .009"
	Reading	1.459"

Micrometer with graduations in inches

On micrometers with graduations in the inch system, the datum line on the barrel of the micrometer is graduated to a distance of 1 inch. This one inch is divided into 10 equal parts, and each of this is further subdivided into 4 equal parts. (Fig 5)

Fig 5

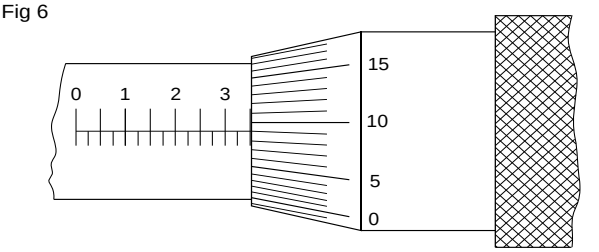


The value of each subdivision = 1/40" or 0.025". The thimble has 25 equal divisions marked on the circumference. The least count is = 1/40"x1/25 = 1/1000" = .001".

When the spindle of the micrometer advances by one division on the thimble, the actual value of the linear movement is = .001".

Example of reading (Fig 6)

Fig 6



Main divisions	3 x .1	= .300"
Subdivisions	2 x .025	= .05"
Thimble divisions	9x.001	= .009"
Reading		.359"

The barrel is graduated into 10 equal divisions each of which is further subdivided into 4 smaller divisions. The length of the sleeve graduations is 1". It is the distance the thimble travels in 40 complete revolutions.

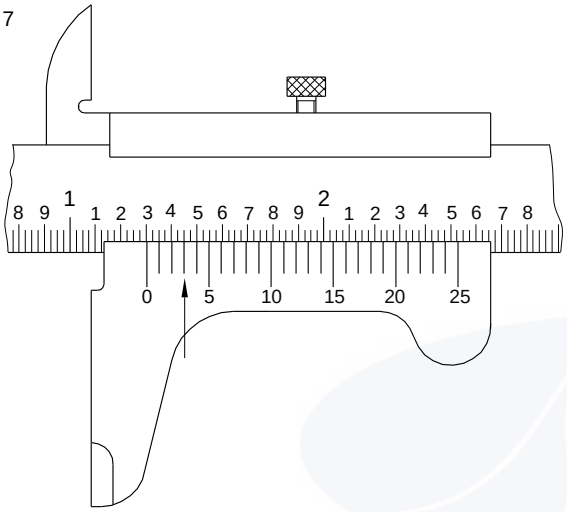
Barrel main divisions = 1/10 of an inch or 0.100" the distance the thimble moves in four complete revolutions. The thimble has 25 equal graduations on its circumference. Each graduation of the thimble is equal to 1/25 of 1/40 or 0.001".

Barrel subdivision 1/40 or 0.025 of an inch is equal to the distance the thimble moves in one complete revolution. The spindle screw has 40 TPI.

Assignment

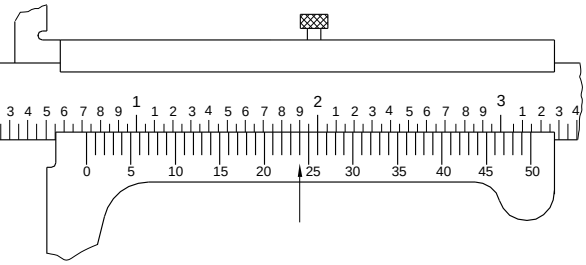
1 Read the vernier caliper measurement as shown in Figures 7 and 8.

Fig 7



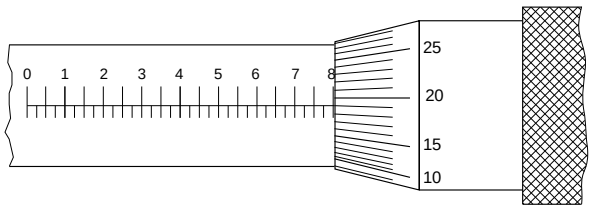
Answer .....inch.

Fig 8



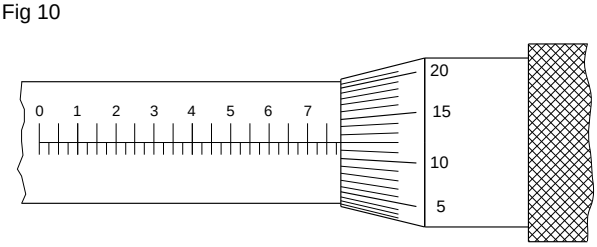
Answer .....inch.

Fig 9



2 Read and record the measurements of an outside micrometer shown in the Figures 9 and 10.

Fig 10



Answer .....inch.
Answer .....inch.

— — — — — — — — —

Relief grooves

Objectives: At the end of this lesson you shall be able to
- **state the importance of relief grooves**
- **distinguish the types of relief grooves.**

Relief grooves are provided in assemblies having sharp corners.

By providing relief grooves, the contact between the surfaces of the components could be ensured without any obstruction. The relief grooves are either external or internal.

The relief made may be a drilled hole, a hacksaw cut, an undercut on cylindrical parts or corners chamfered, counter-sink etc. (Figs 1,2 and 3)

Fig 1

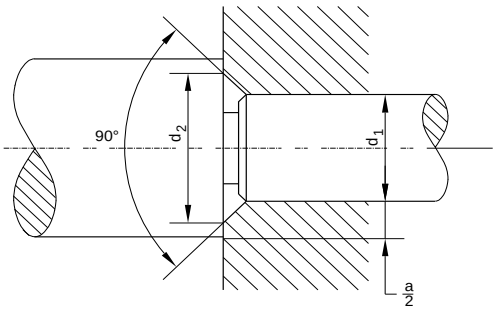


Fig 2

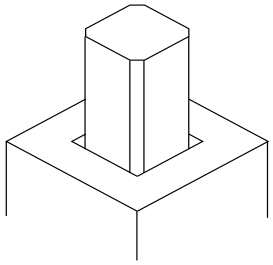
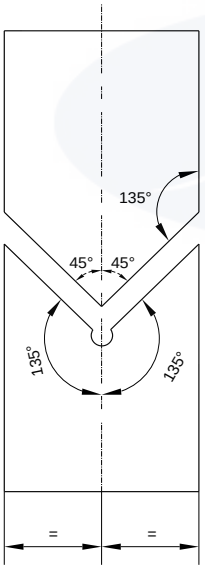


Fig 3



As per B.I.S. the relief grooves are designated as

Relief Groove Type E (internal) (Fig 4)
Relief Groove Type F (external) (Fig 5).

Fig 4

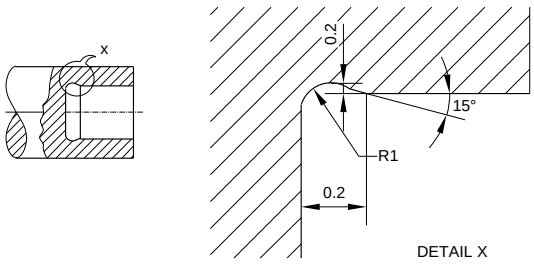
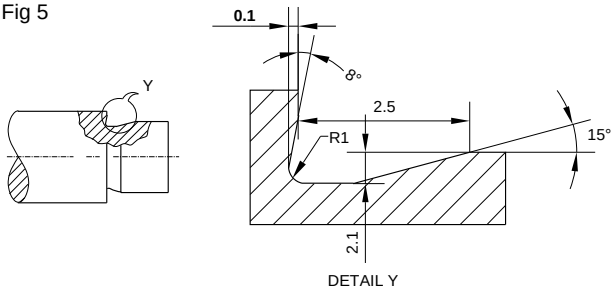


Fig 5



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Letter and number drills

Objectives: At the end of this lesson you shall be able to
- **state the range of drill sizes in number and letter drill series**
- **determine the number and letter drills for given diameters referring to the chart.**

Generally drills are manufactured to standard sizes in the metric system. These drills, are available in specified steps. The drills, which are not covered under the above category, are manufactured in number and letter drills. These drills are used where odd sizes of holes are to be drilled.

Letter drills

The letter drill series consists of drill sizes from `A' to `Z'. The letter `A' drill is the smallest with 5.944mm diameter, and the letter `Z' is the largest, with a 10.490 mm diameter. (Table 1)

In the number drill and the letter drill series, the correct diameter of the drill is gauged with the help of the respective drill gauges. A drill gauge is a rectangular or square shaped metal piece containing a number of different diameter holes. The size of the hole is stamped against each hole. (Fig 1)

Fig 1

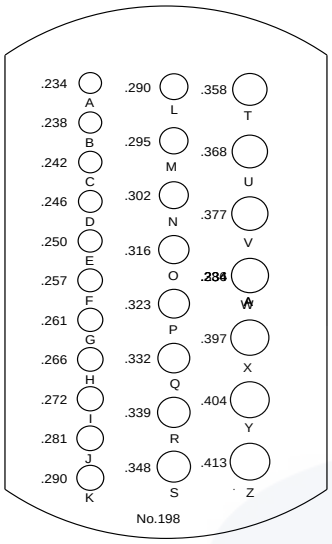


TABLE 1

Letter drill sizes

Letter	Diameter Inches	mm
A	.234	5.944
B	.238	6.045
C	.242	6.147
D	.246	6.248
E	.250	6.35
F	.257	6.528
G	.261	6.629
H	.266	6.756
I	.272	6.909
J	.277	7.036
K	.281	7.137
L	.290	7.366
M	.295	7.493
N	.302	7.671
O	.316	8.026
P	.323	8.204
Q	.332	8.433

Letter drill sizes (contd.)

R	.339	8.611
S	.348	8.839
T	.358	9.093
U	.368	9.347
V	.377	9.576
W	.386	9.804
X	.397	10.084
Y	.404	10.262
Z	.413	10.490

Number drills

The number drill series consists of drills numbered from 1 to 80. The No.1 drill is the largest, with 5.791 mm diameter, and the No.80 drill is the smallest, with 0.35 mm diameter. (Table 2). There is no uniform variation in the drill diameters from number to number. To find the correct diameter of a number drill, refer to a drill Size Chart or a Hand- book. Number drill series are also known as 'wire gauge' series.

TABLE 2

Number drill sizes

No	Diameter Inches	mm
1	.228	5.791
2.	.221	5.613
3	.213	5.410
4	.209	5.309
5	.2055	5.220
6	.204	5.182
7	.201	5.105
8	.199	5.055
9	.196	4.978
10	.1935	4.915
11	.191	4.851
12	.189	4.801
13	.185	4.699
14	.182	4.623
15	.180	4.572
16	.177	4.496
17	.173	4.394
18	.1695	4.305
19	.166	4.216
20	.161	4.089
21	.159	4.039
22	.157	3.988
23	.154	3.912

Number drill sizes (contd.)

No	Diameter Inches	mm
24	.152	3.861
25	.1495	3.797
26	.147	3.734
27	.144	3.658
28	.1405	3.569
29	.136	3.454
30	.1285	3.264
31	.120	3.048
32	.116	2.946
33	.113	2.870
34	.111	2.819
35	.110	2.794
36	.1065	2.705
37	.104	2.642
38	.1015	2.578
39	.0995	2.527
40	.098	2.489
41	.096	2.438
42	.0935	2.375
43	.089	2.261
44	.086	2.184
45	.082	2.083
46	.081	2.057
47	.0785	1.994
48	.076	1.930
49	.073	1.854
50	.070	1.778
51	.067	1.702
52	.0635	1.613
53	.0595	1.511
54	.055	1.395
55	.052	1.321
56	.0465	1.181
57	.043	1.092
58	.042	1.067
59	0.41	1.041
60	.040	1.016
61	0.0390	1.00
62	0.0380	0.98
63	0.0370	0.95
64	0.0360	0.92
65	0.0350	0.90
66	0.033	0.85
67	0.032	0.82
68	0.031	0.79
69	0.0292	0.75
70	0.0280	0.70
71	0.0260	0.65
72	0.0240	0.65
73	0.0240	0.60
74	0.0225	0.58
75	0.0210	0.52
76	0.0200	0.50
77	0.0180	0.45
78	0.0160	0.40
79	0.0145	0.38
80	0.0135	0.35

Number drill sizes (contd.)

Feeler gauge & uses

Objectives: At the end of this lesson you shall be able to
- **state the constructional features of a feeler gauge**
- **state the method of indicating different ranges of feeler gauges**
- **state the method of setting a feeler gauge**
- **state the different uses of feeler gauges.**

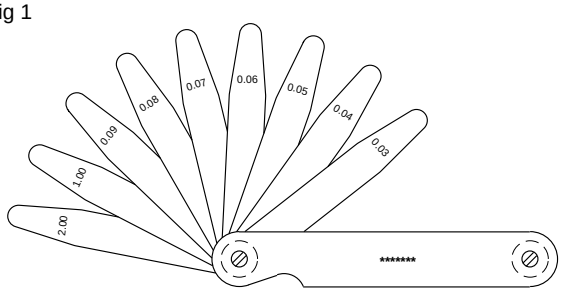
Features

A feeler gauge consists of a number of hardened and tempered steel blades of various thicknesses mounted in a steel case. (Fig 1)

The thickness of individual leaves is marked on it.(Fig 1)

The sizes of the feeler gauges in a set are carefully chosen in order that a maximum number of dimensions can be formed by building up from a minimum number of leaves.

Fig 1



The dimension being tested is judged to be equal to the thickness of the leaves used, when a slight pull is felt while withdrawing them. Accuracy in using these gauges requires a good sense of feel.

B.I.S. Set

The Indian Standard establishes four sets of feeler gauges Nos.1,2,3 and 4 which differ by the number of blades in each and by the range of thickness (minimum is 0.03 mm to 1 mm in steps of 0.01mm). The length of the blade is usually 100 mm.

Example

Set No.4 of Indian Standard consist of 13 blades of different thicknesses.

0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10, 0.15, 0.20, 0.30, 0.40, 0.50.

USES

Feeler gauges are used

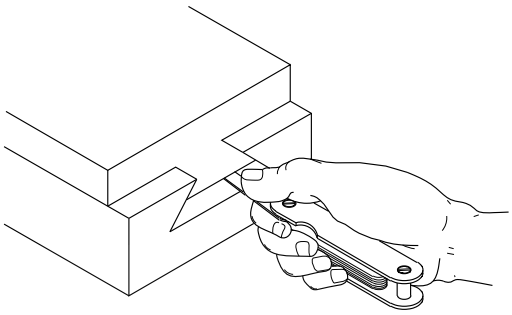
to check the gap between the mating parts

to check and set the spark plug gaps and tappet clearance in an engine etc.

to set the clearance between the fixture (setting block) and the cutter/tool for machining the jobs

to check and measure the bearing clearance, and for many other purposes where a specified clearance must be maintained. (Fig 2)

Fig 2



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Mass production & interchangeable manufacture

Objectives: At the end of this lesson you shall be able to
- **state the advantages and disadvantages of mass production**
- **outline the meaning of the term,'interchangeability'**
- **state the necessity for the limit system**
- **name the different standards of system of limits and fits.**

Mass production

Mass production means production of a unit, component or part in large numbers.

Advantages of mass production

Time for the manufacture of components is reduced.

The cost of a piece is reduced.

Spare parts can be quickly made available.

Disadvantages of mass production

Special purpose machines are necessary.

Jigs and fixtures are needed.

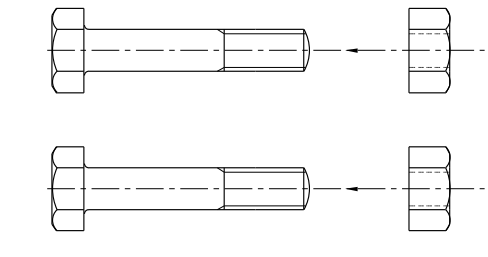
Gauges are to be used instead of conventional precision instruments.

Initial expenditure will be very high.

Selective assembly

The figures illustrate the difference between a selective assembly and a non-selective assembly. It will be seen in (Fig 1) that each nut fits only one bolt. Such an assembly is slow and costly, and maintenance is difficult because spares must be individually manufactured.

Fig 1

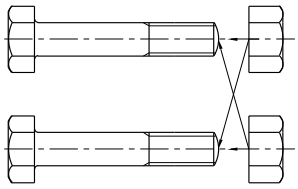


SELECTIVE ASSEMBLY

Non-selective assembly

Any nut fits any bolt of the same size and thread type. Such an assembly is rapid, and costs are reduced. Maintenance is simpler because spares are easily available. (Fig 2)

Fig 2



NON-SELECTIVE ASSEMBLY
INTERCHANGEAB ILITY

Non-selective assembly provides interchangeability between the components.

In modern engineering production, i.e. mass production, there is no room for selective assembly. However, under some special circumstances, selective assembly is still justified.

Interchangeability

When components are mass-produced, unless they are interchangeable, the purpose of mass production is not fulfilled. By interchangeability, we mean that identical components, manufactured by different personnel under different environments, can be assembled and replaced without any further rectification during the assembly stage, without affecting the functioning of the component when assembled.

Necessity of the limit system

If components are to be interchangeable, they need to be manufactured to the same size which is not possible, when they are mass-produced. Hence, it becomes necessary to permit the operator to deviate by a small margin from the exact size which he is not able to maintain for all the components. At the same time, the deviated size should not affect the quality of the assembly. This sort of dimensioning is known as limit dimensioning.

A system of limits is to be followed as a standard for the limit dimensioning of components.

Various standard systems of limits and fits are followed by different countries based on the ISO (International Standards Organisation) specifications.

The system of limits and fits followed in our country is that stipulated by the BIS. (Bureau of Indian Standards)

Other systems of limits and fits

International Standards Organisation (ISO)

British Standard System (BSS)

German Standard (DIN)

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The indian standard system of limits & fits - terminology

Objectives: At the end of this lesson you shall be able to
- **state the terms under the BIS system of limits and fits**
- **define each term under the BIS system of limits and fits**.

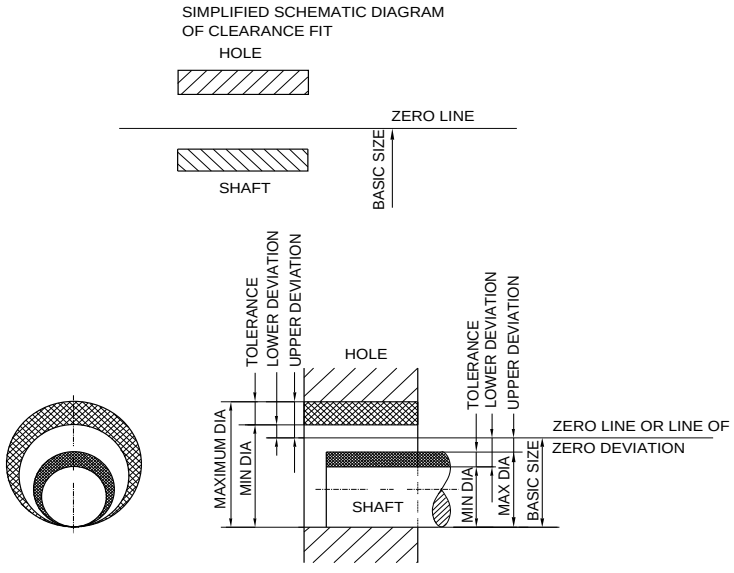
Size

It is a number expressed in a particular unit in the measurement of length.

Basic size

It is the size based on which the dimensional deviations are given. (Fig 1)

Fig 1



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Actual size

It is the size of the component by actual measurement after it is manufactured. It should lie between the two limits of size if the component is to be accepted.

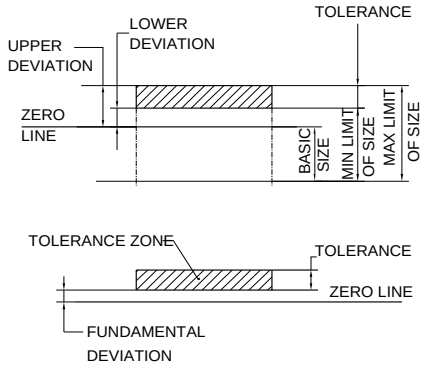
Limits of size

These are the extreme permissible sizes within which the operator is expected to make the component. (Fig 2) (Maximum and minimum limits)

Maximum limit of size

It is the greater of the two limit sizes.(Fig 2) (Table 1)

Fig 2



Minimum limit of size

It is the smaller of the two limits of size. (Fig 2) (Table 1)

Hole

In the BIS system of limits & fits, all internal features of a component including those which are not cylindrical are designated as ` hole'. (Fig 3)

Shaft

In the BIS system of limits & fits, all external features of a component including those which are not cylindrical are designated as shaft. (Fig 3)

Fig 3

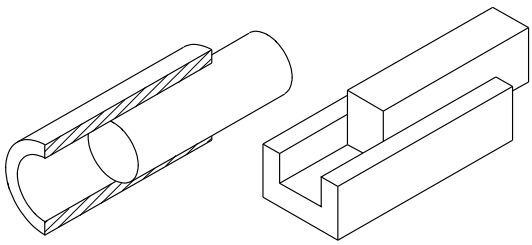


TABLE 1 (Examples)

SL. NO.	SIZE OF COMPONENT	UPPER DEVIATION	LOWER DEVIATION	MAX-LIMIT OF SIZE	MIN-LIMIT OF SIZE
1	+ .008 20 - .005	+ 0.008	- 0.005	20.008	19.995
2	+ .028 20 + .007	+ 0.028	+ 0.007	20.028	20.007
3	- .012 20 - .021	- 0.012	- 0.021	19.988	19.979

Deviation

It is the algebraic difference between a size, to its corresponding basic size. It may be positive, negative or zero. (Fig 2)

Upper deviation

It is the algebraic difference between the maximum limit of size and its corresponding basic size. (Fig 2) (Table 1)

Lower deviation

It is the algebraic difference between the minimum limit of size and its corresponding basic size.(Fig 2) (Table 1)

Upper deviation is the deviation which gives the maximum limit of size. Lower deviation is the deviation which gives the minimum limit of size.

Actual deviation

It is the algebraic difference between the actual size and its corresponding basic size. (Fig 2)

Tolerance

It is the difference between the maximum limit of size and the minimum limit of size. It is always positive and is expressed only as a number without a sign. (Fig 2)

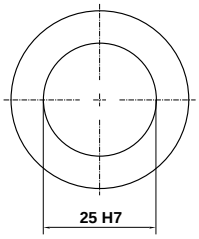
Zero line

In graphical representation of the above terms, the zero line represents the basic size. This line is also called as the line of zero deviation. (Figs 1 and 2)

Fundamental deviation

There are 25 fundamental deviations in the BIS system represented by letter symbols (capital letters for holes and small letters for shafts), i.e for holes - ABCD....Z excluding I,L,O,Q & W. (Fig 4)

Fig 4

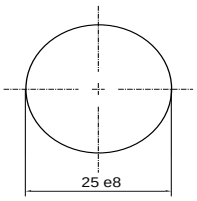


INDICATION FOR HOLES — CAPITAL LETTERS REFER TO HOLES OR INSIDE DIMENSIONS e.g 25 H7

In addition to the above, four sets of letters JS, ZA, ZB & ZC are included. For fine mechanisms CD, EF and FG are added. (Ref.IS:919 Part II - 1979)

For shafts, the same 25 letter symbols but in small letters are used. (Fig 5)

Fig 5

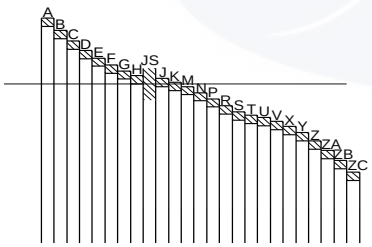


INDICATION FOR SHAFTS

SMALL LETTERS REFER TO SHAFTS OR OUTSIDE DIMENSIONS e.g. 25 e8

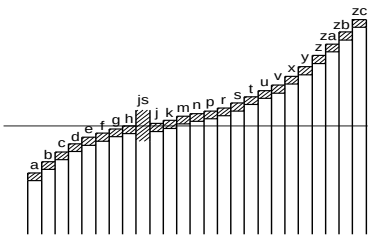
The position of tolerance zone with respect to the zero line is shown in figs 6 and 7.

Fig 6



CAPITAL LETTERS INDICATE FUNDAMENTAL DEVIATION OF HOLES

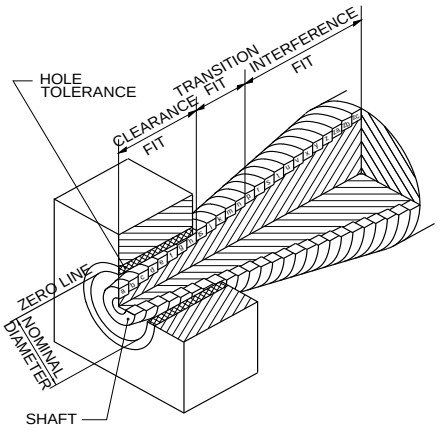
Fig 7



SMALL LETTER INDICATE FUNDAMENTAL DEVIATION OF SHAFTS

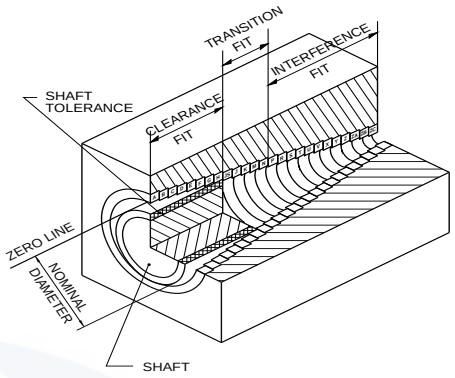
The fundamental deviations are for achieving the different classes of fits. (Figs 8 and 9)

Fig 8



HOLE BASIS SYSTEM

Fig 9



SHAFT BASIS SYSTEM

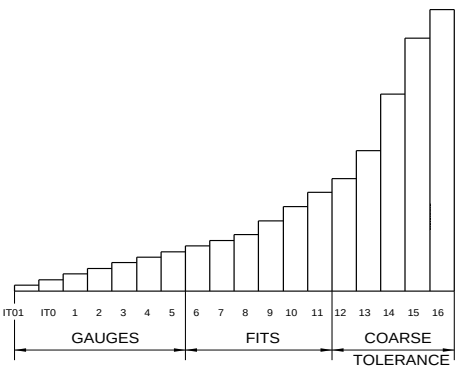
Fundamental tolerance

This is also called as 'grade of tolerance'. In the Indian Standard System, there are 18 grades of tolerances represented by number symbols, both for hole and shaft, denoted as IT01, IT0, IT1....to IT16. (Fig 10) A high number gives a large tolerance zone.

The grade of tolerance refers to the accuracy of manufacture.

In a standard chart, the upper and lower deviations for each combination of fundamental deviation and fundamental tolerance are indicated for sizes ranging up to 500 mm. (Refer to IS 919)

Fig 10



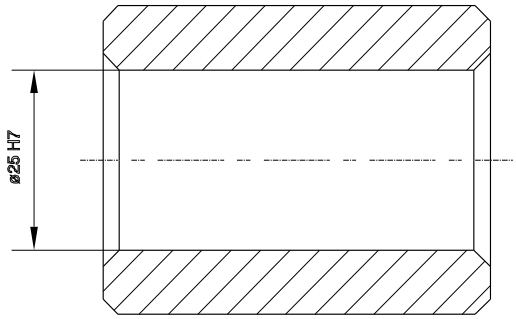
Toleranced size

This includes the basic size, the fundamental deviation and the grade of tolerance.

Example

25 H7 - toleranced size of a hole whose basic size is 25. The fundamental deviation is represented by the letter symbol H and the grade of tolerance is represented by the number symbol 7. (Fig 11)

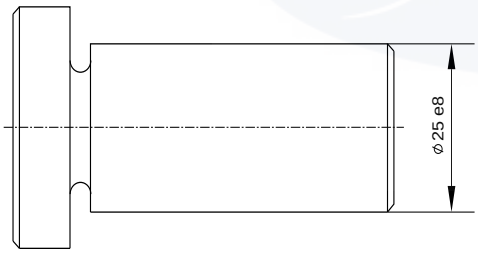
Fig 11



25 e8 - is the toleranced size of a shaft whose basic size is 25. The fundamental deviation is represented by the letter symbol e and the grade of tolerance is represented by the number 8. (Fig 12)

A very wide range of selection can be made by the combination of the 25 fundamental deviations and 18 grades of tolerances.

Fig 12



Example

In figure 13, a hole is shown as 25 ± 0.2 which means that 25 mm is the basic dimension and ± 0.2 is the deviation.

As pointed out earlier, the permissible variation from the basic dimension is called 'DEVIATION'.

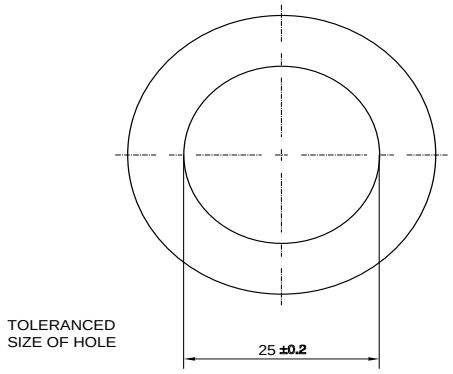
The deviation is mostly given on the drawing with the dimensions.

In the example 25 ± 0.2, ± 0.2 is the deviation of the hole of 25 mm diameter. (Fig 13) This means that the hole is of acceptable size if its dimension is between

25 + 0.2 = 25.2 mm

or 25 - 0.2 = 24.8 mm.

Fig 13



25.2 mm is known as the maximum limit. (Fig 14)
24.8 mm is known as the minimum limit. (Fig 15)

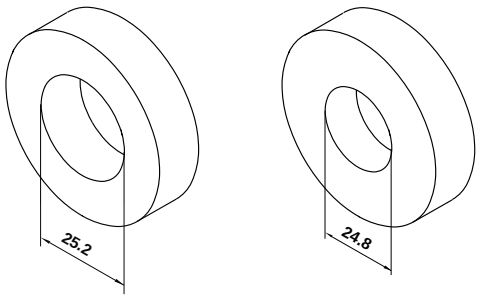
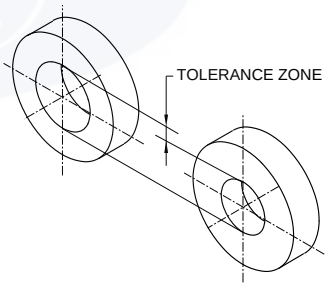


Fig 14 **Fig 15**

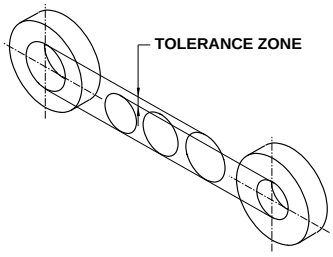
The difference between the maximum and minimum limits is the TOLERANCE. Tolerance here is 0.4 mm. (Fig 16)

Fig 16



All dimensions of the hole within the tolerance zone are of acceptable size as in Fig 17.

Fig 17



As per IS 696, while dimensioning the components as a drawing convention, the deviations are expressed as tolerances.

Fits and their classification as per tHe indian standard

Objectives: At the end of this lesson you shall be able to
- **define 'Fit' as per the Indian Standard**
- **list out the terms used in limits and fits as per the Indian Standard**
- **state examples for each class of fit**
- **interpret the graphical representation of different classes of fits.**

Fit

It is the relationship that exists between two mating parts, a hole and a shaft, with respect to their dimensional differences before assembly.

Expression of a fit

A fit is expressed by writing the basic size of the fit first, (the basic size which is common to both the hole and the shaft,) followed by the symbol for the hole, and by the symbol for the shaft.

Example

30 H7/g6 or 30 H7 - g6 or 30 ⊠

Clearance

In a fit the clearance is the difference between the size of the hole and the size of the shaft which is always positive.

Clearance fit

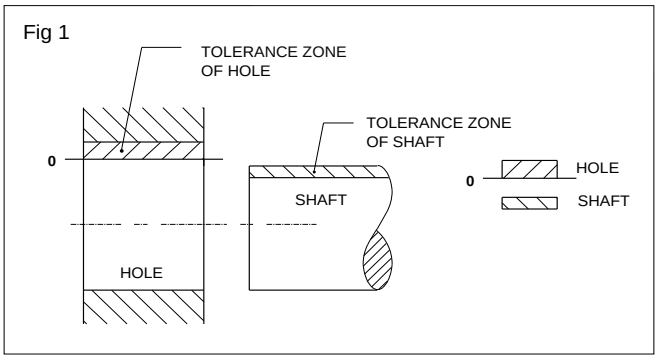
It is a fit which always provides clearance. Here the tolerance zone of the hole will be above the tolerance zone of the shaft. (Fig 1)

***Example* 20 H7/g6**

With the fit given, we can find the deviations from the chart.

For a hole 20 H7 we find in the table + 21.

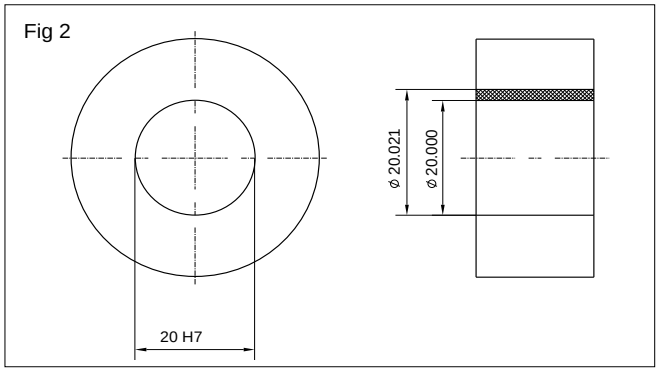
Fig 1



These numbers indicate the deviations in microns.
(1 micrometre = 0.001 mm)

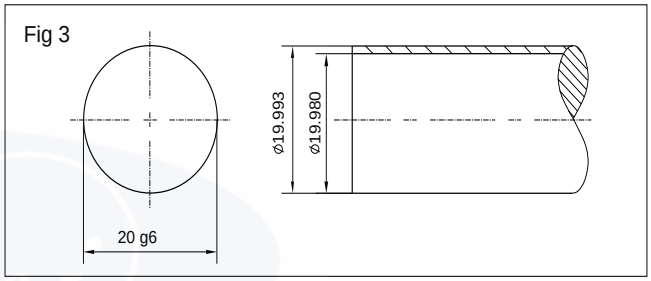
The limits of the hole are 20 + 0.021 = 20.021 mm and 20 + 0 = 20.000mm. (Fig.2)
For a shaft 20 g6 we find in the table – 7
– 20.

Fig 2



So the limits of the shaft are
20 – 0.007 =19.993 mm
and 20 – 0.020 =19.980mm.(Fig 3)

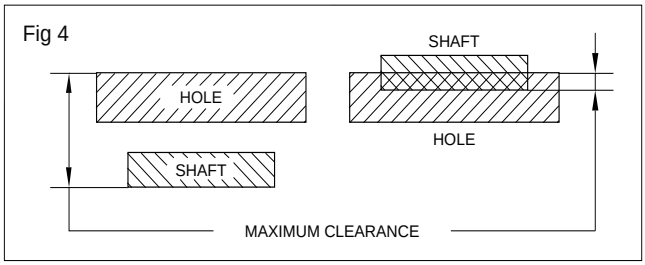
Fig 3



Maximum clearance

In a clearance fit or transition fit, it is the difference between the maximum hole and minimum shaft. (Fig 4)

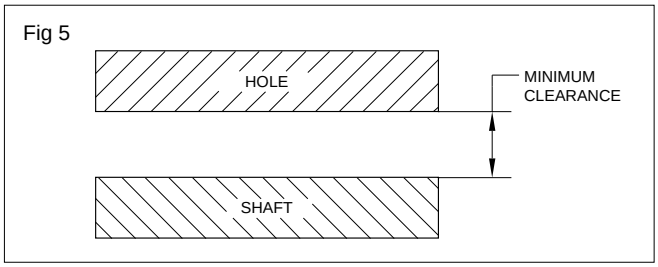
Fig 4



Minimum Clearance

In a clearance fit, it is the difference between the minimum hole and the maximum shaft. (Fig 5)

Fig 5



The minimum clearance is 20.000 - 19.993 = 0.007mm. (Fig 6)

The maximum clearance is 20.021 - 19.980 = 0.041 mm. (Fig 7)

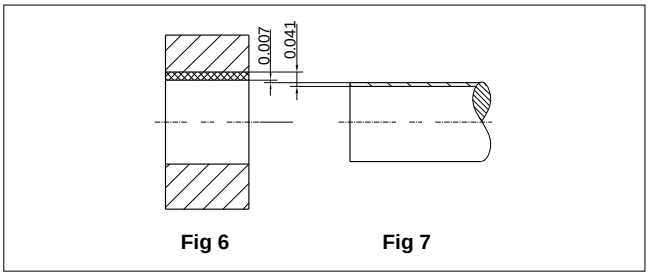


Fig 6 **Fig 7**

There is always a clearance between the hole and the shaft. This is the clearance fit.

Interference

It is the difference between the size of the hole and the shaft before assembly, and this is negative. In this case, the shaft is always larger than the hole size.

Interference Fit

It is a fit which always provides interference. Here the tolerance zone of the hole will be below the tolerance zone of the shaft. (Fig 8)

Example Fit 25 H7/p6 (Fig 9)

Fig 8

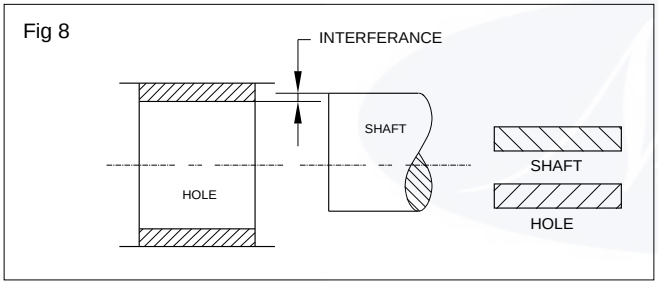
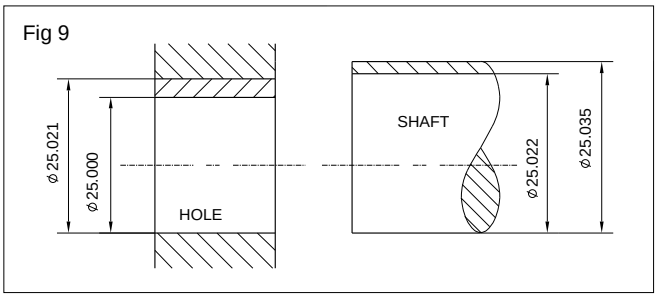


Fig 9

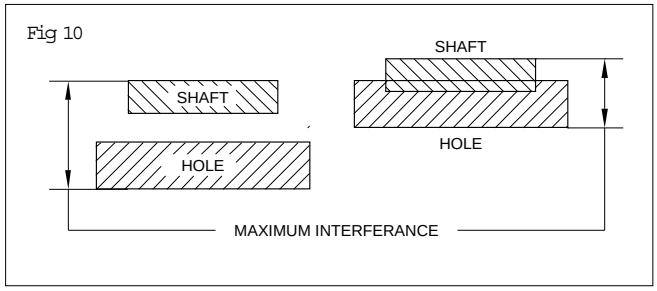


The limits of hole are 25.000 and 25.021 mm and the limits of the shaft 25.022 and 25.035 mm. The shaft is always bigger than the hole. This is an interference fit.

Maximum interference

In an interference fit or transition fit, it is the algebraic difference between the minimum hole and the maximum shaft. (Fig 10)

Fig 10



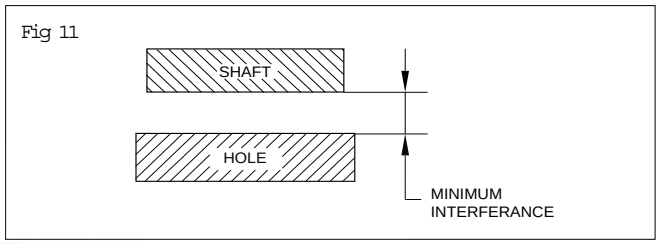
Minimum interference

In an interference fit, it is the algebraic difference between the maximum hole and the minimum shaft. (Fig 11)
In the example shown in figure 9

The maximum interference is = 25.035 – 25.000
= **0.035**

The minimum interference is = 25.022 – 25.021
= **0.001**

Fig 11



Transition fit

It is a fit which may sometimes provide clearance, and sometimes interference. When this class of fit is represented graphically, the tolerance zones of the hole and shaft will overlap each other. (Fig 12)

Example Fit 75 H8/j7 (Fig 13)

The limits of the hole are 75.000 and 75.046 mm and those of the shaft are 75.018 and 74.988 mm.

Fig 12

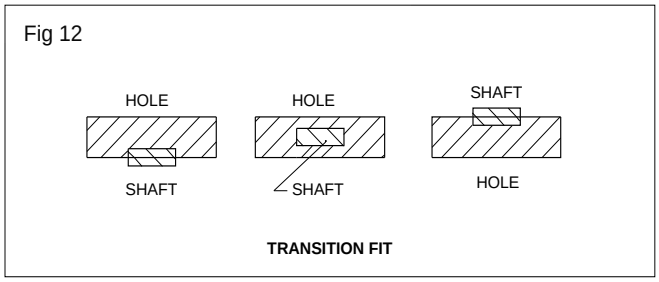
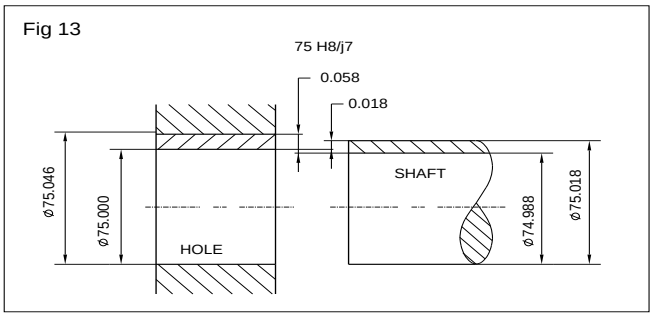


Fig 13



Maximum Clearance = 75.046 - 74.988 = 0.058 mm.

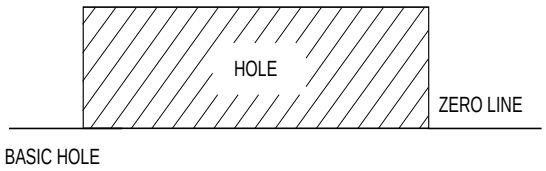
If the hole is 75.000 and the shaft 75.018 mm, the shaft is 0.018 mm, bigger than the hole. This results in interference. This is a transition fit because it can result in a clearance fit or an interference fit.

Hole basis system

In a standard system of limits and fits, where the size of the hole is kept constant and the size of the shaft is varied to get the different class of fits, then it is known as the hole basis system.

The fundamental deviation symbol `H' is chosen for the holes, when the hole basis system is followed. This is because the lower deviation of the hole `H' is zero. It is known as `basic hole'. (Fig 14)

Fig 14



Shaft basis system

In a standard system of limits and fits, where the size of the shaft is kept constant and the variations are given to the hole for obtaining different class of fits, then it is known as shaft basis. The fundamental deviation symbol `h' is chosen for the shaft when the shaft basis is followed. This is because the upper deviation of the shaft `h' is zero. It is known as `basic shaft'. (Fig 15)

The hole basis system is followed mostly. This is because, depending upon the class of fit, it will be always easier to alter the size of the shaft because it is external, but it is difficult to do minor alterations to a hole. Moreover the hole can be produced by using standard toolings.

The three classes of fits, both under hole basis and shaft basis, are illustrated in figure 16.

Fig 15

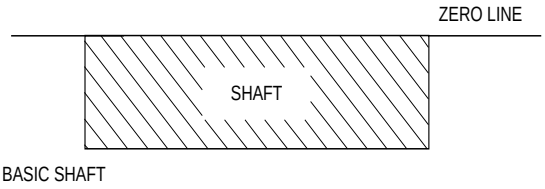
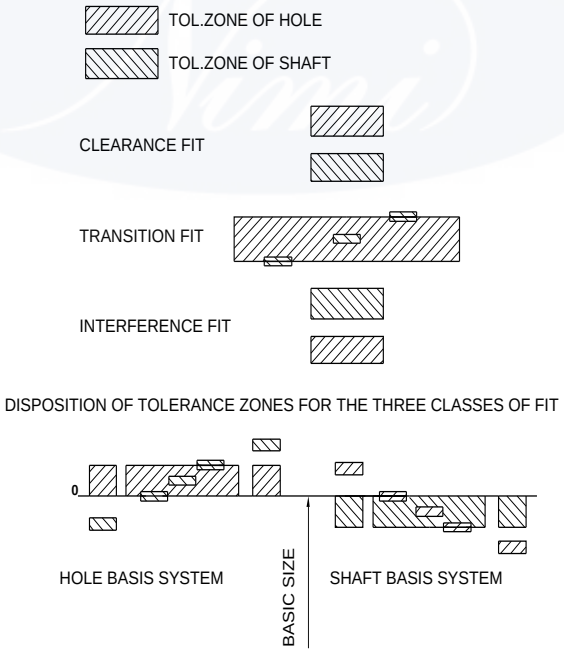


Fig 16



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The BIS system of limits and fits - reading the standard chart

Objective: At the end of this lesson you shall be able to
• refer to the standard limit system chart and determine the limits of sizes.

The standard chart covers sizes upto 500 mm (I.S. 919 of 1963) for both holes and shafts. It specifies the upper and lower deviations for a certain range of sizes for all combinations of the 25 fundamental deviations, and 18 fundamental tolerances.

The upper deviation of the hole is denoted as ES and the lower deviation of the hole is denoted as E I. The upper deviation of the shaft is denoted as **es** and the lower deviation of the shaft is denoted as **ei.**

> ***es* is expanded as ECART SUPERIEUR and *ei* as ECART INFERIEUR.**

Determining the limits from the chart

Note whether it is an internal measurement or an external measurement.

Note the basic size.

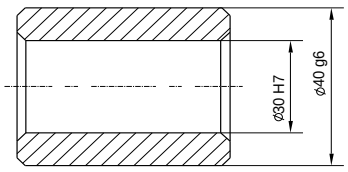
Note the combination of the fundamental deviation and the grade of tolerance.

Then refer to the chart and note the upper and lower deviations which are given in microns, with the sign. Accordingly add or subtract from the basic size and determine the limits of size of the components.

Example

30 H7 (Fig 1)

Fig 1



It is an internal measurement. So we must refer to the chart for 'holes'.

The basic size is 30 mm. So see the range 30 to 40.

Look for *ES*, and *EI* values in microns for H7 combination for 30 mm basic size.

It is given as $^{+25}_{0}$

Therefore, the maximum limit of the hole is 30 + 0.025 = 30.025mm.

The minimum limit of the hole is 30 + 0.000 = 30.000mm.

Refer to the chart and note the values of 40 g6.

NOTE

The tablefor tolerance zones and limits as per IS 2709 is attached.

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Vernier micrometer graduation and reading

Objectives: At the end of this lesson you shall be able to
• state the graduations of a vernier micrometer (metric)
• read a vernier micrometer.

Vernier micrometer

Ordinary metric micrometers can measure only to an accuracy of ±.01mm.

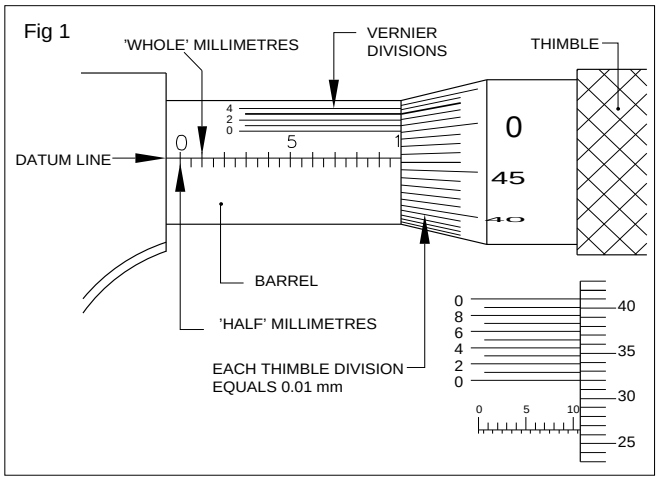
For taking more accurate measurements, vernier micrometers are useful. Vernier micrometers can measure to an accuracy of ±.001 mm.

Construction and graduation

Vernier micrometers are very similar to ordinary micrometers in construction. The difference is in the graduation. These micrometers have additional, equally spaced graduations (vernier graduations) given above the datum line. There are ten such vernier graduation lines marked parallel above the datum line. (Fig 1) The space between these 10 lines is equal to 9 divisions in the thimble. (Fig 1)
The value of 10 vernier divisions is

.0 1 mm X 9
.09 mm.

Fig 1



The value of a vernier division

= ☒ = .009 mm

The least count = 1 thimble division – 1 Vernier division

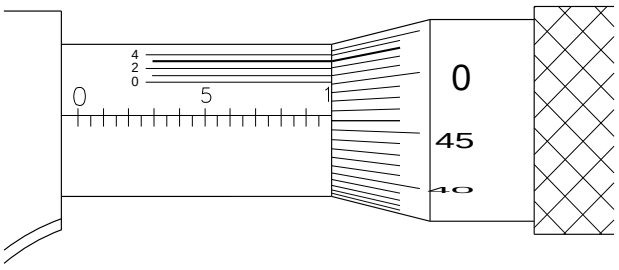
= 0.01 – 0.009mm = .001 mm or ☒

Reading a vernier micrometer (Fig 2)

Example

After measuring, read the full mm divisions visible on the barrel.
full divisions in mm.9 mm

Fig 2



Note the half divisions, if any, visible on the barrel.

1 half division

Read the thimble divisions below the datum line. (Fig 2)

46 divisions

Note the vernier division coinciding with the thimble division.

3rd division

Add up all the readings together

CALCULATION

The range of micrometer is 0 to 25 mm

1	Full mm division visible before the thimble edge	15 = 9.00 mm
2	Half mm division visible after the full mm divsion on barrel.	1 = 0.50 mm
3	Thimble division below the index line	46 = 0.46 mm
4	Vernier division coinciding with thimble division	3 = 0.003 mm
	Reading	**9.963 mm**

Telescopic gauge

Objectives: At the end of this lesson you shall be able to
- **name the parts of a telescopic gauge**
- **state the constructional features of telescopic gauges**
- **state the ranges of telescopic gauges.**

Telescopic gauges are popular for fine work as they are very rigid and have a better 'feel'.

Uses

Used for measuring the sizes of holes, slots and recesses.

Construction (Figs 1 & 2)

Fig 1

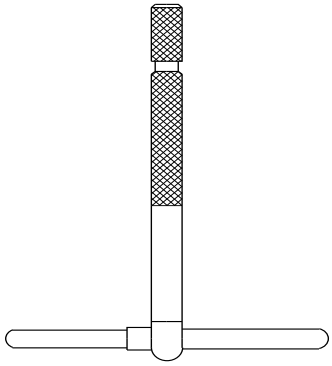
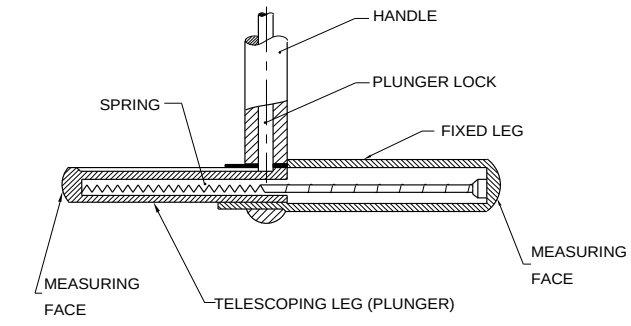
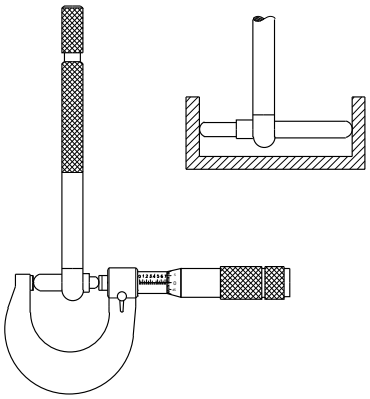


Fig 2



Telescopic gauges are 'T' shaped. They consist of a pair of telescopic legs or plungers connected to a handle. The plungers are spring-loaded to force them apart. After inserting the gauge in a hole or slot, it can be locked in position by turning the knurled handle. It may then be withdrawn from the hole and measured with a micrometer. (Fig 3)

Fig 3



Telescopic gauges are available in a set of 6 nos, to measure holes from 8 mm to 150 mm. (as per MITUTOYO - Series 155)

No.1	8.0 mm to 12.7 mm
No.2	12.7 mm to 19.0 mm
No.3	19.0 mm to 32.0 mm
No.4	32.0 mm to 54.0 mm
No.5	54.0 mm to 90.0 mm
No. 6	90.0 mm to 150.0 mm

Small hole gauges

Objectives: At the end of this lesson you shall be able to
- **name the parts of a small hole gauge**
- **state the construction of a small hole gauge**
- **state the ranges of small hole gauges.**

Telescopic gauges are not suitable for measuring holes below 8 mm. For measuring smaller holes and slots, small hole gauges are used.

Construction (Fig 1)

A small hole gauge consists of a tube having holes on the opposite sides at one end where hardened balls are fixed. The other end of the tube has an external thread. A screwed thimble is fixed with the threaded tube. A plunger with a tapered end, and spring-loaded, is inserted in the tube and tightened with the screwed thimble.

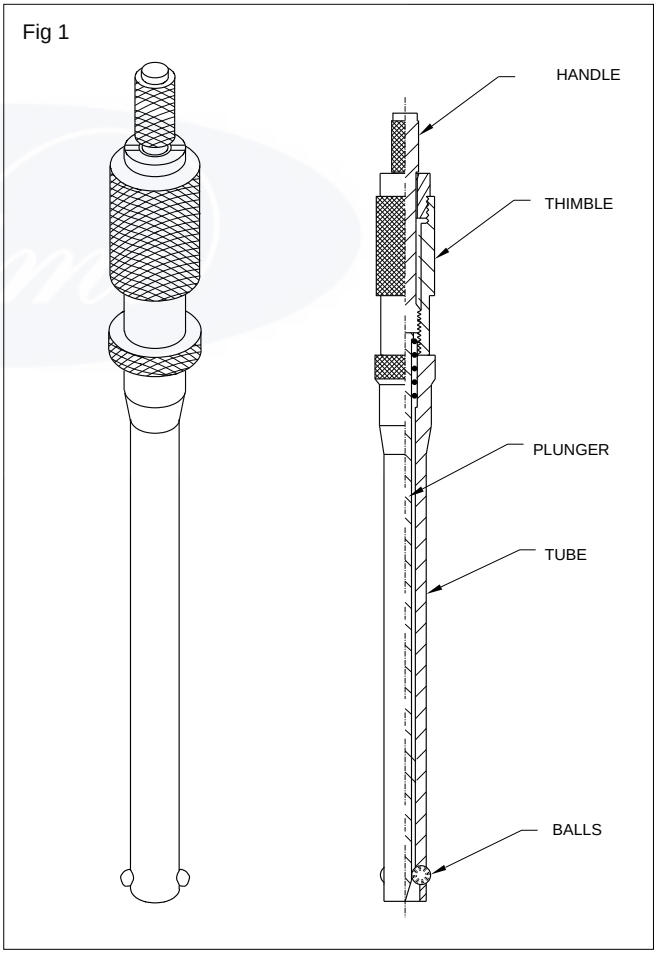
At the end of the thimble a knurled handle is fitted. While rotating the knurled handle in a clockwise direction the plunger moves forward up, and pushes the balls out to contact the surfaces.

A small hole gauge is an instrument used for indirect measurement, while a micrometer is usually used for measuring the sizes directly.

Small hole gauges are available in a set of 4 numbers to measure holes from 3 mm to 13 mm. (as per MITUTOYO - Series 154)

No.1	3 mm to 5 mm
No.2	5 mm to 7.5 mm
No.3	7.5 mm to 10 mm
No.4	10 mm to 13 mm

Fig 1



Originating of reference surfaces

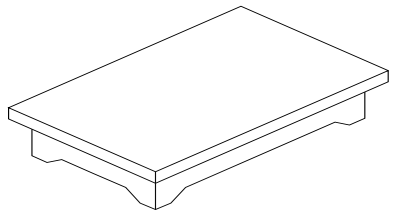
Objectives: At the end of this lesson you shall be able to
- **name the reference surfaces used in machine shop work**
- **state what is a mean true plane**
- **state the Whitworth principle of originating true surfaces.**

Reference surfaces are used in engineering workshops in manufacturing and inspection processes.

Reference surfaces used in workshops

The most widely used reference surfaces are cast iron surface plates and marking tables. (Fig 1) Granite and plate glass are also used to make reference surfaces as they are stable material.

Fig 1

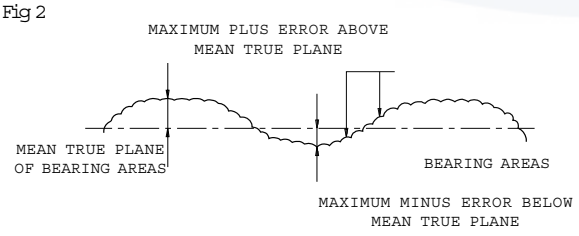


The most accurate reference surface normally available is the toolmaker's flat. This is a disc of hardened steel with lapped surfaces.

Mean true plane

When measuring flatness or straightness, reference is made to an imaginary perfect plane which is called THE MEAN TRUE PLANE. (Fig 2)

Fig 2



The mean true plane is an imaginary plane of perfect flatness and straightness placed in such a manner that plus errors and minus errors are balanced above and below it.

Originating true surfaces

To prepare a true plane without error is almost impossible. However, it is essential to have an accurate reference surface for precision measurement. A method adopted to originate a reference surface is known as the THREE-PLATE TECHNIQUE OF SURFACE GENERATION.

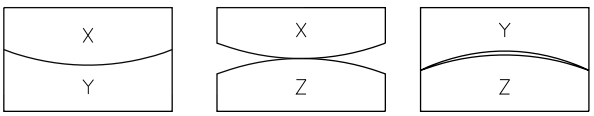
According to this (Whitworth principle), if three surfaces are compared with one another in alternate pairs they will only mate perfectly in all positions when they are absolutely flat.

If we consider three plates as X,Y and Z, two plates 'X' and 'Y' can be scraped and mated without being flat. (Fig 3)

Any error in the flatness will be shown up when they are compared with 'Z'.

When X,Y and Z mate each other in all positions, all the surfaces originated will be flat.

Fig 3



Straight edges

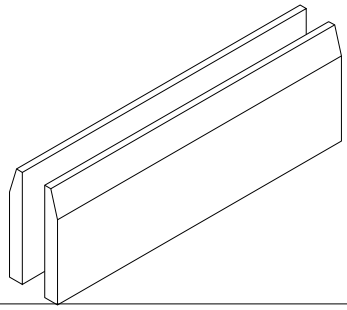
Objectives: At the end of this lesson you shall be able to
- **name the different types of straight edges**
- **state the features and uses of each type of straight edge**
- **state the different methods of testing straightness.**

For testing straightness and to use a guide for marking long straight lines, straight edges made of steel or cast iron are used.

Steel straight edges

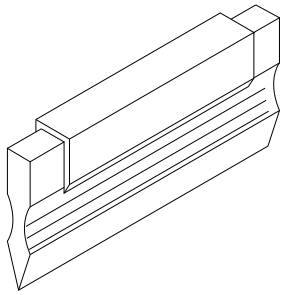
These are usually available up to 2 metres in length and may be rectangular in cross-section or have one edge bevelled. (Fig 1)

Fig 1



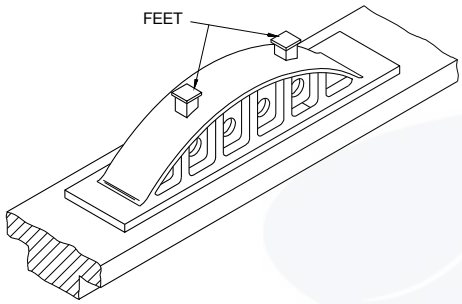
Toolmaker's steel straight edges are available in smaller lengths with bevelled edge. Some of these straight edges will have an acute angle of 60° for checking internal angles. (Fig 2)

Fig 2



Cast iron straight edges (Fig 3)
These are made from close-grained, grey, cast iron and can be considered as narrow surface plates. They are available up to 3 metres length and are used for testing machine tool slideways. Cast iron straight edges have ribs, and bow-shaped tops to prevent distortion. These straight edges are provided with feet to prevent distortion under their own weight.

Fig 3

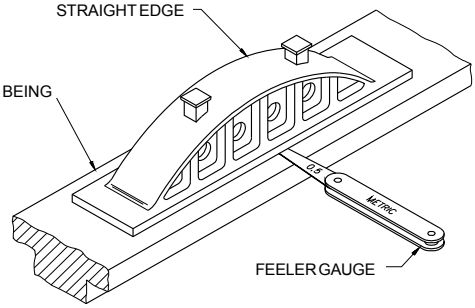


Use of straight edges

Checking with feeler gauges

In certain situations when the gap between the surface and the straight edge is more, a feeler gauge can be used (Fig 4) to determine the extent of deviation.

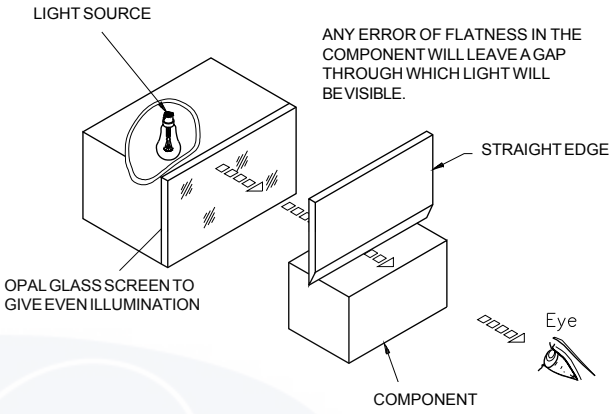
Fig 4



Use of light box

Where precision straight edges (toolmaker's) are used, a light box which can provide uniform illumination will be of

Fig 5



advantage. Through the gap between the straight edge and the component a strip of light will be visible. (Fig 5) By practice the quality of surface can be determined by the amount of light passing through the non-contact surfaces.

From practice it is said that if the gap is more than 0.002 mm, white light will be seen, and if it is less than 0.002 mm, it will be tinted light.

To make this judgement about the amount of deviation, one needs a great deal of practice.

The same is applicable in the case of a try square.

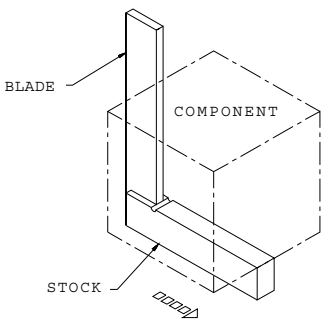
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Testing squareness

Objectives: At the end of this lesson you shall be able to
- **state the different methods of testing squareness**
- **state the advantages of a cylinder square.**

The squareness of surfaces is usually tested by visual observation.(Fig 1) But there are many situations where the magnitude of the error has to be clearly determined. While there are different methods of doing this, the simple methods are by using precision try squares and cylindrical squares along with feeler gauges or slip gauges.

Fig 1



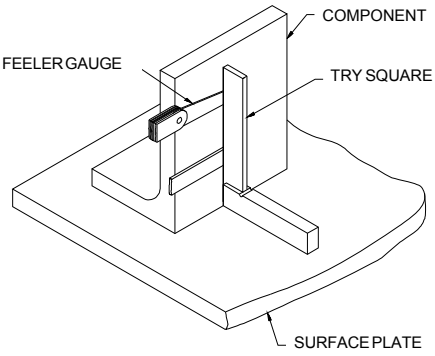
Use of feeler gauges (Fig 2)

This is done by using a feeler gauge to determine the gap between the work and the try square.

A reasonable degree of accuracy can be obtained by the correct sense of feel.

An ordinary precision engineer's square can be used for this purpose.

Fig 2

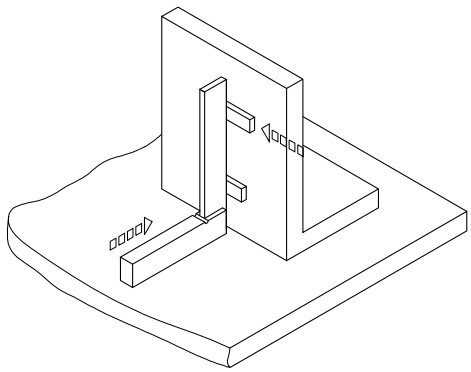


Try square and slip gauges (Fig 3)

These can be used when higher accuracy is demanded. For this a precision engineer's square with a bevelled blade may be selected.

Any thin slip gauge is first placed between the try square blade and the work and held firmly. Then another slip gauge which correctly fits the gap on the top is selected by progressively increasing the slip gauge size until an appropriate feel is achieved.

Fig 3

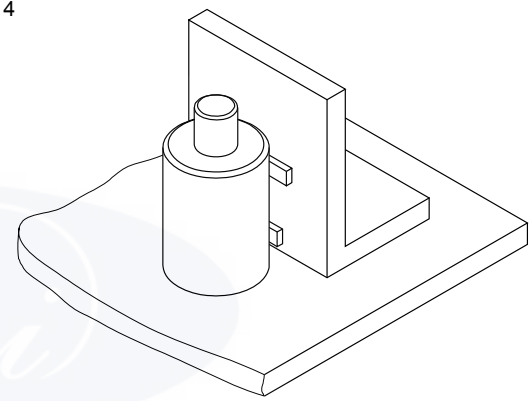


The difference between the slip sizes is the error in squareness.

Cylinder square and slip gauges (Fig 4)

The method of checking is similar to the above, but a higher degree of accuracy is achieved because of the line contact. (Fig 4)

Fig 4



Precision spirit level

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

- **state the working principle of a spirit level**
- **name the different types of spirit levels**
- **state the features of a precision spirit level**
- **state the application of each type of spirit level.**

Spirit levels are used to check or set equipment in horizontal positions.(Fig 1)

Principle of a spirit level

In a spirit level a curved glass tube partly filled with a liquid is used. (Fig 2) A bubble is trapped in the tube. The bubble and the liquid are both acted upon equally by force of gravity.

The liquid being of higher density is pulled down to the bottom of the tube and the bubble always floats on the top. The bubble will move to the highest point when the level is tilted. (Fig 3)

The accuracy of the level depends upon the radius of curvature of the vial. In a sensitive spirit level, if it is tilted to 10 seconds of an arc, the bubble will move to a distance

Fig 1

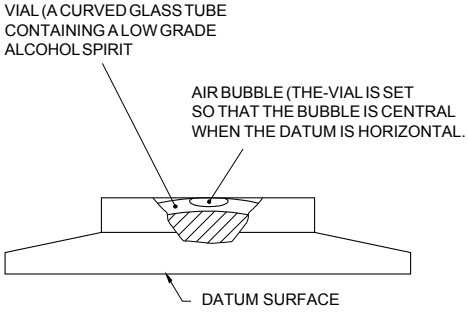


Fig 2

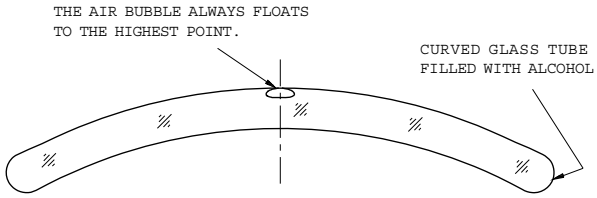
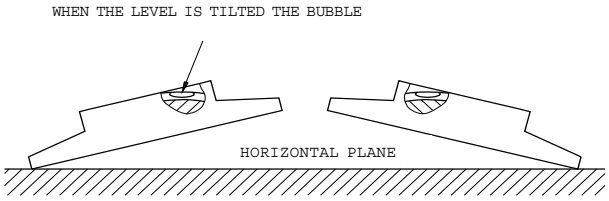


Fig 3



of 2 mm. To achieve this, the glass tube has to be bent to a radius of approximately 41 metres. This is impracticable. Therefore a thick glass tube is taken and is precision ground internally to a barrel shape giving this radius. The liquid used is industrial alchohol and the tube is then sealed at both ends.(Figs 4 and 5)

Fig 4

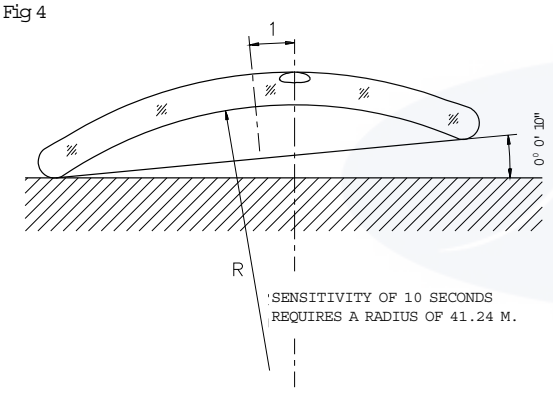
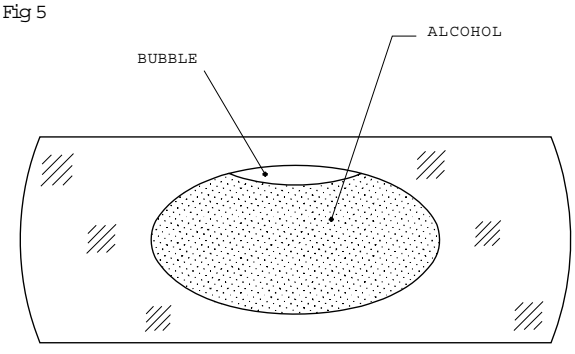


Fig 5



Types of spirit levels

There are two types of spirit levels in use.

- **Engineer's precision spirit level** (Figs 6 and 7)
- **Block level** (Fig 8)

The common engineer's spirit level is capable of checking horizontal level and twist.

Fig 6

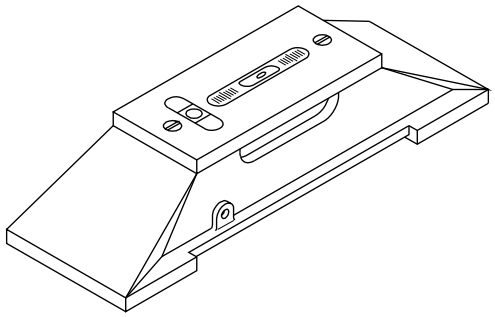
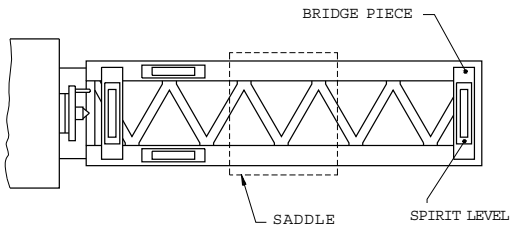
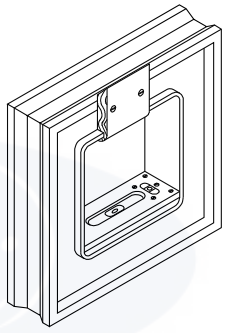


Fig 7



TESTING A LATHE BED FOR LEVEL AND WIND

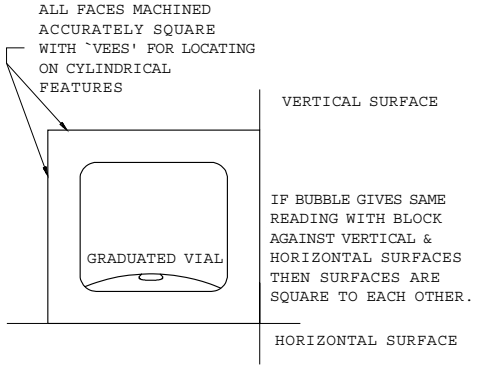
Fig 8



The twist or wind is tested by placing the spirit level across.

The block level can be used for checking vertical and horizontal alignment (squareness) of machine tool slides. (Fig 9)

Fig 9



Precision engineer's square

Objectives: At the end of this lesson you shall be able to
- **name the different standard engineer's squares**
- **distinguish the features of different engineer's squares**
- **state the different grades of try squares and their uses**
- **specify engineer's squares as per Indian Standard**
- **state the features and uses of cylindrical squares.**

Engineer's squares of different types are available for checking squareness of components. I.S.I. recommends three types of squares.

TYPES

Type 1 Engineer's square, bevel edged with stock.

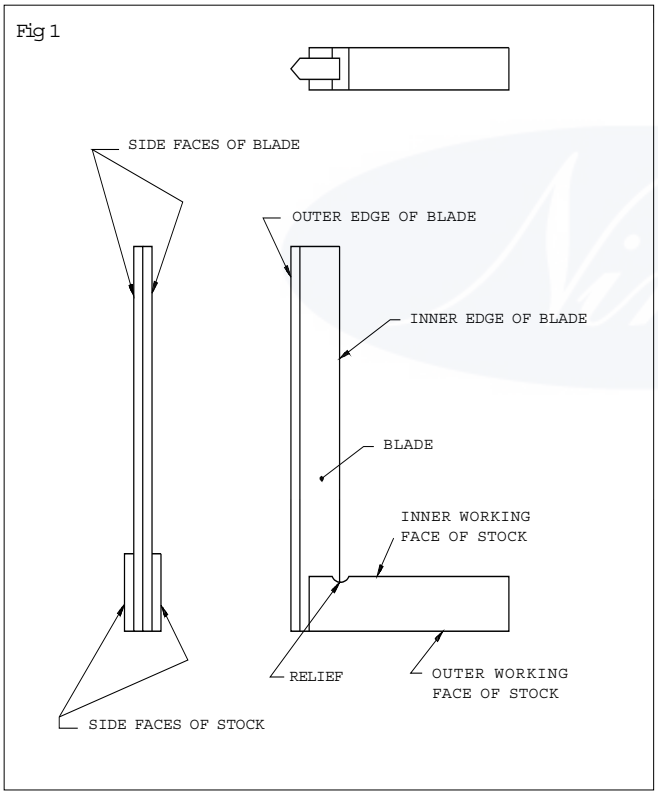
Type 2 Engineer's square with flat edge and without stock.

Type 3 Engineer's square with flange.

Engineer's square, bevel edged with stock (Type 1)

The outer edge of the blade is bevelled, and the blade is fitted on to a stock. (Fig 1)

Fig 1



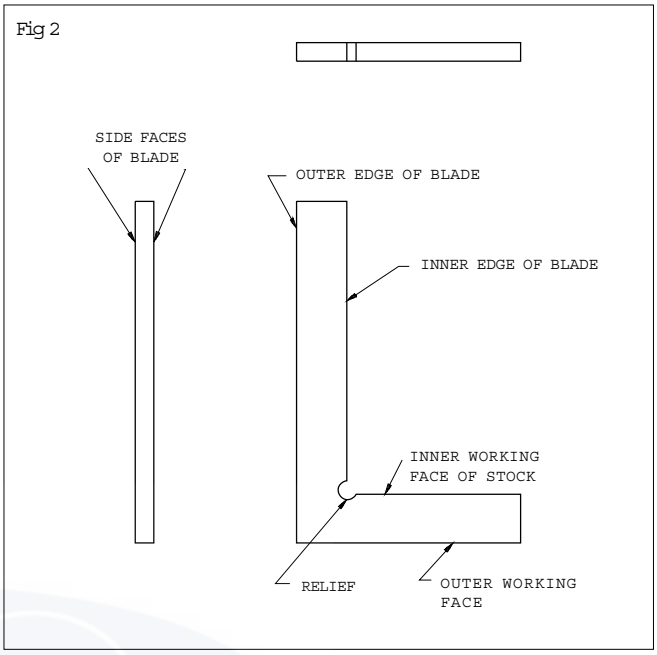
Since the blade is bevelled it makes only a line contact and, therefore, it is useful for precision work.

Engineer's square without stock (Type 2)

In this case the blade and stock are integral.(Fig 2)

The blade and stock are of uniform thickness. The blade is thicker than that provided in Type I.

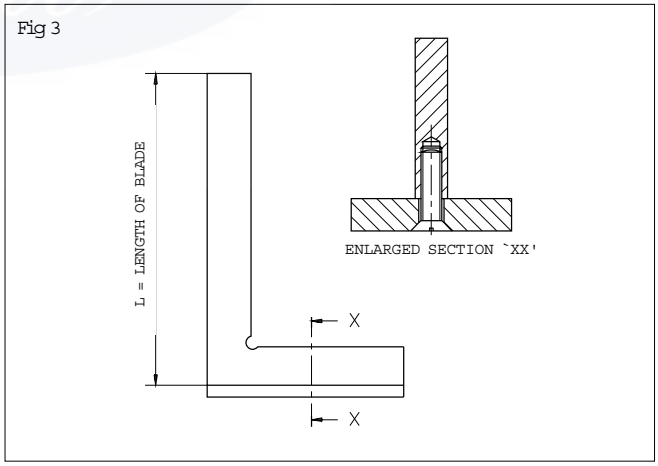
Fig 2



Engineer's square with flange (Type 3)

These try squares are available from 500 mm and above. These are particularly useful on marking tables. (Fig 3)

Fig 3



Grades

Engineer's square are made in three grades.

- Grade A
- Grade B
- Grade C

Grade A is the most accurate.

Grades A and B are used in fine tool room inspection and, reference work and grade C for general machine shop work.

Unless otherwise specified Grade 'A' squares shall be supplied with bevelled edges and Grade B and C squares with flat edges.

Designation of engineer's squares

Engineer's squares are specified by their nominal length, grade of accuracy and type. The length of the blade is taken from the outer working face of the stock to the end of the blade. (Fig 3)

- Grade of Accuracy A, B or C.
- Type (i.e.Type 1, 2, or 3).

Examples

Engineer's square

200 A-1 - IS: 2103

300 B-2 - IS: 2103

500 C-3 - IS: 2103

I S : 2103 indicates the Indian Standard number relating to the specification.

Cylinder squares

Cylinder squares are not commercially available but many inspection rooms favour the use of these for use on surface plates or on marking tables.

These are made from hardened die steel or mild steel case hardened.

They have a cylindrical surface and the end faces are precision ground.

These squares have better stability than the other precision engineer's squares.

They also give a line contact when checking flat surfaces.

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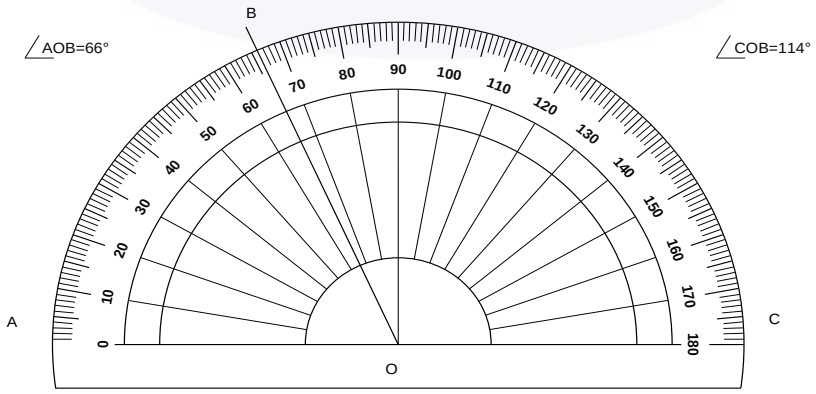
Measurement of angles

Objectives: At the end of this lesson you shall be able to
- **state the units and fractional units of angles**
- **express degrees, minutes and seconds using symbols.**

The unit of an angle

For angular measurements a complete circle is divided into 360 equal parts. Each division is called a degree. (A half circle will have 180°.) (Fig 1)

Fig 1



Subdivisions of an angle

For more precise angular measurements, one degree is further divided into 60 equal parts. This division is one MINUTE ('). The minute is used to represent a fractional part of a degree and is written as 30° 15'.

One minute is further divided into smaller units known as seconds ("). There are 60 seconds in a minute.

An angular measurement written in degrees, minutes and seconds would read as 30° 15' 20".

Examples for angular divisions

1	complete circle	360°
1/2	circle	180°
1/4	of a circle (right angle)	90°

Sub divisions 1 degree or 1° = 60 mts or 60'
1 min or 1' = 60 secs or 60"

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Vernier bevel protractor

Objectives: At the end of this lesson you shall be able to
- **identify the parts of a universal bevel protractor**
- **state the functions of each part**
- **list out the uses of a vernier bevel protractor.**

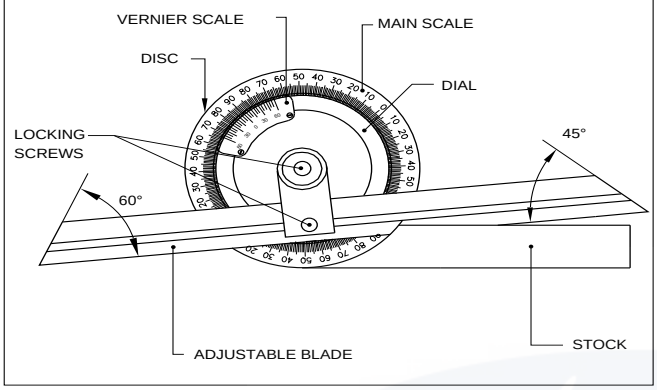
The vernier bevel protractor is a precision instrument meant for measuring angles precisely to an accuracy of 5 minutes. (5')

Parts of a vernier bevel protractor

The following are the parts of a vernier bevel protractor.

(Fig 1)

Fig 1



Stock

This is one of the contacting surfaces during the measurement of an angle. Preferably it should be kept in contact with the surface from which the inclination is measured.

Disc

The disk is an integrated part of the stock. It is circular in shape, and the edge is graduated in degrees.

Dial

It is pivoted to the disc and can be rotated through 360°. The vernier scale of the instrument is attached to the dial. The dial is locked to the disc during reading the measurement.

Blade

This is the other contacting surface of the instrument that contacts the work during measurement, preferably the inclined surfaces. It is fixed to the dial with the help of the clamping lever. A parallel groove is provided in the centre of the blade to enable it to be longitudinally positioned whenever necessary.

Locking screws

Two knurled locking screws are provided, one to lock the dial to the disc, and the other to lock the blade to the dial.

All parts are made of good quality alloy steel, properly heat-treated and highly finished. A magnifying glass is sometimes fitted for clear reading of the graduations.

Uses of a vernier bevel protractor

The vernier bevel protractor is used to measure acute angles, i.e. less than 90° (Fig 2) obtuse angles i.e more than 90° (Fig 3) for setting work-holding devices to angles on machine tools, work-tables etc. (Figs 4 & 5)

Fig 2

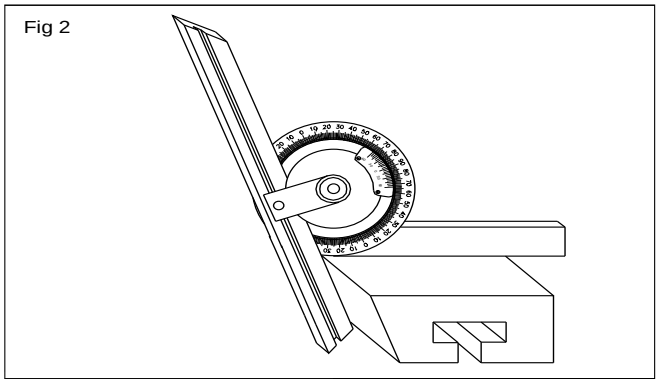


Fig 3

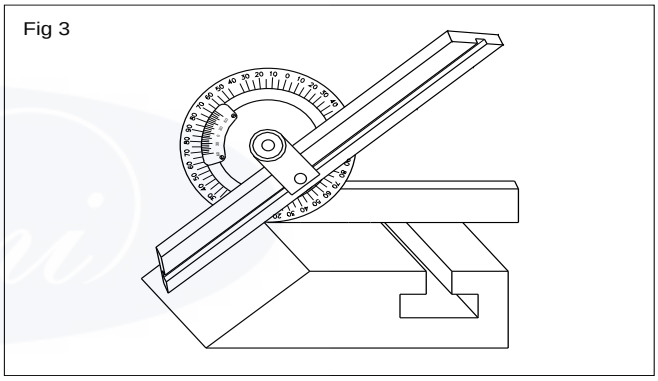


Fig 4

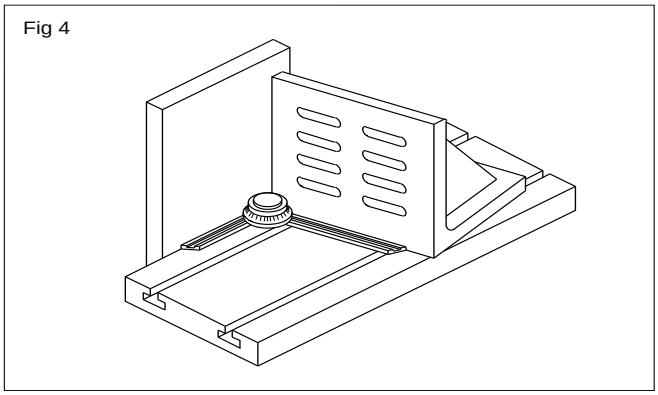
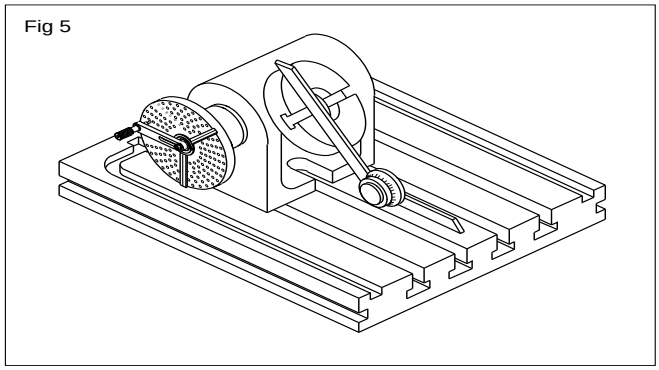


Fig 5



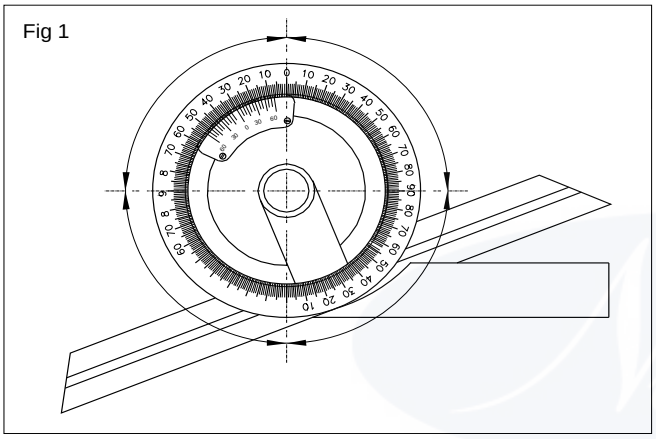
Graduations on universal bevel protractor

Objectives: At the end of this lesson you shall be able to
- **state the main scale graduations on the disc**
- **state the vernier scale graduations on the dial**
- **determine the least count of the vernier bevel protractor.**

The main scale graduations (Figs 1 & 2)

For purposes of taking angular measurements, the full circumference of the disc is graduated in degrees. The 360° are equally divided and marked in four quardrants, from 0 degree to 90 degrees, 90 degrees to 0 degree, 0 to 90 degrees and 90 degrees to 0 degrees. Every tenth division is marked longer and numbered. Each division represents 1 degree. The graduations on the disc are known as the main scale divisions. On the dial, 23 divisions spacing of the main scale is equally divided into 12 equal parts on the vernier. Each 3rd line is marked longer and numbered as 0, 15, 30, 45, 60. This constitutes the vernier scale. Similar graduations are marked to the left of 0 also. (Fig 1)

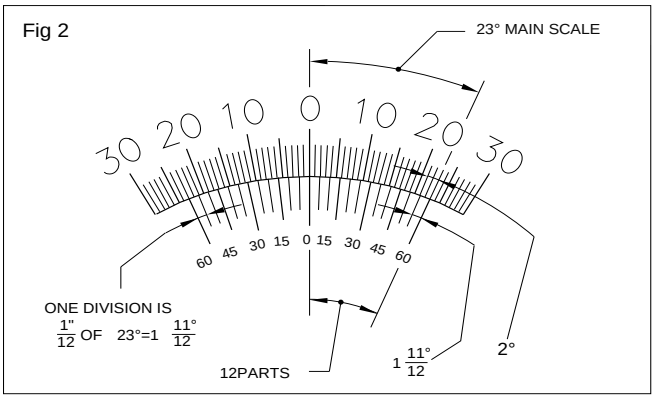
Fig 1



One vernier scale division (VSD) (Fig 2)

$$\frac{23^\circ}{12} = 1\,\frac{11^\circ}{12} = 1^\circ\,55'$$

Fig 2



The least count of the vernier bevel protractor

When the zero of the vernier scale coincides with the zero of the main scale, the first division of the vernier scale will be very close to the 2nd main scale division. (Fig 2)

Hence, the least count is

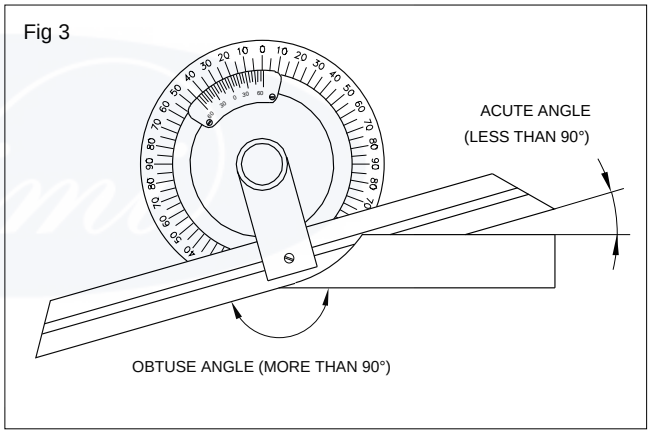
2 MSD – 1 VSD

$$\text{i.e. the Least count} = 2^\circ - \frac{23^\circ}{12}$$

$$= \frac{1^\circ}{12} = 5'$$

For any setting of the blade and stock, the reading of the acute angle and the supplementary obtuse angle is possible, and the two sets of the vernier scale graudations on the dial assist to achieve this. (Fig 3)

Fig 3



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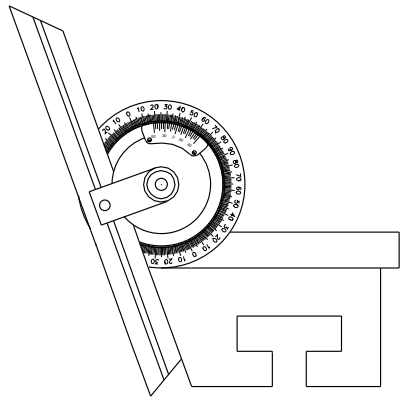
Reading of universal bevel protractor

Objectives: At the end of this lesson you shall be able to
- **read vernier bevel protractor for acute angle setting**
- **read vernier bevel protractor for obtuse angle setting.**

For reading acute angle set up (Fig 1)

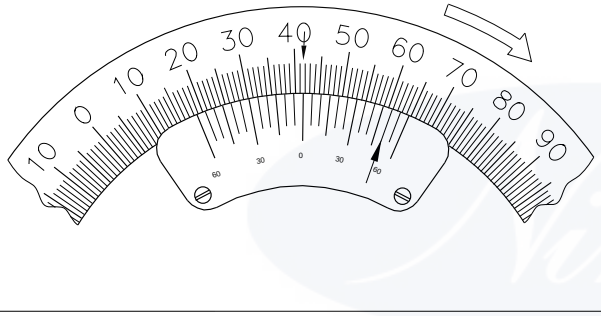
First read the number of whole degrees between zero of the main scale and zero of the vernier scale. (Fig 2)

Fig 1



Note the line on the vernier scale that exactly coincides with any one of the main scale divisions and determine its value in minutes.

Fig 2



To take the vernier scale reading, multiply the coinciding divisions with the least count.

Example: 10 x 5' = 50'

Total up both the readings to get the measurements. = 41° 50'

If you read the main scale in an anticlockwise direction, read the vernier scale also in an anticlockwise direction from zero.

If you read the main scale in a clockwise direction, read the vernier scale also in a clockwise direction from zero.

For obtuse angle set up (Fig 3)

The vernier scale reading is taken on the left side as indicated by the arrow.(Fig 4) The reading value is subtracted from 180° to get the obtuse angle value.

Reading 22° 30'
Measurement
180° — 22° 30'=157° 30'

Fig 3

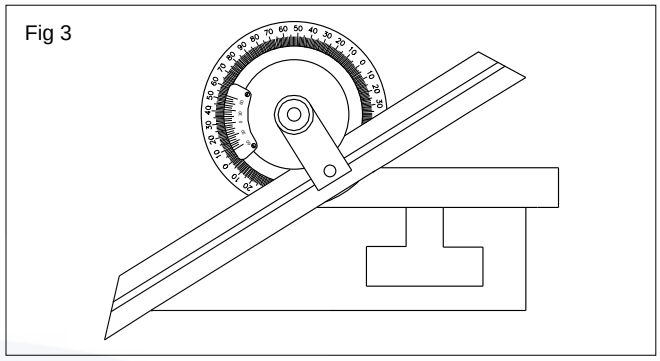
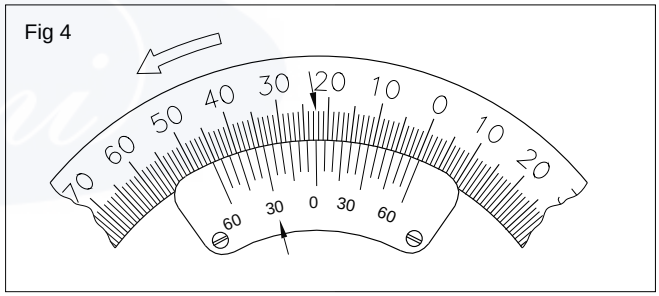


Fig 4



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Vernier depth gauge

Objectives: At the end of this lesson you shall be able to
- **name the parts of a vernier depth gauge**
- **state the constructional features of a vernier depth gauge.**

Applications of Vernier Depth Gauge (Fig 1)

A vernier depth gauge is a very commonly used precision instrument for the measuring of holes, recesses, slots and steps.

Its construction and method of reading are similar to those of a vernier caliper.

Parts of a Vernier Depth Gauge (Fig 2)

Base (1), Graduated beam (2), Clamping screw (3),

Fine adjustment mechanism (4) andVernier scale (5).

The base (anvil) is the fixed unit and serves as a datum for measurement. It also carries the vernier scale and the fine adjustment mechanism.

The beam with the main scale graduations is the sliding member or part.

Fine adjustments for measurement are made after tightening the clamping screw and the fine adjustment mechanism.

While taking measurements the base should be firmly held against the reference surface. (Fig 3)

Fig 1

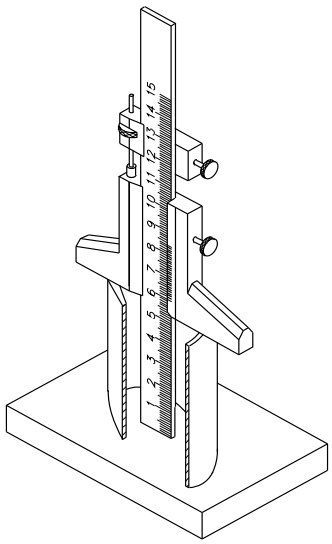


Fig 2

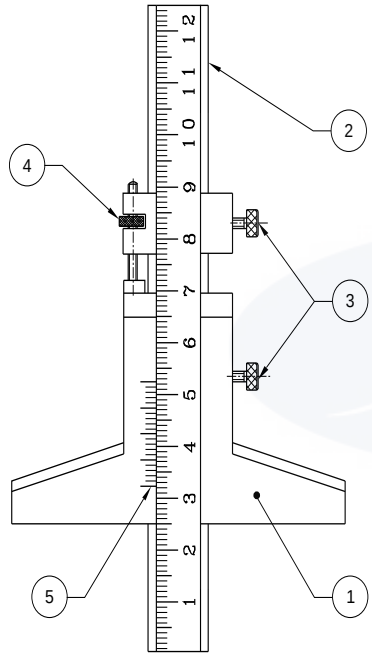
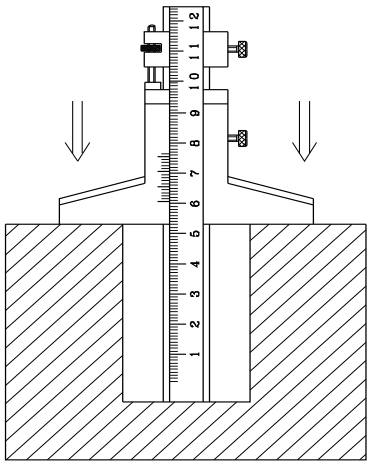


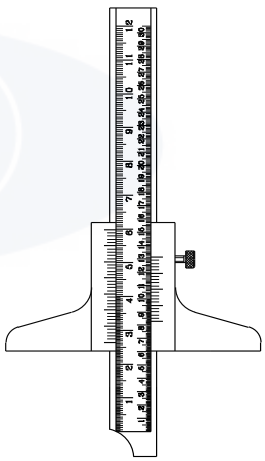
Fig 3



The relief given at the end of the beam of some vernier depth gauges is to avoid the seating in the corners of slots and to ensure correct reading. (Fig 4)

Remove burrs, if any, before taking measurements. Excessive pressure on the beam, while taking measurements will lift the base from the reference surface and will show wrong measurements.

Fig 4



Vernier height gauge

Objectives: At the end of this lesson you shall be able to
- **name the parts of a vernier height gauge**
- **state the functions of each part**
- **list out the specific uses of a vernier height gauge.**

Specific uses of a Vernier Height Gauge

Accurate measurements are important in layout (marking off) and inspection work. (Figs 1 & 2)

Vernier height gauges are particularly suitable for marking off accurate distances, and centre locations.

The graduations and readings are the same as those of a vernier caliper.

Fig 1

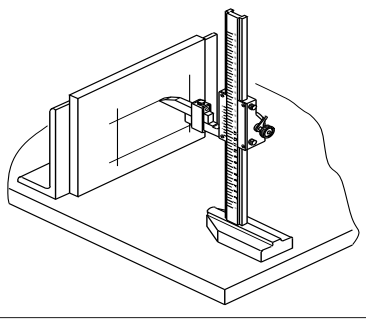
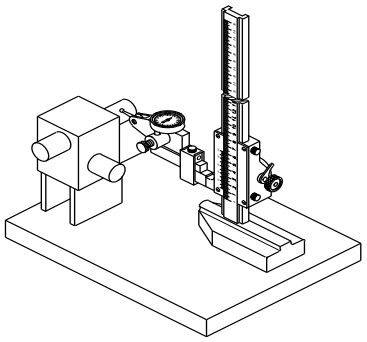


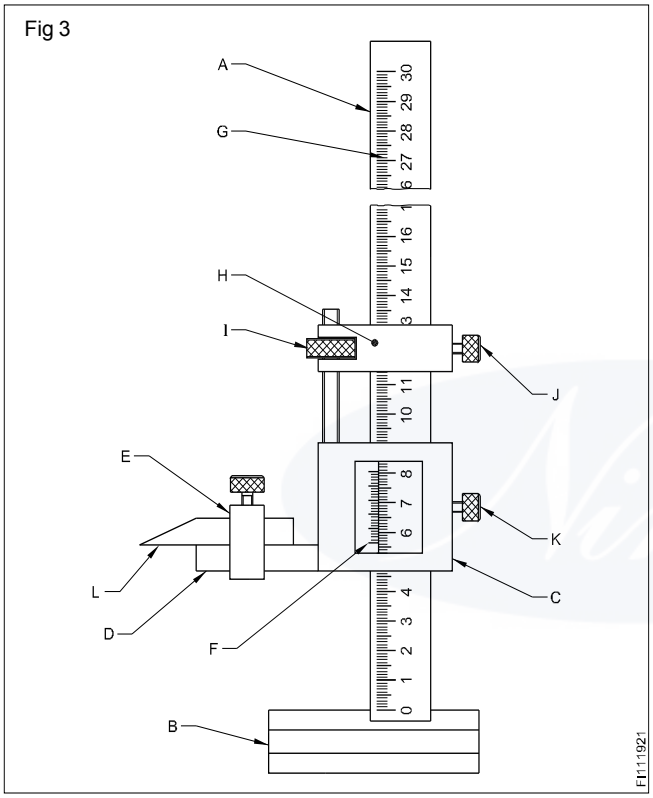
Fig 2



Parts of a Vernier Height Gauge and their functions

The main parts of a vernier height gauge and their functions are given here. (Fig 3)

Fig 3



Base (1)

This is the datum from which measurements and settings are made. The underside of the base is hardened, ground and lapped.

Beam (2)

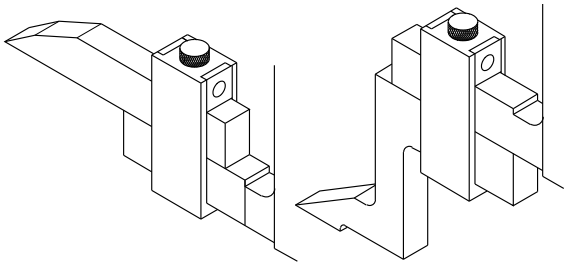
This is similar to the beam scale of a vernier caliper and is attached to the base.

Vernier Slide (3)

This unit slides on the beam and carries the vernier plate (5), locking screws (6), fine setting device (4) and scriber (7). Some vernier height gauges are provided with a rack and pinion arrangement for moving the slide along the beam.

Vernier height gauges are provided with both straight and offset scribers.(Fig 4)

Fig 4

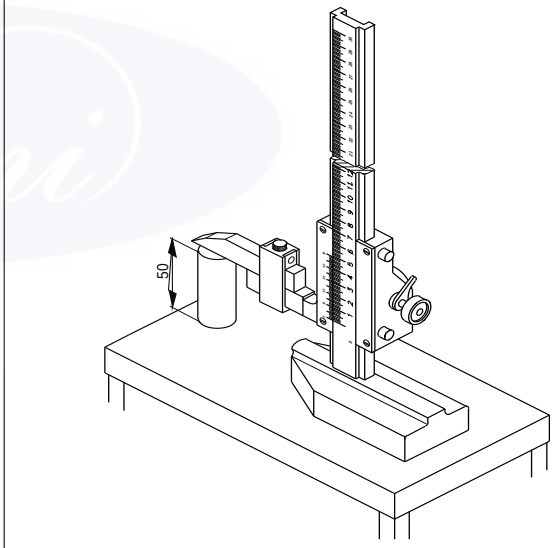


Zero setting of the Vernier Height Gauge.

The offset scriber permits zero setting of the instrument from the datum surface.

While using a straight scriber, the zero setting of the instrument is at a level above the datum surface. In this case the zero setting is to be checked using the precision round block, supplied along with the instrument. (Fig 5)

Fig 5



Vernier height gauges with which we can measure from the datum surface without the special offset scribers are also available.

The size of the vernier height gauge is stated by the height of the beam. The most commonly used size has a beam of 300 mm height.

Vernier height gauges are used on surface plates or other accurate flat surfaces.

Centre lathe-parts and specification

Objectives: At the end of this lesson you shall be able to
- **name the main parts of a lathe**
- **specify the size of a lathe.**

Turning and centre lathe

Turning is a machining process to bring the raw material to the required cylindrical shape and size by metal removal. This is done by feeding a cutting tool against a rotating work.

The machine tool on which turning is carried out is known as a lathe.

Constructional features of a lathe

A lathe has provisions to:

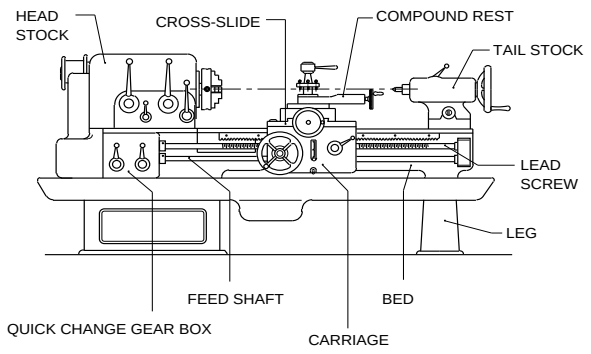
- hold the cutting tool and to feed it against the direction of rotation
- have the parts fixed and sliding to get a relative movement of the cutting tool with respect to the rotation of the work
- fit accessories and attachments for performing the different operations.

Main parts (Fig 1)

The following are the main parts of a lathe.

- Headstock
- Tailstock
- Carriage
- Cross-slide
- Compound slide
- Bed
- Quick change gear box
- Legs
- Feed shaft
- Lead screw

Fig 1

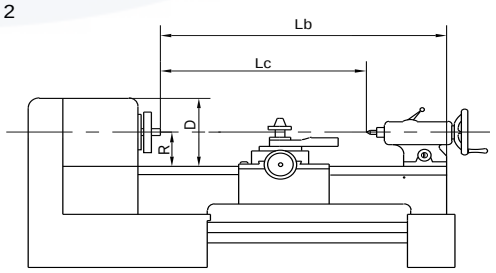


CENTRE LATHE - MAIN PARTS

The size of a lathe is specified by (Fig 2)

- the maximum diameter of work that can be held
- the swing over the bed. This is the perpendicular distance from the lathe axis to the top of the bed.
- the length of the bed.
- the maximum length of work that can be turned between centres.

Fig 2



R-RADIUS OF WORK (CENTRE HEIGHT OF LATHE)
D-DIAMETER OF WORK (SWING)
Lc-LENGTH BETWEEN CENTRES
Lb-LENGTH OF THE BED

— — — — — — — — —

Precautions in lathe work

Objective: At the end of this lesson you shall be able to
- **state the precautions to be observed before starting work on a lathe, during work and after.**

Before starting

Before starting the work ensure that

- the lubricating system is functioning
- the meshing gears are in proper mesh and the power feed levers are in neutral position
- the work area is clean and tidy
- the safety guards are in proper condition and are correctly placed.

During working

Shift the levers to change speeds and feeds only when the rotating parts have fully stopped.

Wear an apron which is not loose, and have the sleeves folded.

Avoid wearing rings or watches during working.

Remove the chips with a hook.

Wear shoes.

After work

Clean the machine with a brush and wipe with cotton waste.

Oil the bed-ways and the lubricating points.

Clean the precision instruments and wipe them dry before storing.

Clean the cutting tools and place them in their respective places.

Clean the surroundings of the lathe, wipe the spilt oil and coolant and remove the swarf.

Headstock

Objectives: At the end of this lesson you shall be able to
- **state the function of the headstock**
- **differentiate between cone pulley headstock and all geared headstock.**

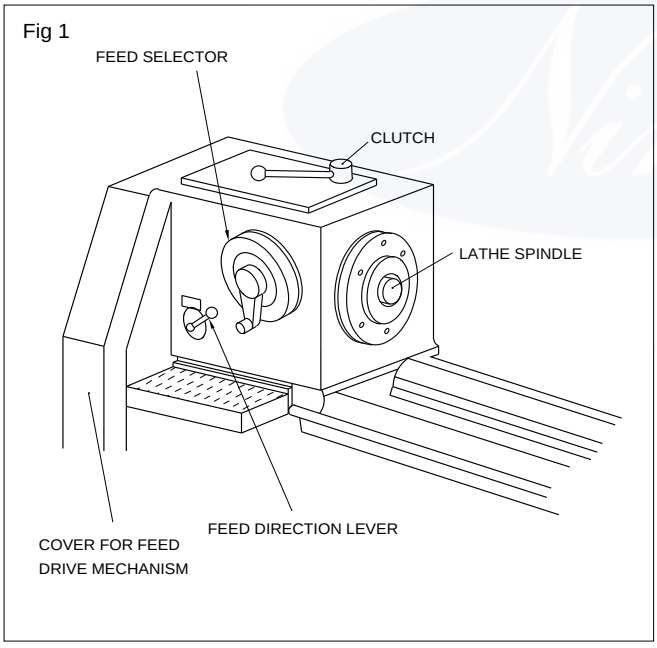
Functions (Fig 1)

To provide a means to assemble the work-holding devices. Transmit the drive from the main motor to the work.

To accommodate shafts, gears and levers for a wide range of varying work speeds.

To ensure arrangement for lubricating the gears, shafts and bearings.

Fig 1



Types of headstocks

The following are the two types of headstocks.

- All geared headstock
- Cone pulley drive headstock

All geared headstock (Fig 2)

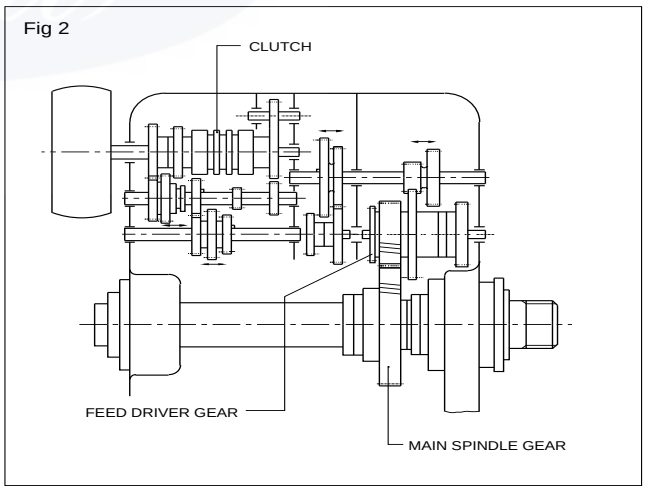
It is a box section casting having a removable top cover. It has internal webs for stiffening, and to take shaft bearings. It has an input shaft which is connected by means of 'V' belts to the main motor, and it runs at a constant speed. It is equipped with clutches and a brake.

There may be two or more intermediate shafts on which sliding gears are mounted. The main spindle is the last driven shaft in the headstock assembly. The nose of the spindle is outside the headstock casting, and is designed to accommodate the work-holding devices.

The levers operating the forks for the sliding gears are situated outside in front of the headstock casting.

In the all-geared headstock, lubricating oil is filled for splash lubrication of the internal gears. A sight glass with an oil level mark is provided to see the oil level.

Fig 2

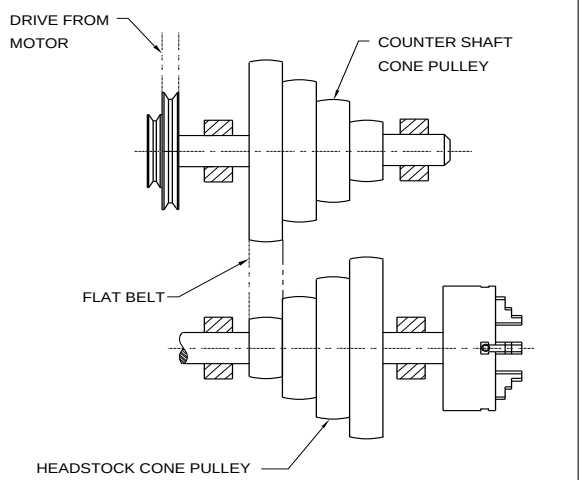


Cone pulley headstock (Fig 3)

It has a stepped cone pulley mounted on the main spindle, and it is free to revolve. It is connected by means of a flat belt to a similar cone pulley, with steps arranged in the reverse order. This cone pulley gets the drive from the main motor.
The spindle is mounted on the bearing on the headstock casting and has a gear wheel called 'bull gear' keyed to it. A pinion is coupled to the cone pulley.

The back gear unit has a shaft which carries a gear and a pinion. The number of teeth of the gear and pinion on the back gear shaft corresponds to the number of teeth on the bull gear and pinion on the cone pulley. The axis of the back gear shaft is parallel to the axis of the main spindle. The back gear is engaged or disengaged with the cone

Fig 3



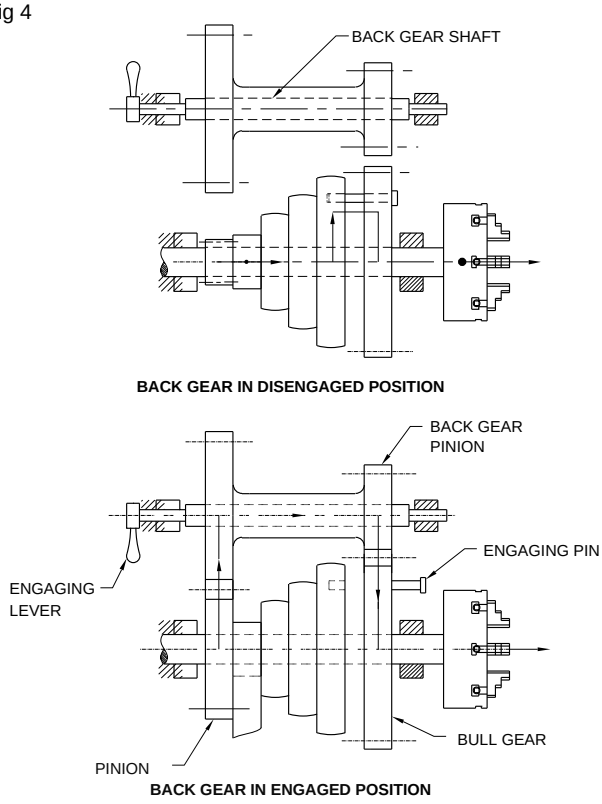
pulley system by means of a lever. The back gear unit is engaged for reducing the spindle speeds. (Fig 4)

A three-stepped cone pulley headstock provides 3 direct ranges of speeds through a belt connection. With the back gear in engagement, 3 further ranges of reduced speeds can be obtained.

Advantages

Can take up heavy load.

Fig 4



Less noise during working.

Easy to maintain.

Disadvantages

The number of spindle speeds is limited to the number of steps in the cone pulley.

It takes time to change the spindle speeds.

— — — — — — — — — —

Lathe bed

Objectives: At the end of this lesson you shall be able to
- **state the functions of a lathe bed**
- **name the differnt types of bed-ways**
- **state the advantages of a gap bed.**

Functions of a lathe bed

The functions of a lathe bed are:

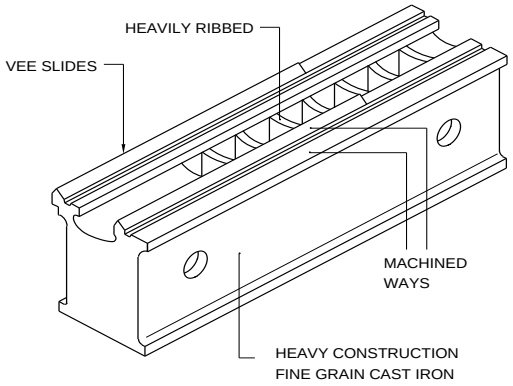
- to locate the fixed units in accurate relationship to each other

- to provide slide-ways upon which the operating units can be moved.

Constructional features of a lathe bed (Fig 1)

The lathe bed generally consists of a single casting. In larger machines, the bed may be in two or more sections accurately assembled together. Web bracings are employed to increase the rigidity. For absorbing shock and vibration,the beds are made heavy.

Fig 1



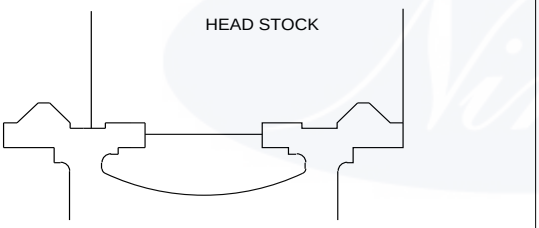
A combined swarf and coolant tray is provided on lathes. This may be an integral part with the lathe bed.

The bed is generally carried by cast iron or welded sheet metal legs of box section. This provides the necessary working height for the lathe. Very often the electrical switch gear unit and the coolant pump assembly are housed in the box section of the legs at the headstock end.

Bed-ways (Fig 2)

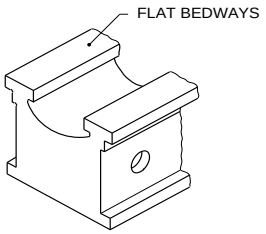
The bed-ways or slideways assist in accurate location and sliding of the accessories/parts mounted on this. The bed-ways are of three types.

Fig 2



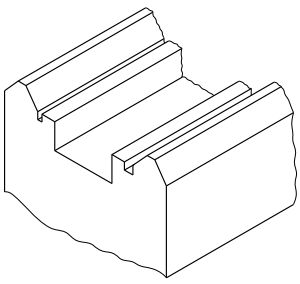
Flat bed-ways (Fig 3)

Fig 3



'V' bed (Fig 4)

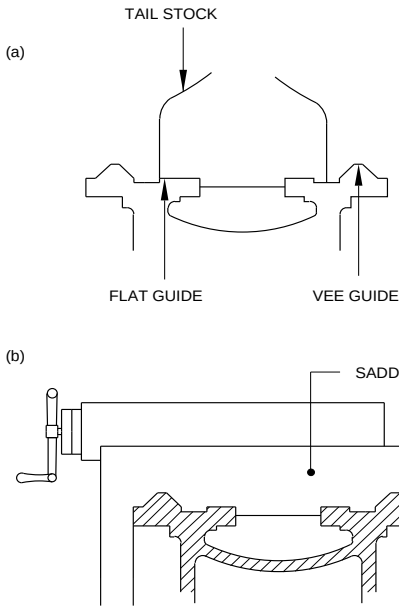
Fig 4



Combination bed (Figs 5a 5b)

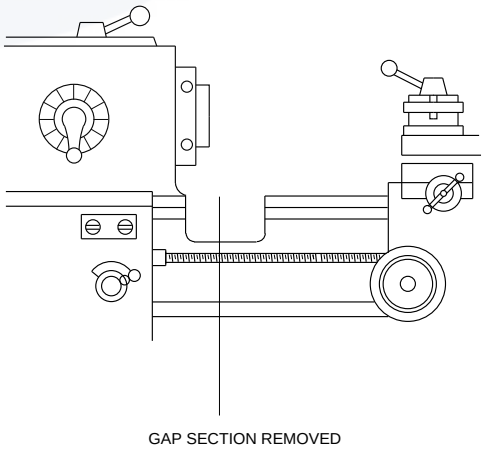
Normally the bed-ways stop at a distance away from the headstock with a gap at this point. This enables to mount larger diameters of the work.

Fig 5



Some lathes have a detachable section of the bed, which can be fitted when desired, to enable the saddle to operate close to the headstock. (Fig 6)

Fig 6



The bed-ways are highly finished by grinding. Some lathes have their bed-ways hand-scraped. Some have their bed-ways hardened and ground. The wear-resisting qualities of bearing surfaces are improved by employing chilled iron castings.

The beds are mostly made up of closely ground, grey cast iron.

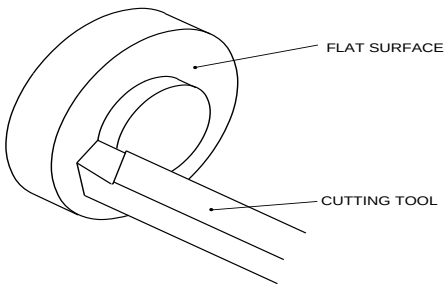
Lathe operations - facing

Objectives: At the end of this lesson you shall be able to
- **state the meaning of facing**
- **state the purpose of facing**
- **state the defects in faced works**
- **state the reasons for the defects**
- **state the remedies to overcome the defects in facing.**

Facing

This is an operation of removing metal from the work-face by feeding the tool at right angles to the axis of the work.(Fig 1)

Fig 1



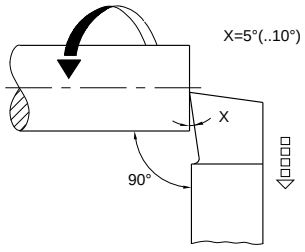
Purpose of facing

- To have a reference plane to mark and measure the step lengths of the work.
- To have a face at right angle to the axis of the work.
- To remove the rough surface on the faces of the work and have finished faces instead.
- To maintain the total length of the work.

Facing may be rough or finish facing. Rough facing is done to remove the excess metal on the face of the work by coarse feeding with more depth of cut, leaving sufficient metal for finishing. Rough facing is done by feeding the tool from the periphery of work towards the centre of the work. Finish facing is the operation to have a smooth face by removing the rough surface produced by the rough facing.

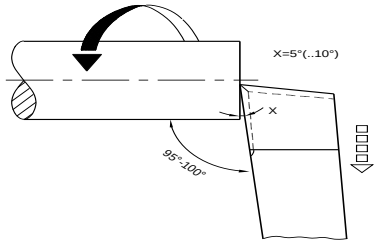
Finish facing is done by feeding the tool from the centre of the work towards the periphery. (Figs 2a and 2b)

Fig 2a



RELIEF GROUND ON TOOL

Fig 2b



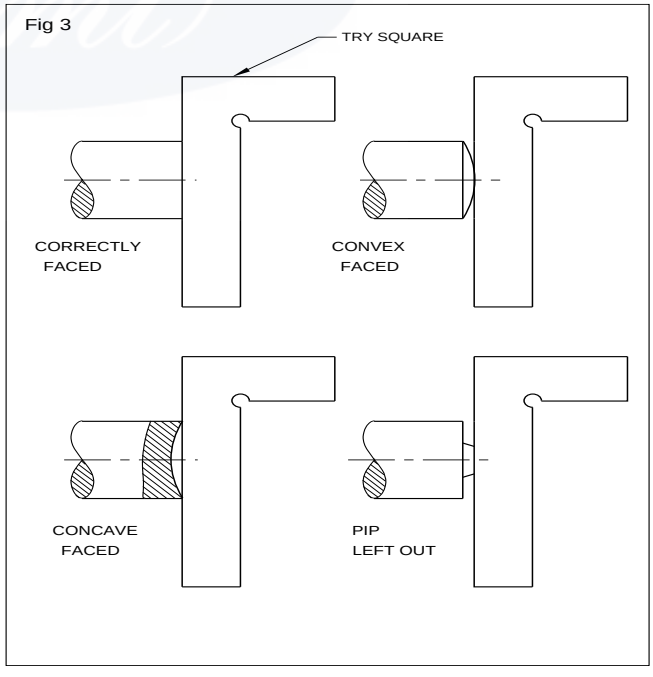
RELIEF WITH TILTED TOOL

Rough facing is done by choosing a spindle RPM according to the average diameter of the work, the recommended cutting speed, with a coarse feed and more depth of cut.

Finish facing is done by choosing a cutting speed about twice that of the cutting speed for roughing, with a fine feed rate of 0.05 mm approximately and with a depth of cut of not more than 0.1 mm.

The following are the defects found in facing work (Fig 3)

Fig 3



A concave face

This is caused by the tool digging into the work during the feeding as the tool is not clamped rigidly. By clamping the tool rigidly with minimum overhang, this defect can be avoided.

A convex face

This is caused by the blunt cutting edge of the tool and the carriage not being locked. To avoid this defect, re-sharpen the tool and use it; Also lock the carriage to the bed of the lathe.

A pip left in the centre

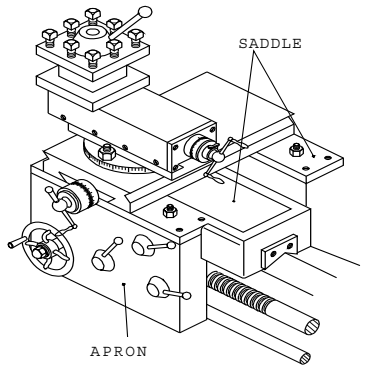
This is due to the tool not being set to the correct centre height. By placing the tool to the centre height, this defect can be avoided.

Lathe parts - carriage

Objectives: At the end of this lesson you shall be able to
- **state the functions of a carriage**
- **name the parts of a carriage.**

Carriage is the feature of a lathe that provides the method of holding and moving the cutting tool. (Fig 1) It can be locked at any desired position on the lathe bed. It consists of two major parts namely, apron and saddle.

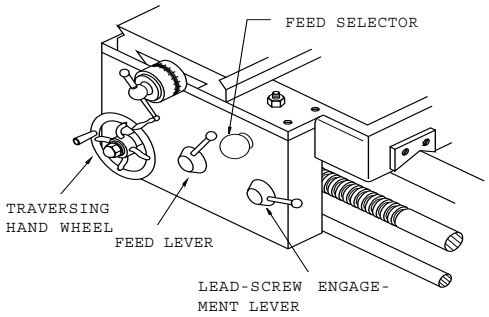
Fig 1



Apron (Fig 2)

The apron is bolted to the front of the saddle. It contains mechanisms for moving and controlling the carriage. The main parts of an apron are :
- traversing handwheel
- feed lever
- feed selector
- lead screw engagement lever.

Fig 2



Saddle (Fig 3)

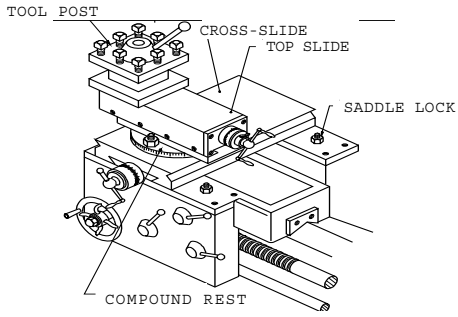
It is a 'H' shaped casting having 'V' guide grooves at the bottom face, corresponding to the lathe bed-ways for mounting on the lathe bed and for sliding.

Parts of a saddle

Cross-slide

The cross-slide is mounted on the top of the saddle, and it provides cross movement for the tool. This is fitted at

Fig 3



right angles to the bed and is moved by means of a screwed spindle, fitted with a handle. A graduated collar, mounted on the screw rod along with the hand wheel, helps to set the fine movements of the cross- slide.

Compound rest

The compound rest is fitted on the top and to the front of the cross-slide. The compound rest can be swivelled horizantally through 360°.

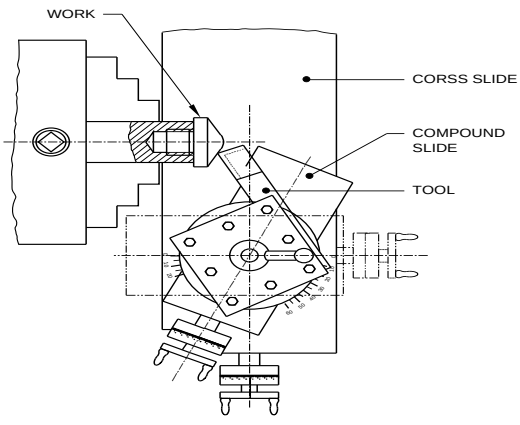
Top slide

The top slide is fitted on the top of the compound rest. It supports the tool post which holds the cutting tool. The top slide provides a limited horizantal movement for the cutting tool.

By swivelling the compound rest, the top slide can be set at an angle to the cross-slide. (Fig 4)

Usually the compound rest is set in such a way that the top slide is at right angles to the cross-slide.

Fig 4

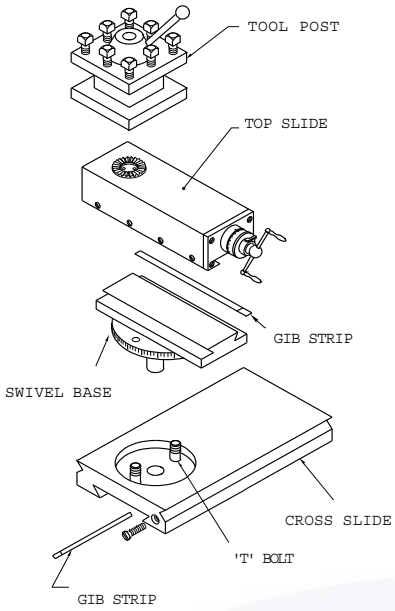


Tool post

Objectives: At the end of this lesson you shall be able to
- **name the commonly used types of tool posts.**
- **compare the features of different types of tool posts**

The tool post holds and firmly supports the tool or tools. The tool post is fitted on the top slide. (Fig 1)

Fig 1



The commonly used types of tool posts are:

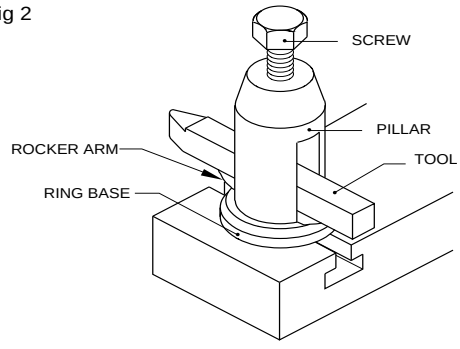
- American type tool post or single way tool post indexing type tool post or square tool post

- quick change tool post.

Single way tool post (Fig 2)

It consists of a circular tool post body and a pillar with a slot for accommodating the tool or tool-holder. A ring base, a rocker arm (boat piece) and a tool-clamping screw complete the assembly of this type of tool post.

Fig 2

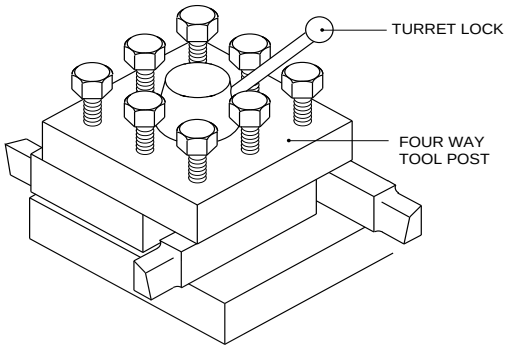


The tool is positioned on the boat piece and clamped. The centre height of the tool tip can be adjusted with the help of the rocker arm and the ring base. Only one tool can be fixed in this type of tool post. The rigidity of the tool is less as it is clamped with only one bolt.

Indexing type tool post (Fig 3)

It is also called as square tool post or a four-way tool post. Four tools can be fixed in this type of tool posts, and any one can be brought into the operating position, and the square head is clamped with the help of the handle lever. By loosening the handle lever, the next tool can be indexed and brought in to the operating position. The indexing may be manual or automatic.

Fig 3



INDEXING TYPE TOOL POST

The advantages are as follows.

Each tool is secured in the tool post by more than one bolt, and, therefore, the rigidity is more.

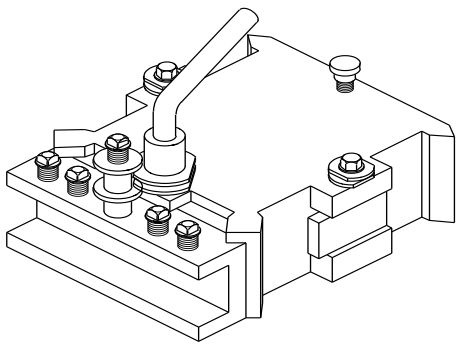
Frequent changing of the tool for different operations need not be done as all the four tools can be clamped at the same time.

The disadvantage is that skill is required to set the tools, and it takes more time to set to the centre height.

Quick change tool post (Fig 4)

Modern lathes are provided with this type of tool posts. Instead of changing the tools, the tool holder is changed in which the tool is fixed. This is expensive and requires a number of tool-holders. But it can be set to the centre height easily, and has the best rigidity for the tool.

Fig 4



QUICK CHANGE TOOL POST

Lathe parts - tail stock

Objectives: At the end of this lesson you shall be able to
- **name the parts of a tailstock**
- **state the uses of a tailstock**
- **state the functioning of a tailstock.**

Tailstock

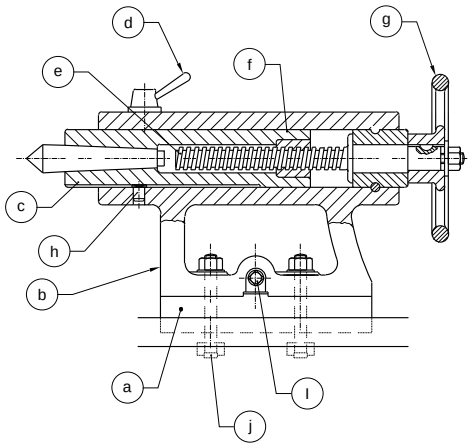
It is a sliding unit on the bed-ways of the lathe bed. It is situated on the right hand side of the lathe. It is made in two parts namely the `base' and the `body'. The base bottom is machined accurately and has `V' grooves corresponding to the bed-ways. It can slide over the bed and can be clamped at any position on the bed by means of the clamping unit. The body of the tailstock is assembled to the base. Graduations are marked on the rear end of the base and a zero line is marked on the body.

When both zero lines coincide,the axis of the tailstock is in line with the axis of headstock.

The body and base are made out of cast iron. The parts of a tailstock are: (Fig 1)

- base (a)
- body (b)
- spindle (barrel) (c)
- spindle locking lever (d)
- operating screw rod (e)
- operating nut (f)
- tailstock hand wheel (g)
- key (h)
- clamping unit (i)
- adjusting screws (j).

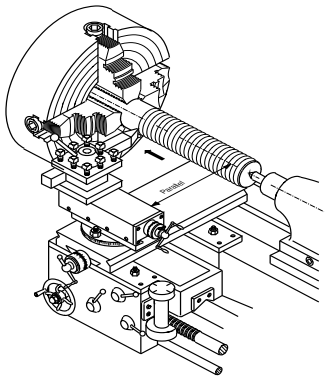
Fig 1



Functioning of a tailstock

By rotating the hand wheel, the barrel can be moved forward or backward. The barrel can be locked in any required position. The hollow end of the barrel at the front is provided with a Morse taper to accommodate the cutting tools with a taper shank. Graduations are sometimes marked on the barrel to indicate the movement of the barrel. With the help of the adjusting screws, the body can be moved over the base laterally, and the amount of movement may be read approximately refering to the graduations marked. This arrangement is to offset the centre of the tailstock as required for taper turning.

Fig 2

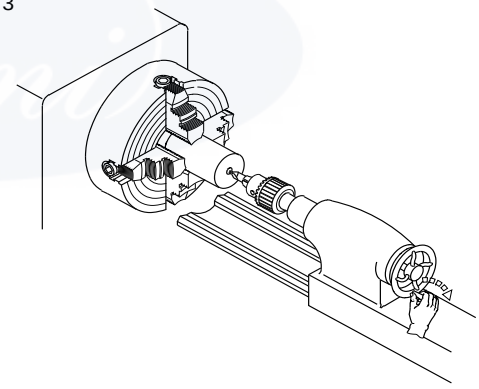


LONG WORKPIECE HELD BETWEEN CENTRES

Purpose of the tailstock

To accommodate the dead center to support lengthy work to carry out lathe operations. (Fig 2)

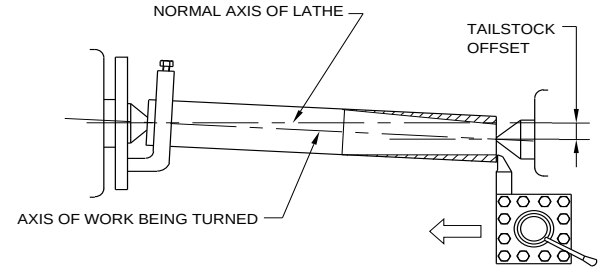
Fig 3



To hold cutting tools like drills, reamers, drill chucks provided with taper shank. (Fig 3)

To turn external taper by offsetting the body of the tailstock with respect to the base. (Fig 4)

Fig 4



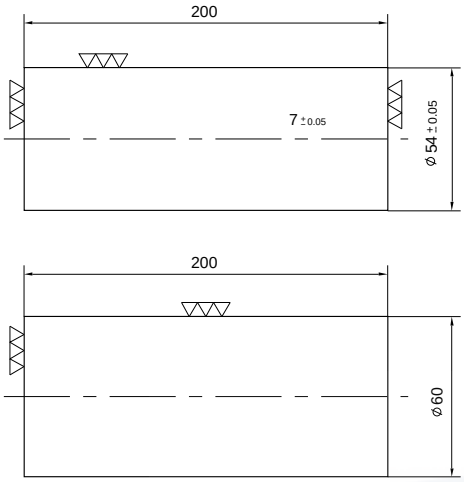
Lathe operations — plain turning

Objectives: At the end of this exercise you shall be able to
- **state the meaning of plain turning**
- **distinguish between the two stages of plain turning.**

Plain turning (Parallel turning) (Fig 1)

This operation involves removal of metal from the work and it has a cylinder for the full travel of the tool on the work, keeping the same diameter throughout the length.

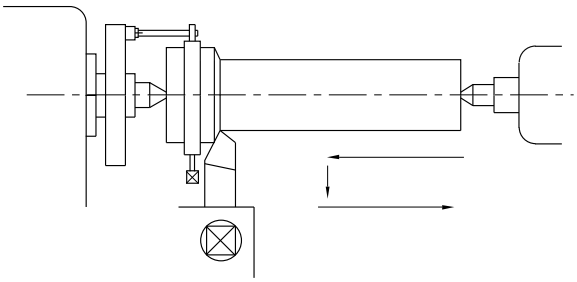
Fig 1



Plain turning is done in two stages.

- Rough turning, using roughing tool or knife tool. (Fig 2)

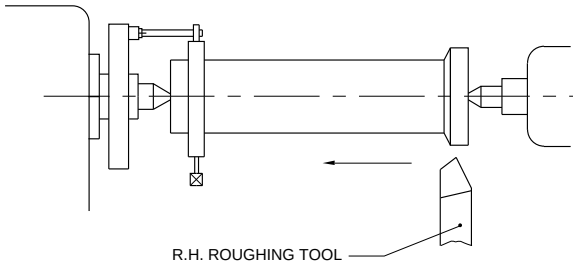
Fig 2



- Finish turning using a finishing tool. (Fig 4)

The spindle speed is calculated according to the material being turned, the tool material and the recommended cutting speed.

Fig 3



Rough turning

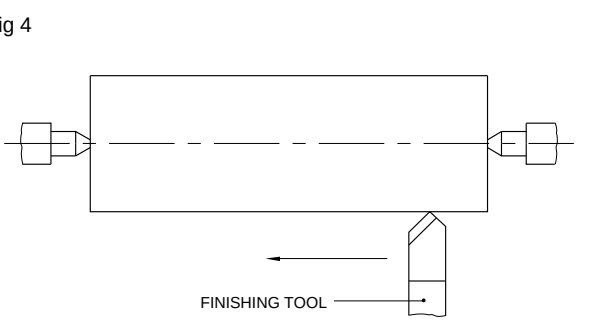
By rough turning the maximum amount of material is removed and the job is brought close to the required size, leaving sufficient metal for finishing. Surface finish and accuracy are not good. While rough turning, the spindle speed is less and the feed is more. A roughing tool or a knife tool is used.

Finish turning

It is done, after the rough turning is completed to bring the size of the work to the required accuracy and good surface finish by removing the rough marks produced by the rough turning. For finish turning, the speed is higher (1_ to 2 times more than for rough turning) and the feed is very less. A round nose finish turning tool or a knife with a larger nose radius than normal is used for finish turning.

While plain turning for roughing or finishing, long jobs are held between centres. It is necessary to change the ends to obtain a true parallel surface throughout the length. (Fig 3)

Fig 4



Cutting tool materials

Objectives: At the end of this lesson you shall be able to
- **state the qualities of good cutting tool material**
- **distinguish the characteristics of cold hardness, red hardness and toughness**
- **state the factors to be remembered when selecting tool material**
- **name the different tool materials**
- **state the characteristics of different tool materials.**

Cutting tool materials

Tool materials should be:

- harder and stronger than the material being cut

- tough to resist shock loads

- resistant to abrasion thus contributing to long tool life.

Cutting tool material should possess the following qualities.

- Cold hardness
- Red hardness
- Toughness

Cold hardness

It is the amount of hardness possessed by a material at normal temperature. Hardness is the property by which it can cut/scratch other metals. When hardness increases, brittleness also increases,and a material, which has too much of cold hardness, is not suitable for the manufacture of cuttting tools.

Red hardness

It is the ability of a tool material to retain most of its cold hardness property even at very high temperatures. While machining, the friction between the tool and the work, the tool and the chips, causes heat to be generated, and the tool loses its hardness, and its efficiency to cut diminishes. If a tool maintains its cutting efficiency even at increased temperatures during cutting, it can be said that it possesses the red hardness property.

Toughness

The property to resist breakage due to sudden load that results during metal cutting is termed as `toughness' This will reduce the breakage of the cutting edges of tools.

The following factors are to be considered, when selecting a tool material.

- Material to be machined

- Condition of the machine tool (rigidity and efficiency)

- The total quantity of production and the rate of production
- The dimensional accuracy required and the quality of surface finish
- The amount of coolant applied and method of application.

- Condition and form of material to be machined.

Grouping of tool material

The three groups under which tool materials fall are:

- ferrous tool materials
- non-ferrous tool materials
- non-metallic tool materials.

Ferrous tool materials

These materials have iron as their chief constituent. High carbon steel (tool steel) and high speed steel belong to this group.

Non-ferrous tool materials

These do not have iron, and they are formed by alloying elements like tungsten, vanadium and molybdenum. Stelite belongs to this group.

Carbides

These materials are also non-ferrous. They are manufacutred by powder metallurgy technique. Carbon and tungsten are the chief alloying elements.

Non-metallic materials

These tool materials are made out of non metals. Ceramics and diamonds belong to this group.

High carbon steel is the first tool material introduced for manufacuring cutting tools. It has poor red hardness property, and it loses its cutting efficiency very quickly. Alloying elements like tungsten, chromium and vanadium, are used to produce high speed steel tool material. Its red hardness property is more than that of high carbon steel.

High speed steel is used for making solid tools, brazed tools and inserted bits. It is costlier than high carbon steel. Carbide cutting tools can retain their hardness at very high temperatures, and their cutting efficiency is higher than that of high speed steel. Due to its brittleness and cost, a carbide tool cannot be used as a solid tool. It is used as a brazed tool and throw-away tool bit.

Types of cutting tools

Objectives: At the end of this lesson you shall be able to
- **distinguish between end-cutting and side-cutting tools**
- **state the features of each type**
- **classify the different shapes of cutting tools used for lathe operations**
- **distinguish the characteristics and uses of different shapes of lathe tools.**

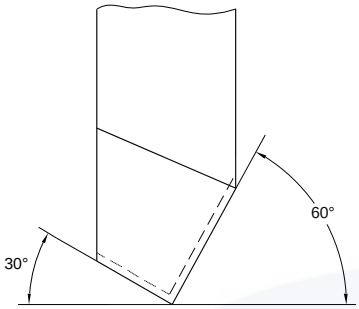
Cutting tool – classification

Cutting tools are classified as:

- single point cutting tools
- multi-point cutting tools
- form tools.

Single point cutting tools have one cutting edge which performs the cutting action. Most of the lathe cutting tools are single point cutting tools. (Fig 1)

Fig 1

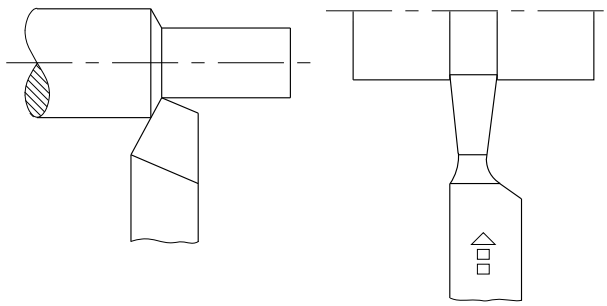


SINGLE POINT LATHE TOOL

Single point cutting tools used on lathes may be grouped into:

- side-cutting tools
- end-cutting tools. (Fig 2)

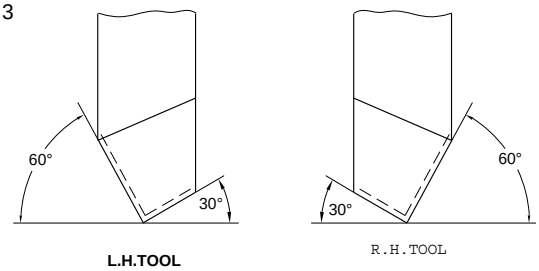
Fig 2



SIDE CUTTING TOOL END CUTTING TOOL

Side cutting edge tools have their cutting edges formed on the side of the cutting tool, and are used on lathes for most of the operations. They are again classified as right hand tools and left hand tools. (Fig 3) A right hand tool operates from the tailstock end towards the headstock, and a left hand tool operates from the headstock end towards the tailstock. The cutting edge is formed accordingly.

Fig 3



L.H.TOOL

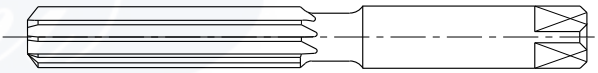
End-cutting tools have their cutting edge at the front end of the tools and are used on lathes for plunge cut operations.

Multi-point cutting tools (Fig 4)

These tools have more than one cutting edge and remove metal from the work simultaneously by the action of all the cutting edges. The application of multi-point cutting tools on the lathe is mostly done by holding the tool in the tailstock and feeding it to the work.

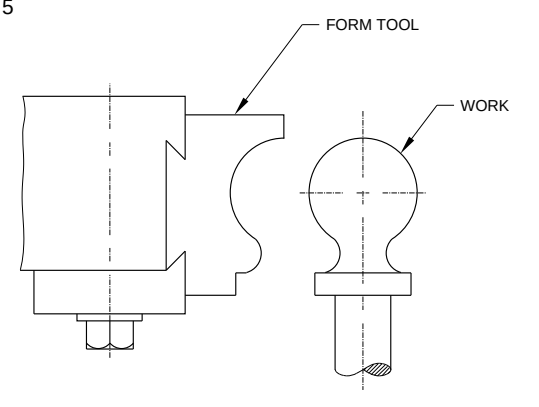
Form tools (Fig 5)

Fig 4



These tools reproduce on the work the form and shape of the cutting edges to which they are ground. Form tools perform the operations on the work by the plunging action, and are fixed on the tool post, square to the axis of the work, and are fed by the cross slide. They may have their cutting edges formed on square or rectangular section tool blanks acting radially. The form tools may be either circular form tools or tangential form tools. They may

Fig 5



require special holders to which they are fixed, and the holders themselves are clamped on the tool posts for the operations.

Lathe cutting tool types

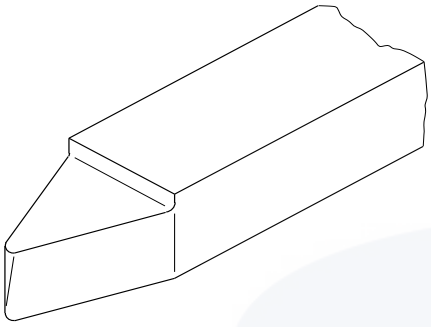
The tools used on lathes are
solid type tools
brazed type tools
inserted bits with holders
throw-away type tools. (carbide)

Solid tools (Fig 6)

These are tools having their cutting edges ground on solid bits of square, rectangular and round cross-sections. Most of the lathe cutting tools are of the solid type, and high carbon steel and high speed steel tools are used. The length and cross-section of the tool depend upon the capacity of the machine, the type of tool

post and the nature of the operation.

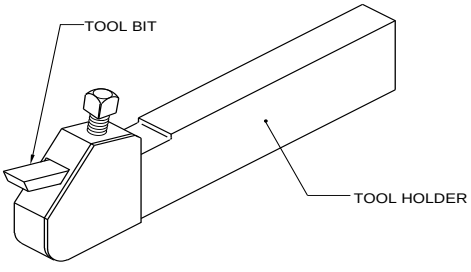
Fig 6



Inserted bits with holders (Fig 7)

Solid high speed steel tools are costly; hence, they are sometimes used as inserted bits. These bits are small in sizes, and are inserted in the holes of the holder. These holders are held and clamped in the tool posts to carry out the operations.The disadvantage in this type of tools is that the rigidity of the tool is poor.

Fig 7

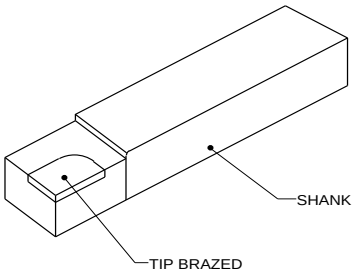


Brazed tools (Fig 8)

These tools are made up of two different metals. The cutting portions of these tools are of cutting tool materials, and the body of the tools do not possess any cutting ability, and are tough. Tungsten carbide tools are mostly of the brazed type. Tungsten carbide bits of square, rectangular and triangular shape are brazed to the tips of the shank.

The tips of the shank metal pieces are machined on the top surface according to the shape of the fits so as to accomodate the carbide bits. These tools are economical, and give better rigidity for the tools than the inserted bits clamped in the tool-holders. This is applicable to high speed steel brazed tools also.

Fig 8

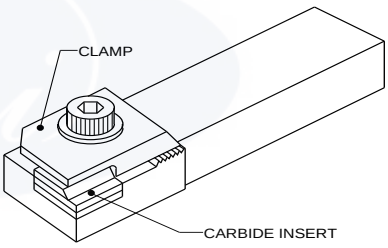


Throw-away type tools (Fig 9)

Carbide brazed tools when blunt or broken need grinding which is time consuming and expensive. Hence, they are used as throw-away inserts in mass production. Special tool- holders are needed and the carbide bits of rectangular, square or triangular shapes are clamped in the seating faces and machined on this type of special holders.

The seating faces are machined in such a way that the rake and clearances needed for the cutting bits are automatically achieved when the bits are clamped.

Fig 9



Lathe cutting tool shapes

Lathe cutting tools are available in a variety of shapes for performing different operations. Some of the lathe cutting tools generally used are:

- facing tool (Figs 10a and 10b)

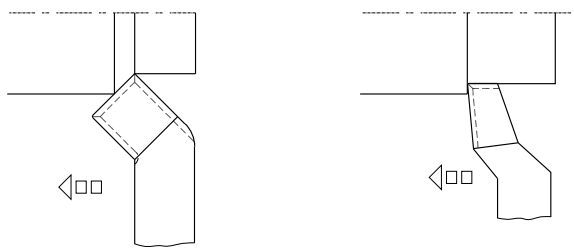
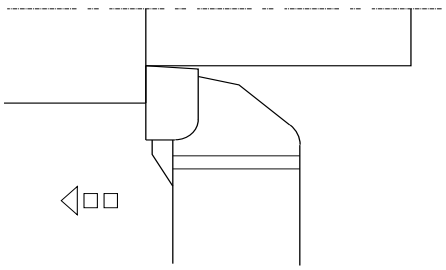


Fig 10a

Fig 10b

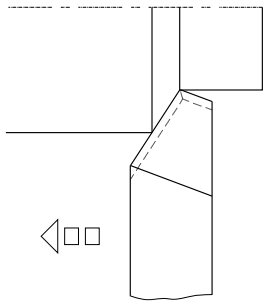
- knife edge tool (Fig 11)

Fig 11



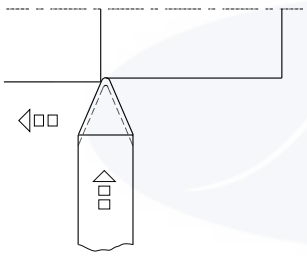
- roughing tool (Fig 12)

Fig 12



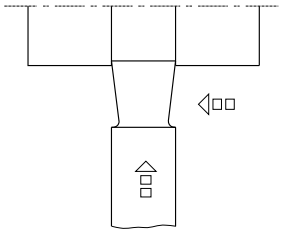
- round nose finishing tool (Fig 13)

Fig 13



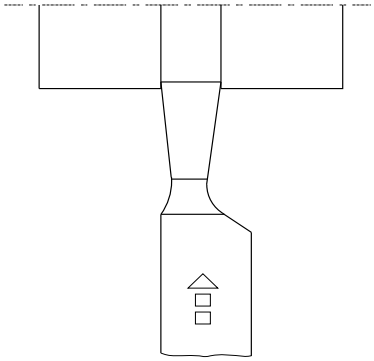
- broad nose finishing tool (Fig 14)

Fig 14



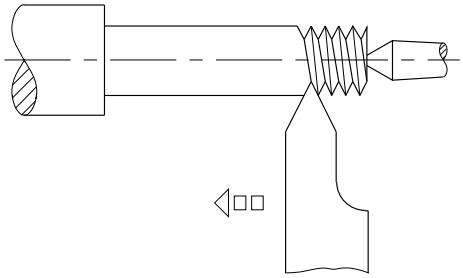
- undercutting tool / parting off tool (Fig 15)

Fig 15



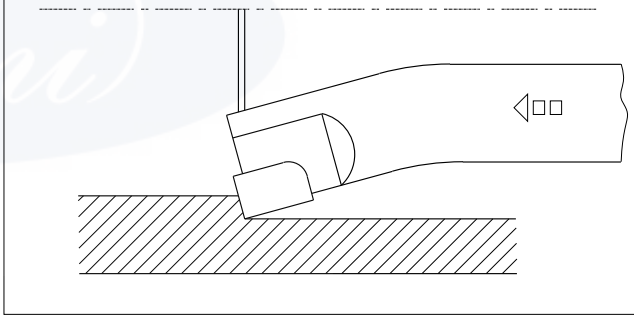
- external threading tool (Fig 16)

Fig 16



- boring tool (Fig 17)

Fig 17



Cutting tools - tool angles and their fuctions

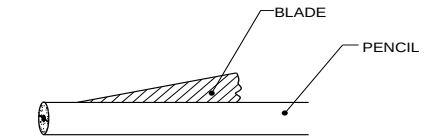
Objectives: At the end of this lesson you shall be able to

- **state the functions of angles and clearances given on the cutting tools**
- **state the types of angles of a lathe cutting tool**
- **state the characteristics of a rake angle**
- **state the characteristics of a clearance angle**

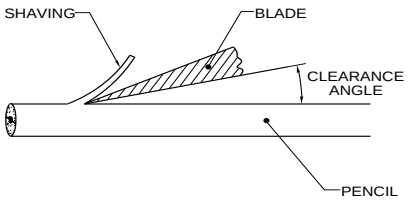
The tool acts like a wedge during turning. The wedge shaped cutting edge penetrates into the work and removes the metal. This necessitates the grinding of a tool cutting edge to a wedge shape.

When we sharpen a pencil with a pen knife by trial and error, we find that the knife must be presented to the wood at a definite angle, if success is to be achieved. (Fig 1)

Fig 1



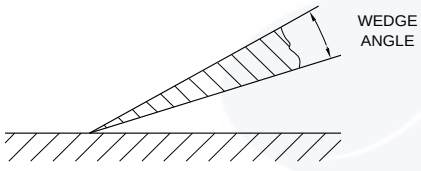
NO CLEARANCE
THE BLADE SKIDS ALONG THE PENCIL WITHOUT CUTTING



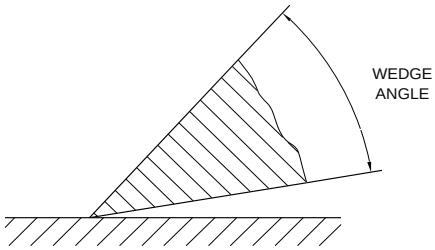
CLEARANCE
THE BLADE BITES INTO THE PENCIL AND CUTS

If, in the place of a wooden pencil, a piece of soft metal such as brass is cut, it will be found that the cutting edge of the blade soon becomes blunt, and the cutting edge gets crumbled. For the blade to cut the brass successfully, the cutting edge must be ground to a less acute angle. (Fig 2)

Fig 2



SHARPENED FOR CUTTING WOOD



SHARPENED FOR CUTTING METAL

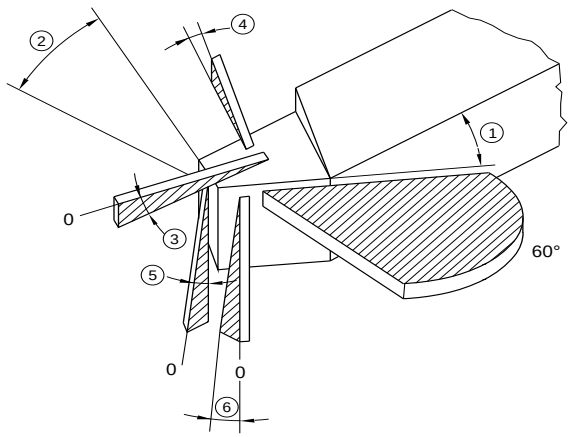
The angle shown in Fig 1 is called as clearance angle and that shown in Fig 2 is a wedge angle.

Angles ground on a lathe cutting tool (Fig 3)

All the angles given below may not be located or found in every tool. As an example a roughing tool is chosen. The angles and clearances ground on this tool are:

- approach angle (1)
- trail angle (2)
- top rake angle (3)
- side rake angle (4)
- front clearance angle (5)
- side clearance angle (6)

Fig 3



Approach angle (Fig 4)

This is also known as side cutting-edge angle. This is ground on the side of the cutting tool. The cutting will be oblique while cutting. The angle ground may range from 25° to 40° but as a standard a 30° angle is normally provided. The oblique cutting has the advantages over the orthogonal cutting, in which the cutting edge is straight. More depth of cut is given in the case of oblique cutting, since, when the tool is fed to the work, the contact surface of the tool increases gradually as the tool advances, whereas in the case of the orthogonal cutting, the length of the cutting edge for the given depth fully contacts the work from the begining itself which gives a sudden maximum load on the tool face. The area over which heat is distributed is greater in oblique cutting. (Fig 5)

Fig 4

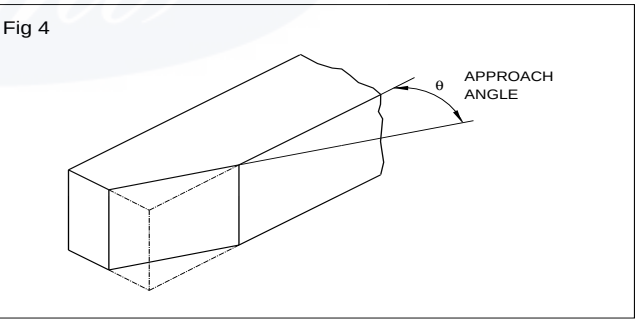
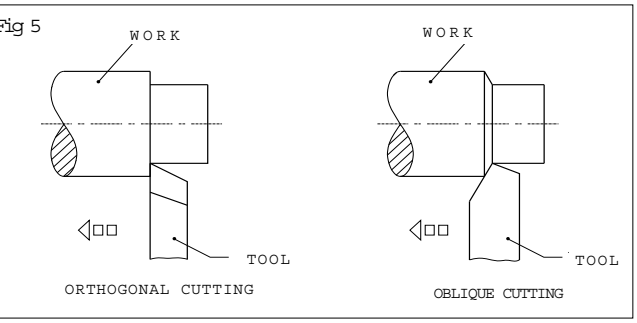


Fig 5

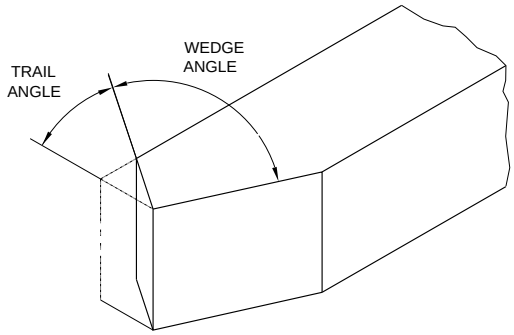


Trail angle (Fig 6)

It is also known as end-cutting edge angle, and is ground at 30° to a line perpendicular to the axis of the tool, as illustrated.

The approach angle and trail angle ground will form the wedge angle of 90° for the tool.

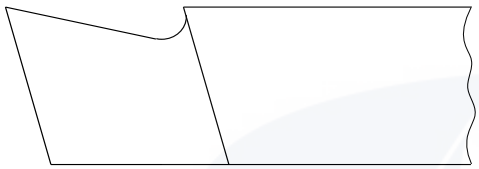
Fig 6



Top or back rake angle (Fig 7)

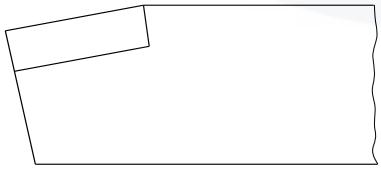
The rake angle ground on a tool controls the geometry of chip formation. Thereby, it controls the cutting action of the tool. The top or back rake angle of the tool is ground on the top of the tool, and it is a slope formed between the front of the cutting edge and the top of the face. If the slope is from the the front towards the back of the tool, it is known as a positive top rake angle, and if the slope is from the back of the tool towards the front of the cutting edge, it is known as a negative back rake angle. (Fig 8)

Fig 7



POSITIVE RAKE

Fig 8



NEGATIVE RAKE

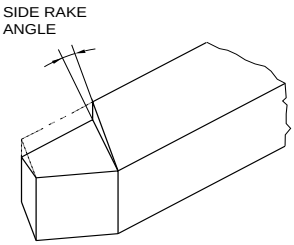
The top rake angle may be ground positive, negative or zero according to the material to be machined. When turning soft, ductile materials, which form curly chips, the positive top rake angle ground will be comparatively more than for turning hard brittle metals.

When turning hard metals with carbide tools, it is the usual practice to give a negative top rake. Negative top rake tools have more strength than tools with positive top rake angles.

Side rake angle (Fig 9)

A side rake angle is the slope between the side of the cutting edge to the top face of the tool width wise. The slope is from the cutting edge to the rear side of the tool. It varies from 0° to 20°, according to the material to be machined.

Fig 9

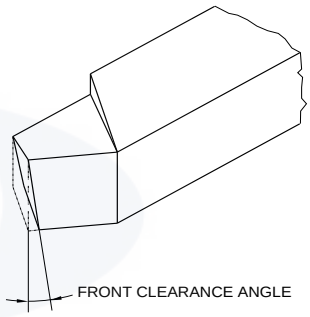


The top and side rake, ground on a tool control the chip flow, and this results in a true rake angle which is the direction in which the chip that shears away from the work passes.

Front clearance angle (Fig 10)

It is the slope between the front of the cutting edge to a line perpendicular to the axis of the tool drawn downwards which is known as the front clearance angle. The slope is from the top to the bottom of the tool, and permits only the cutting edge to contact the work, and avoids any rubbing action. If the clearance ground is more, it will weaken the cutting edge.

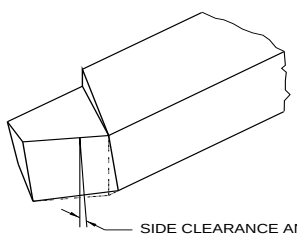
Fig 10



Side clearance angle (Fig 11)

The clearance angle is the slope formed between the side cutting edge of the tool with a line perpendicular to the tool axis drawn downwards at the side cutting edge of the tool. The slope is from the top of the side cutting edge to the bottom face. This is also ground to prevent the tool from rubbing with the work, and allows only the cutting edge to contact the work during turning. The side clearance angle needs to be increased when the feed rate is increased. When grinding rake and clearance angles, it is better to refer to the standard chart provided with the recommended values and grind. However, actual operation will indicate the performance of the tool, and will indicate to us, if any modifications are needed for the angles ground on the tool.

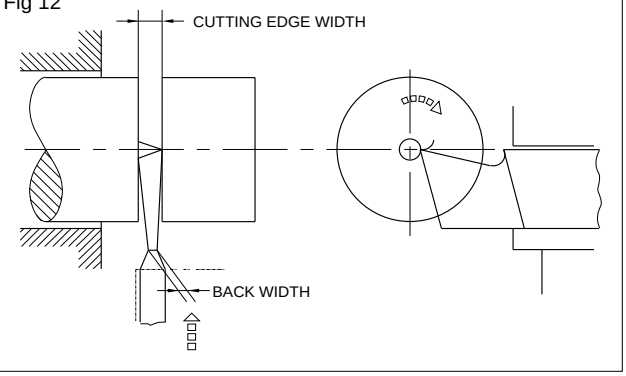
Fig 11



Side relief angle (Fig 12)

This angle is ground on parting and undercut tools on both sides. This will provide for the width of the cutting edge to be slightly broader than the back of the cutting edge.

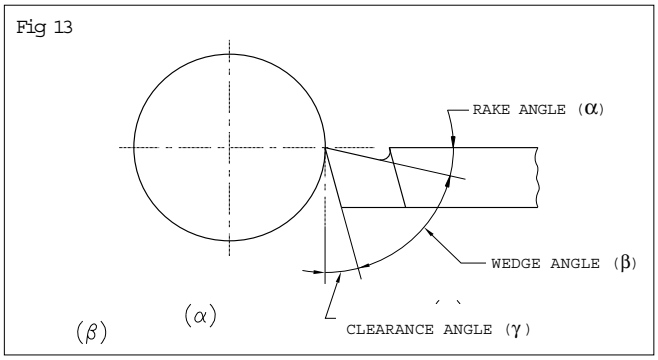
Fig 12



A side relief angle permits clearance between the sides of the tool and the groove walls, formed by the plunging action of the tool, thereby, preventing the tool from getting jammed in the groove, causing breakage. The relief is kept as minimum as possible. Too much of relief will weaken the tool cutting-edge tail, and also permit the chips to clog in the gap, in both cases causing the tool to break. Side relief is also provided sometimes to the main cutting edge of the facing tools, permitting the cutting point only to perform the operation, when the tool axis is set perpendicular to the lathe axis. The side relief angle normally does not exceed 2°.

Relationship between rake, clearance and wedge angles (Fig 13)

Fig 13



The rake angle , clearance angle and the wedge anlge have close relationship for effeciency in cutting. Execessive rake angle reduces the wedge angle, which helps in good peneteration, and it is particularly useful for cutting soft metals. A decreased wedge angle weakens the tool strength. Therefore, for cutting hard metals, the rake angle is zero or negative. The clearance angle is generally fixed depending on the geometry of the surface being cut.

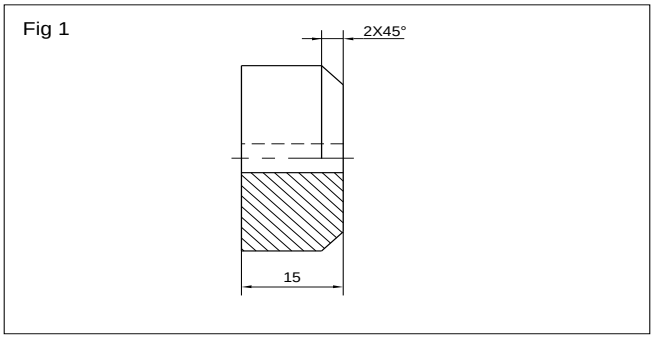
Lathe operations - chamfering

Objectives: At the end of this lesson you shall be able to
- **state the meaning of chamfering**
- **state the purpose of chamfering**
- **name the methods of chamfering**
- **differentiate between the different methods of chamfering.**

Chamfering (Fig 1)

It is a lathe operation performed by a cutting tool on the edges of faces of the external diameters and bore diameters for a restricted length, forming a bevelled edge.

Fig 1



Purpose of chamfering

The following are the purposes of chamfering.

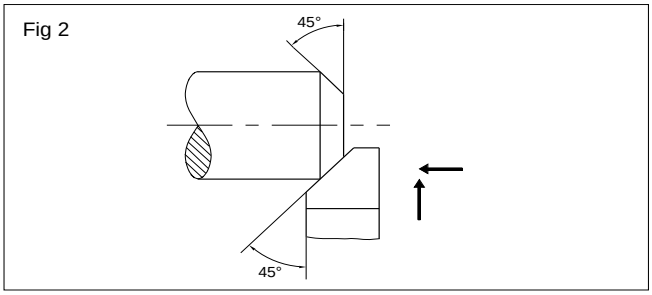
- To remove burrs and sharp edges from the turned components to make their handling safe.
- To permit for easy assembly of the mating components a shaft and a hole.
- To avoid formation of feather edges on the threaded parts.
- For better appearance.

Methods of chamfering

With the help of a cutting tool,having its cutting edge ground and formed to the angle of chamfer, and by directly applying the tool on to the edge of work, chamfering can be done. (Fig 2)

With the tool fixed in the tool post and by swivelling the compound slide to the angle of chamfering, and forming the bevelled edge is also one of the methods. (Fig 3) Chamfering can be done with a smooth file also.

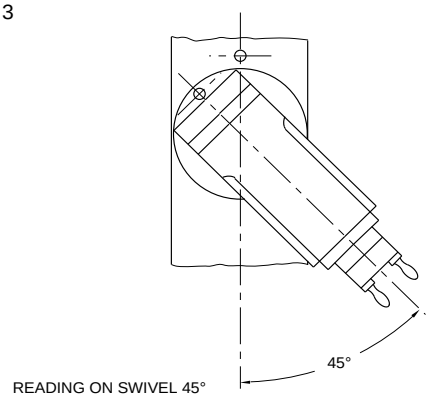
Fig 2



Using a chamfering tool (Fig 2)

Most of the chamfers are bevelled at 45°, and a tool with its cutting edge ground at 45° to the axis of the tool is used. The tool is held in the tool-post, with its axis square to the

Fig 3



axis of the work, and the cutting tool is fed on to the work surface where the chamfering is to be done. The reading of the graduated collar of the slide is noted when the tool's cutting edge just touches the work edge. Feeding is done by the hand wheel to the number of divisions determined according to the depth. The depth may be given by either the compound slide or a cross-slide since the angle is 45°. The cutting speed may be the same as that of the finish turning, and the feed may be by hand but it should be continuous and uniform.

Using a tool and the swivelling compound slide

(Fig 3)

A knife tool with a nose radius is used. The tool is held in the tool-post to centre height with a minimum overhang. The compound slide is swivelled to the angle of the chamfer. The carriage is locked and the feeding of the tool is done by the compound slide hand wheel. Successive cuts are given depending upon the length to be chamfered.

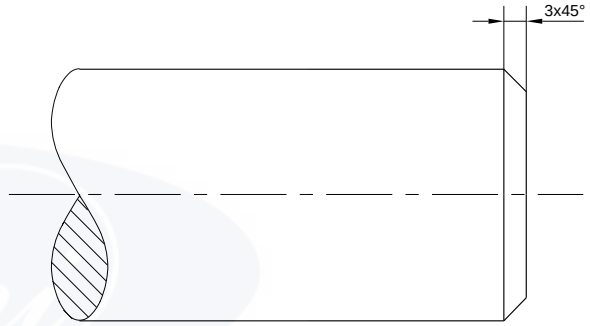
Using a file

This is a crude method and by this the accuracy of the chamfered angle as well as the length of the chamfer will not be maintained. The file is held on to the edge of the work tilted to the angle of the chamfer and moved along the edge of the rotating work. A gentle pressure is applied and the length of the chamfer is observed. The procedure is continued till the required length of the work is chamfered.

The chamfering angle is mostly 45° which is used for chamfering threaded components. But at times, it may be 30° or 60°.

Remember that the length of the chamfer does not refer to the length after chamfering but it is the distance measured parallel to the axis. (Fig 4)

Fig 4



Alignment of lathe centres

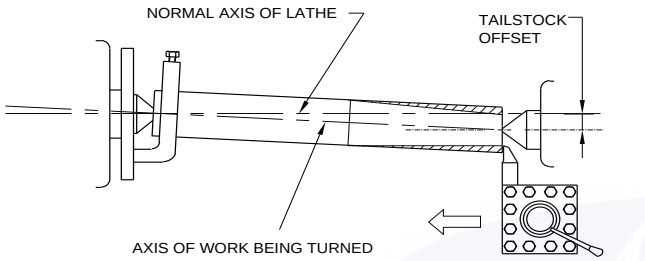
Objectives: At the end of this lesson you shall be able to
- **state the purpose of aligning lathe centres**
- **indicate the effect if the centres are not aligned**
- **state the methods of aligning lathe centres.**

In order to produce a true cylinder in parallel turning on work mounted between lathe centres, it is important that the headstock and the tailstock centres lie in a straight line,parallel to the axis of the lathe.

If the lathe centres are not aligned:

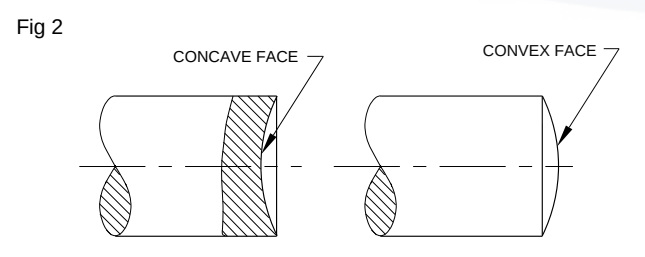
the work will be tapered (Fig 1)

Fig 1



facing will produce curved surfaces, the curvature being either concave or convex according to the direction of offset. (Fig 2)

Fig 2



WORK WILL NOT BE FACED SQUARE IF CENTRES ARE NOT ALIGNED

The tailstock consists of two parts - the base plates and the tailstock body. The base plate is machined to fit on the guideways of the lathe.

The body is mounted on the base plate and may be adjusted either towards or away from the cutting tool by means of the two adjusting screws. This allows the tailstock centre to be adjusted for alignment with the headstock centre.

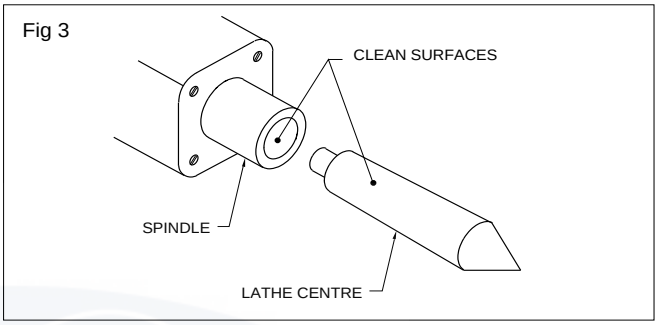
Before attempting to adjust the alignment of the lathe centres, it is important that both the headstock and the tailstock centres be checked as follows.

Withdraw both the centres and remove any nicks or burrs from their tapered shanks.

Examine the condition of the points of both the centres.

Clean the tapered holes in the headstock and the tailstock spindles with a cloth. Check and remove burrs, if any in the spindle. (Fig 3)

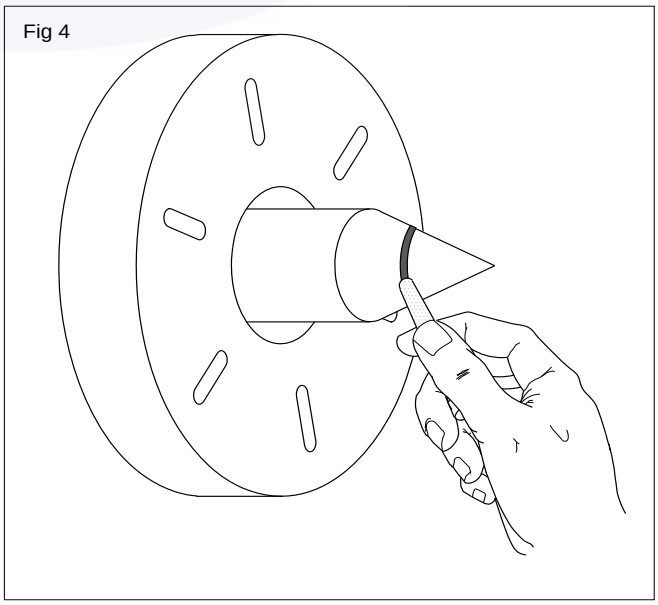
Fig 3



Replace the centres. Soft centres, if used, must be fitted into the headstock.

Check that the live centre in the headstock is running true. (Fig 4)

Fig 4



Methods of alignment

The lathe centres may be aligned by any of the following methods.

By visually aligning the points of the live and dead centres.

By visually aligning the marked centre lines on the end of the tail stocks.

The above methods should not be used for accurate works.

By taking trial cuts at each end of the work. Check finished diameter with a micrometer.

By using a parallel test bar and dial indicator. This is a fast and accurate method.

By the use of a micro-set adjustable centre. It is constructed to permit the centre to be offset slightly.

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Centre drilling

Objectives: At the end of this lesson you shall be able to
- **state the purpose of centre drilling**
- **state the defects in centre drilling**
- **indicate the causes for the defects**
- **state the remedies to avoid the defects.**

Centre drilling (Figs 1 and 2)

It is an operation of drilling and countersinking a hole on the face of the work, on the axis of the work. It is done by a cutting tool known as centre drill or combination drill held in a drill chuck. The drill chuck is mounted in the tailstock spindle and fed into the work by rotating the tailstock hand wheel. The spindle speed is calculated, taking into consideration the plain drilling diameter and the recommended cutting speed for drilling.

Fig 1

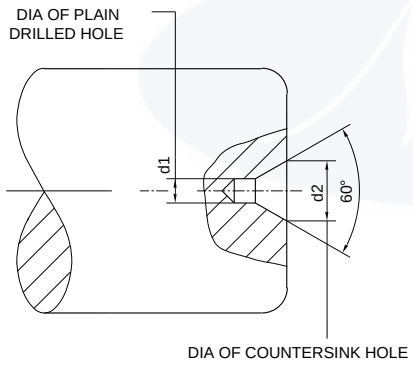
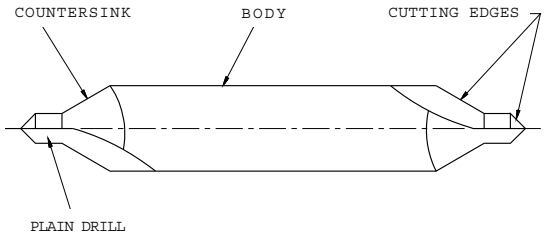


Fig 2

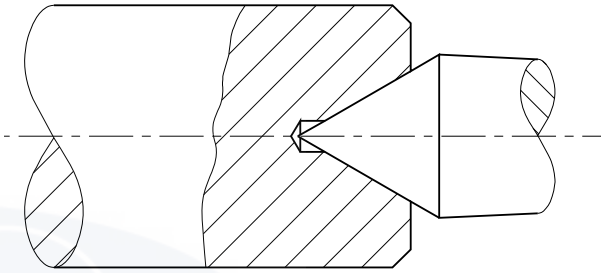


Defects in centre drilled holes

The two major defects in centre drilling are:

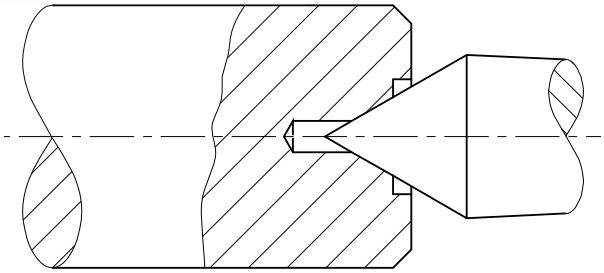
- insufficient depth of the plain drilled portion. (Fig 3)

Fig 3



- centre drilling done too deep.(Fig 4)

Fig 4



In the case of insufficient depth of drilling, the conical portion of the centre drill will not have any contact with the bearing surface of the centre drilled hole. This will lead to undue friction, overheating and damage to the tip of the centre drill. Sometimes breakage is also pssible and the broken part of the centre may get welded to the centre hole.

This defect can be avoided by feeding the centre drill up to 3/4 of the 60° countersink portion.

If the centre drill is fed too much a plain drilled portion will be formed by the body of the centre at the nose of the

bearing surface of the centre hole, and the area of contact beween the bearing surface and the work supporting centre will be the only point of contact, as illustrated in Fig 4. This will not provide proper support to the work and, any operation, if carried out, may result in dimensional inaccuracy, chatter and poor surface finish.
To rectify this defect, face the work, if the length of the work permits, and feed the centre drill to the recommended length.

Points to be considered while centre drilling

- Choose the right size and type of centre drill according to the diameter of the work.
- Select the recommended cutting speed and calculate the spindle rpm, taking into consideration the small plain drilling diameter of the centre drill.
- The job diameter does not influence the spindle speed.
- The face of the work should be free from any 'pips'.
- The alignment of the lathe centres should be perfect.
- The drill used should not damage the holding fingers and also the Morse taper shank.
- Ensure that all the three jaws of the chuck act simultaneously.
- The overhang of the tail stock barrel should be as minimum as possible.
- Any damage on the bearing surface of the lathe centre or the centre hole will not allow the work to run true.

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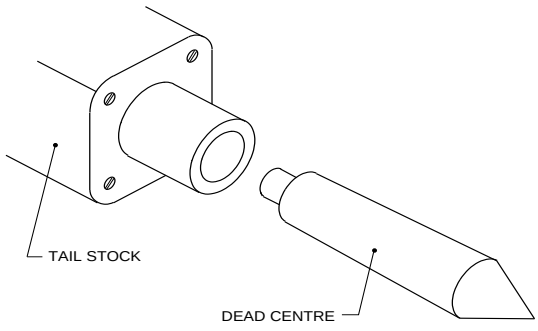
Lathe accessories - lather centres

Objectives: At the end of this lesson you shall be able to
• state what is a lathe centre
• distinguish between live centre and dead centre
• state the purpose of lathe centres
• name the different types of centres
• indicate the specific uses of each type of centre.

Lathe centre

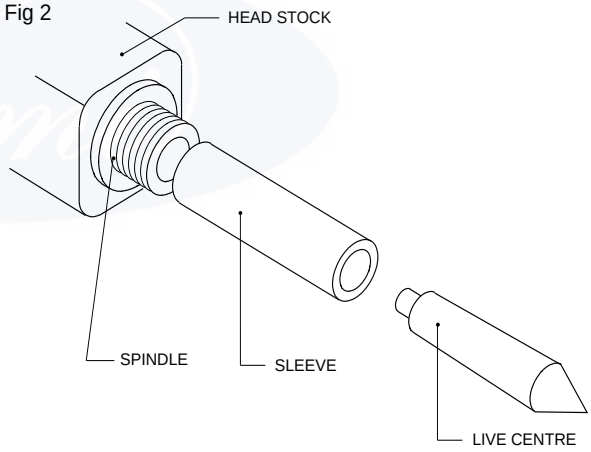
It is a lathe accessory. It is used to support lengthy works for carrying out lathe operations. When the work is held in the chuck, the lathe centre assembled in a tailstock supports the overhanging end of the work. The work is to be provided with a centre drilled hole on the face of the overhanging end. When the job is held in between centres to carry out the operation, it functions together with a driving plate and a suitable lathe carrier. The centre, which is accomodated in the main spindle sleeve, is known as the 'live centre' and the centre fixed in the tailstock spindle is known as the 'dead centre'. In construction, both centres are identical. Lathe centres have a conical point of 60° included angle, the body provided with a Morse taper shank and a tang. (Figs 1 and 2).

Fig 1



IN FINAL POSITION - CENTRE TO PROJECT 1 TO $1\frac{1}{2}$ TIMES LENGTH OF POINT

Fig 2

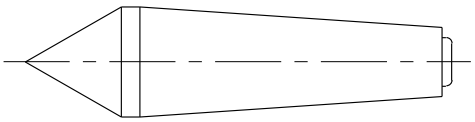
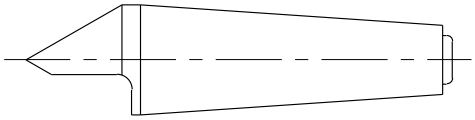
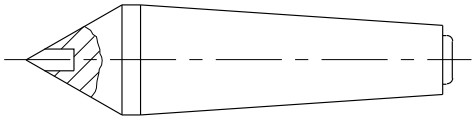
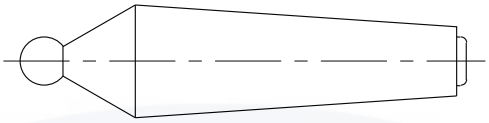
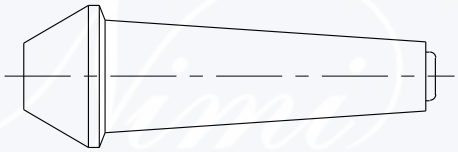
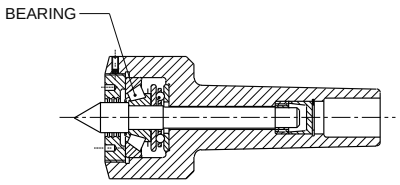
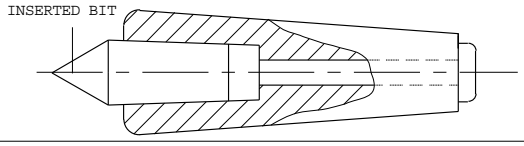
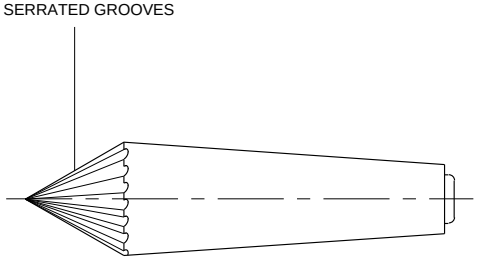


The dead centre is made out of high carbon steel, hardened and ground whereas the live centre need not have its conical tip hardened as it revolves with the work. A good lubricant should be used for the dead centre.

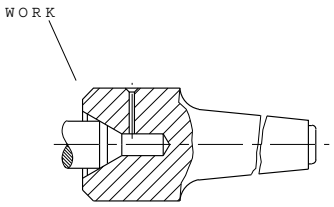
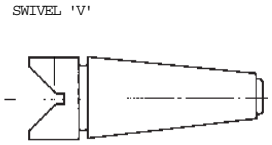
Types of centres and their uses

The following table gives the names of the most widely used types of lathe centres, their illustration, and specific uses.

TYPES OF LATHE CENTRES

1	Ordinary centres (common type)		Used for geneal purpose
2	Half centre		Though it is termed as half centre, little less than half is relieved at the tip portion. Used while facing the job without disturbing the setting.
3	Tipped centre		A carbide or a hard alloy tip is brazed into an ordinary steel shank. The hard tip is wear-resistant.
4	Ball centre		Minimum wear and strain. Particularly suitable for taper turning.
5	Pipe centre		Used for supporting pipes, shells and hollow end jobs.
6	Revolving centre		Frictionless. Used for supporting heavy jobs and jobs revolving with high speeds. A high-speed steel inserted centre, is supported by two bearings housed in a body.It is also called the revolving dead centre.
7	Insert type centre		Economical. Only the small high-speed steel insert is replaced.
8	Self-driving live centre		Usually mounted on the headstock spindle. Used while machining the entire length of the job in one setting. Grooves cut around the circumference of the centre point provide for good gripping for the job. This centre can be used only for soft metal jobs and not for hardened jobs.

TYPES OF LATHE CENTRES (contd.)

9	Female centre		This centre is used to support the end of the job where no countersink hole is permitted.
10	Swivel 'V' centre		This centre is used to support a job in the 'V' portion and to drill holes across the round job by using a drill bit in the headstock spindle.

Lathe parts - main spindle

Objectives: At the end of this lesson you shall be able to
- **state the functions of the main spindle**
- **state the constructional features of a main spindle**
- **name the different types of spindle noses**
- **distinguish the functional features of each type of spindle nose.**

Main spindle

The main spindle is fitted on the headstock. It has facilities for holding and rotating the work-holding devices, and, therefore, the work itself.

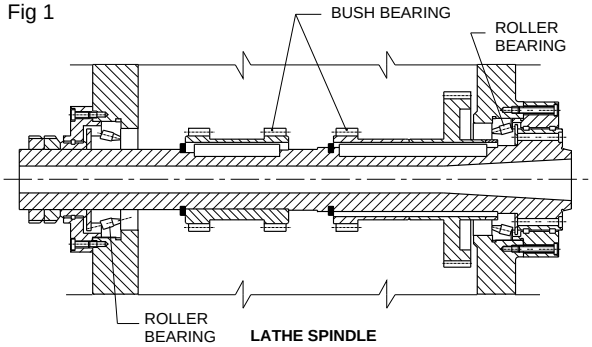
Features (Fig 1)

The main spindle is hollow so as to accept the bar stock and also to reduce the weight. It is hardened, ground and super finished to high accuracy. In the assembled condition in the headstock, its axis is perfectly parallel to the lathe bed-ways. The main spindle is carried and supported by anti-frictional ball, roller, thrust and taper roller bearings according to the design of the machine.

The portion of the main spindle,which is outside the headstock box section, is known as the spindle nose.

It is bored internally to a Morse-taper to accept the adapter sleeve which, in turn,accomodates the live centre. The periphery of the spindle nose has provisions for mounting the work-holding devices.

Fig 1



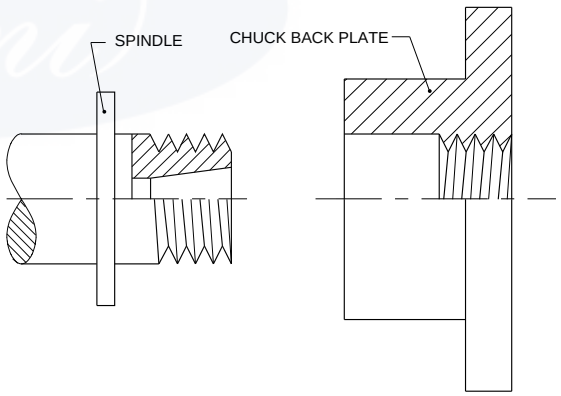
LATHE SPINDLE

Types of spindle noses and their features

Plain threaded spindle nose (Fig 2)

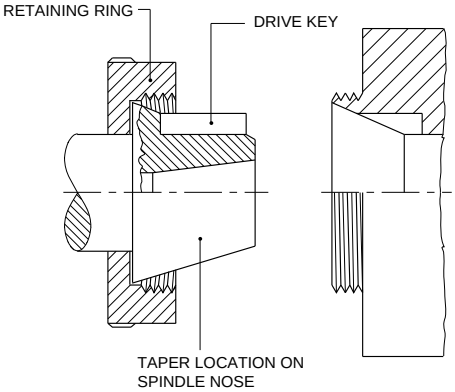
Long taper nose spindle (Fig 3)

Fig 2



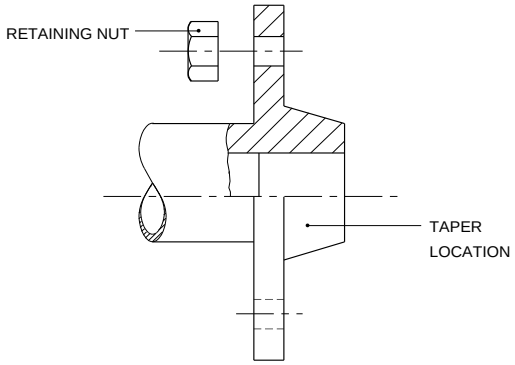
PLAIN THREADED SPINDLE NOSE

Fig 3



LONG TAPER NOSE SPINDLE

Fig 4



SHORT TAPER NOSE SPINDLE

Short taper nose spindle (Fig 4)

Spindle nose mountings with tapered matching surfaces are preferred as they are self-aligning, and compensate for normal wear without much loss of accuracy.

The spindle located in bearings enables to have its axis and the axis of the work-holding device mounted upon it parallel to the bed slideways of the machine both in the horizontal and vertical planes.

The main spindle, its bearings and the headstock castings are sufficiently rigid to prevent the mass of the work and the work-holding device, together with the cutting forces, from deflecting the spindle axis from its normal alignment.

Feed mechanism of lathe

Objectives: At the end of this lesson you shall be able to
- **name the parts of the feeding mechanism**
- **state the functional features of the feeding mechanism.**

Feed mechanism (Fig 1)

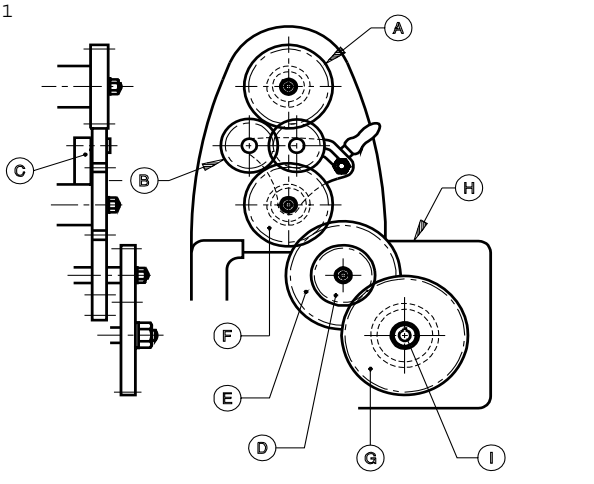
The feed mechanism of a lathe enables automatic feeding for the tool longitudinally and transversely as needed. By automatic feeding the finish on the work will be better, the feeding of the tool will be at a uniform continuous rate and it takes less time to finish the operation while manual labour is avoided.

The feed mechanism comprises of the following.

- Spindle gear (A)
- Tumbler gear unit (B)
- Fixed stud gear (C)
- Change gear unit (DEFG)
- Quick change gear box (H)
- Feed shaft / Lead screw (I)
- Apron mechanism (not in the figure)

The proportionate tool movement for each revolution of work is achieved through all the above units of the feed mechanism.

Fig 1



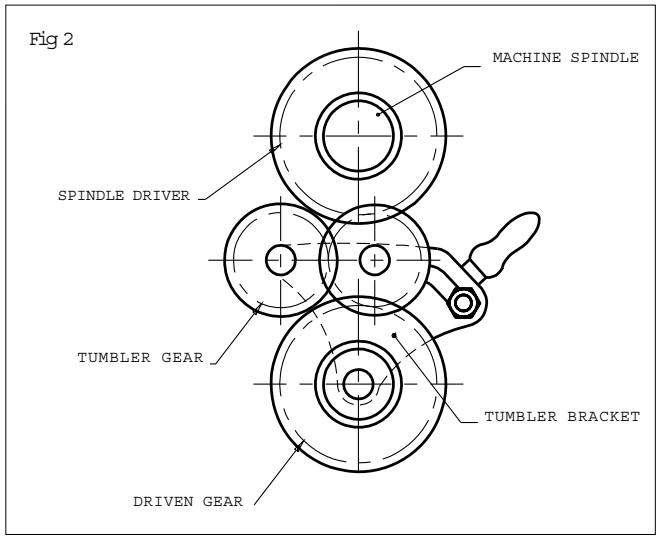
Spindle gear

The spindle gear is fitted to the main spindle, and it is outside the headstock casting. It revolves along with the main spindle.

Tumber gear unit

The tumbler gear unit itself is of three gears, having the same number of teeth and it connects the spindle gear to the fixed gear. It is also called the reversing gear unit as it is used to change the direction of feed of the tool for the same direction of rotation of the spindle. It can be engaged and disengaged with the fixed stud gear by the operation of the hand lever provided in the unit. (Fig 2)

Fig 2



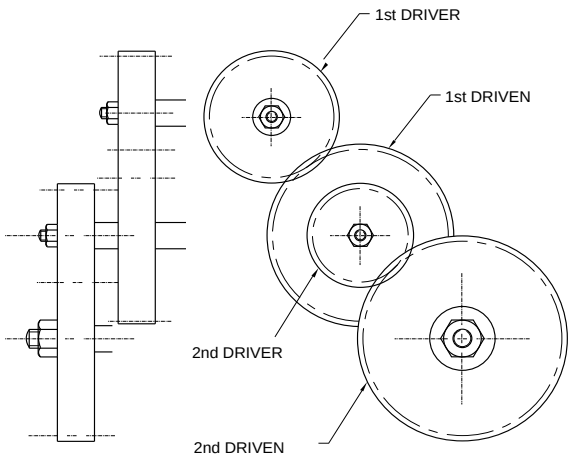
The fixed stud gear

The fixed stud gear gets the drive from the main spindle gear through the tumbler gear unit and runs at the same number of revolutions per minute as the spindle gear on most lathes.

Change gear unit

The fixed stud gear transmits its drive through a change gear unit to the quick change gear box. The change gear unit has provision for changing the driver, the driven and the idler gears from the set of change gears available for the purpose of feed changing as an additional unit. (Fig 3)

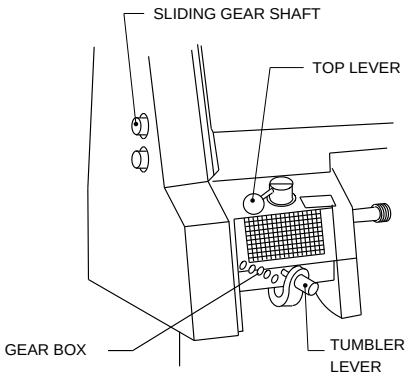
Fig 3



Quick change gear box

The quick change gear box is provided with levers outside the box casting, and by shifting the levers, different gears are brought in mesh so that different feed rates can be given to the tool. A chart listing the different feed rates for the different positions of the levers is fixed to the casting, and by referring to the table, the levers may be engaged in position for the required feed rate. (Fig 4)

Fig 4



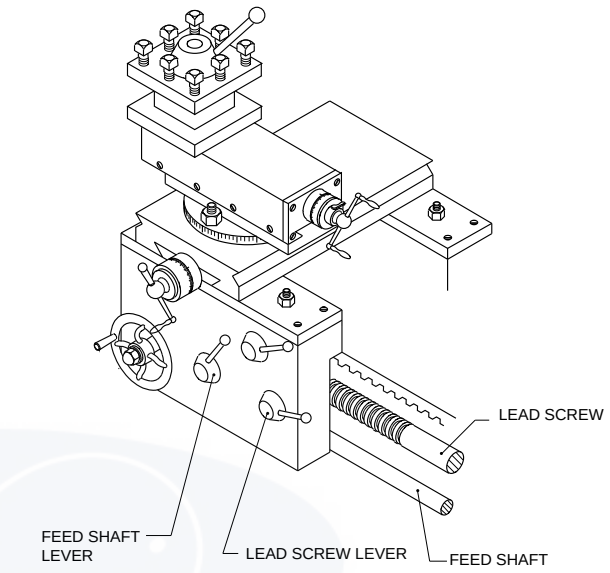
The feed shaft

The feed shaft gets its drive from the quick change gear box, and through the apron mechanism, the rotary movement of the feed shaft is converted into the linear movement of the tool.

The apron mechanism

The apron mechanism has the arrangement for transmitting the drive from the feed shaft to the saddle for longitudinal movement of the tool or to the cross-slide for the transverse movement of the tool. (Fig 5)

Fig 5



Lathe carriers

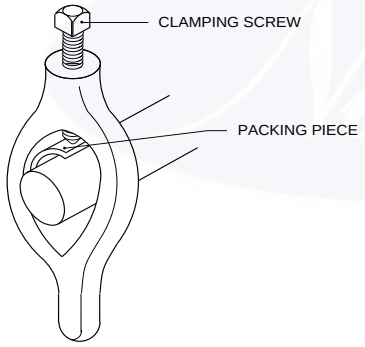
Objectives: At the end of this lesson you shall be able to
- **state the function of lathe carriers**
- **state the features of different types of lathe carriers**
- **name the different types of lathe carriers**
- **distinguish between the uses of different types of lathe carriers.**

They are otherwise called as lathe dogs. They are used to drive the work during turning between centres. The work is clamped firmly in the lathe carrier. It consists of a cast iron body and a clamping screw. It is available with a straight tail or bent tail. They are available in a set of 10, capable of accommodating works with a wide range of diameters. The tails of the carriers are meant to locate and drive the workpiece for turning. (Fig 1) To protect the finished surface from damage, a packing piece (made of soft material) is used under the clamping screw.

The types of lathe carriers commonly used are:

- straight tail carrier
- bent tail carrier
- clamp type carrier

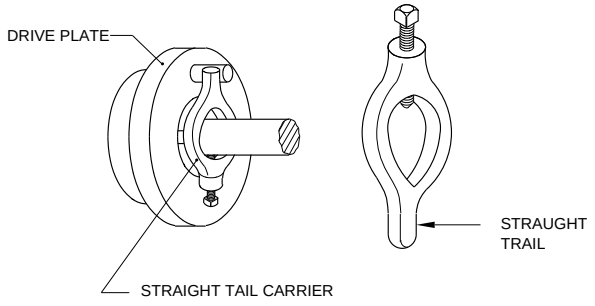
Fig 1



FITTING CARRIER TO WORK

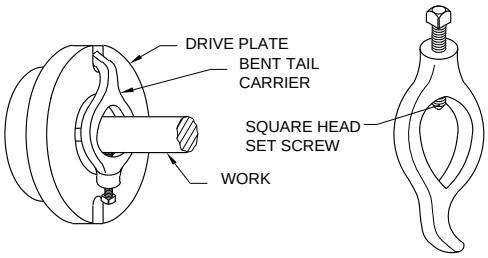
The tail of the straight tailed carrier locates against the driving pin of the driving plate and provides a positive drive for the workpiece. (Fig 2)

Fig 3



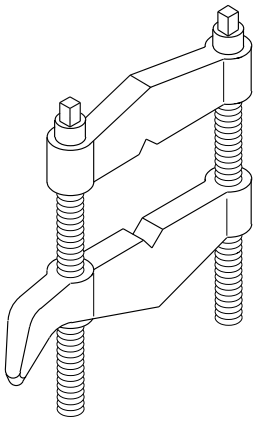
A bent tailed lathe carrier engages into a 'u' slot of the catch plate and drives the workpiece. (Fig 3)

Fig 2



The clamp type lathe carrier is designed with a clamping plate and adjustable screws. It holds a wide range of diameters of work because it is provided with a `V' groove and adjustable bolts and nuts. This carrier may be used to hold square and rectangular sectioned rods also. It is also very useful to hold small diameter jobs because of the provision of the 'V' groove. (Fig 4)

Fig 4



CLAMP TYPE

Driving plate and face plate

Objectives: At the end of this lesson you shall be able to
- **distinguish between the features and the uses of dif- ferent driving plates**
- **name the parts of a face plate**
- **distinguish between the features and uses of different face plates**
- **identify the face plate accessories.**

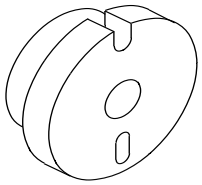
When turning jobs between centres, driving plates are used. They are:

- catch plate
- driving plate
- safety driving plate.

Catch plate

It is designed with a 'U' slot and an elliptical slot to accommodate the bent tail of the lathe carrier. (Fig 1)

Fig 1

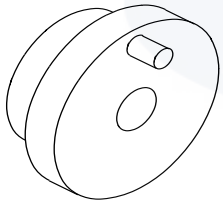


CATCH PLATE

Driving plate with pin

It is designed with a projected pin which locates the straight tail of the lathe carrier. (Fig 2)

Fig 2

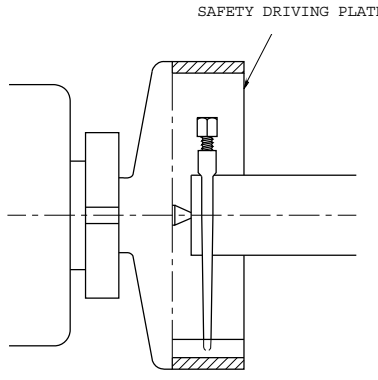


DRIVE PLATE

Safety driving plate

It is similar in construction to that of a driving plate but equipped with a cover to protect the operator from any injuries. (Fig 3)

Fig 3



It is made of cast steel and is machined to have its face perfectly at right angles to the bore. It is provided with a stepped collar at the back. The bore is designed to suit the spindle nose to which the plate has to be mounted.

Uses

The driving plate with a straight tail carrier provides a positive drive for the workpiece.

Catch plates with bent tail carriers use a minimum length of the workpiece for clamping purposes.

A safety driving plate protects the operator from likely injuries.

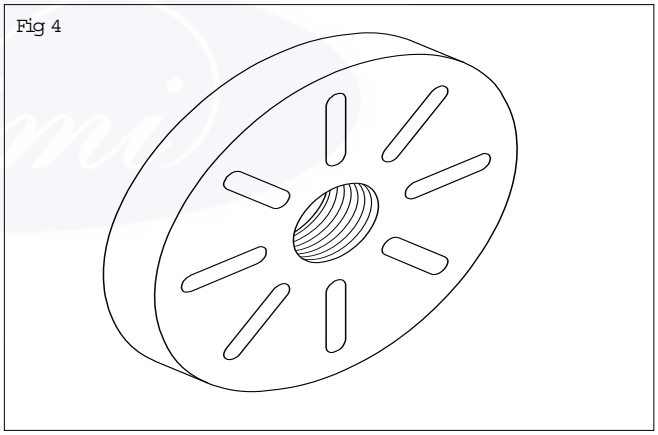
Face plates

They are similar in construction to the lathe catch plates but are larger in diameter.

The different types of face plates are:

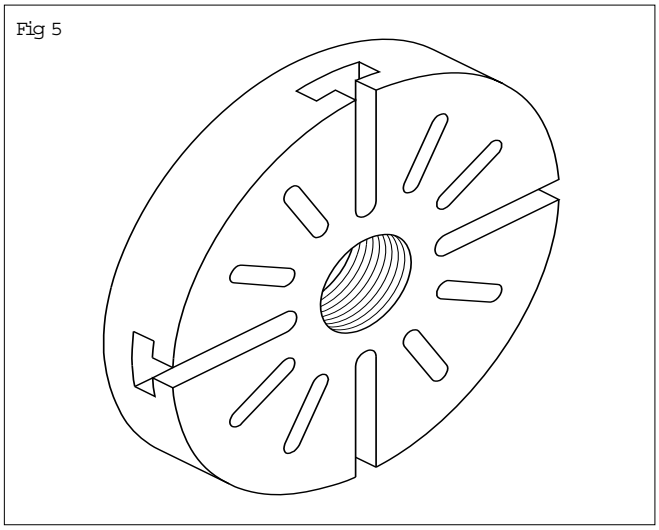
- face plates with only elongated radial slots (Fig 4)

Fig 4



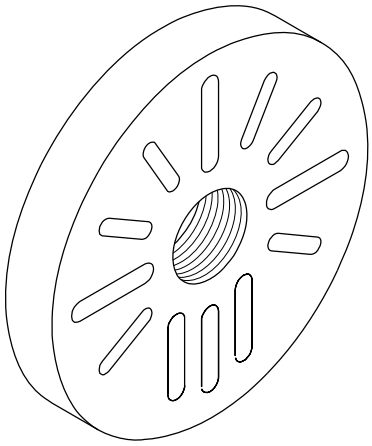
- face plates with elongated slots and 'T' slots. (Fig 5)

Fig 5



- face plates with elongated radial slots and additional parallel slots. (Fig 6)

Fig 6



Face plates are used along with the following accessories.

Clamps, 'T' bolts, Angle plate, Parallels, Counterweight,

Stepped block, 'V' Block etc.

Uses

Large, flat, irregular shaped workpieces, castings, jigs and fixtures may be firmly clamped to a face plate for various turning operations.

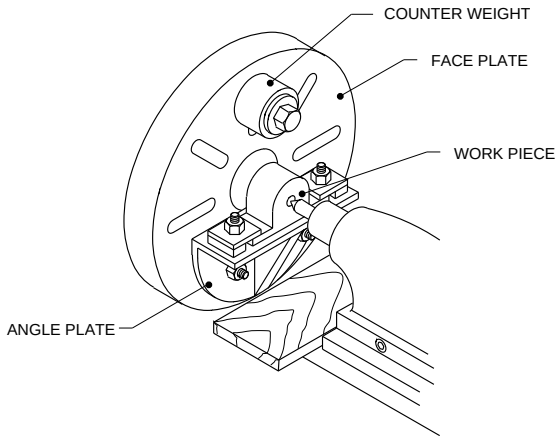
A work can be mounted on a face plate while the face plate is on the lathe spindle or on the workbench. If the workpiece is heavy or awkward to hold, the workpiece is mounted while the face plate is on the workbench. Before mounting the face plate set up to the spindle, it is advantageous to locate the workpiece on the face plate and centre the workpiece. Centre a punch mark or hole approximately on the face plate. This makes it easier to true the work after the face plate is mounted on to the spindle.

The position of the bolts and clamps is very important, if a workpiece is to be clamped effectively.

If a number of duplicate pieces are to be machined, the face plate itself can be set up as a fixture, using parallel strips and stop blocks.

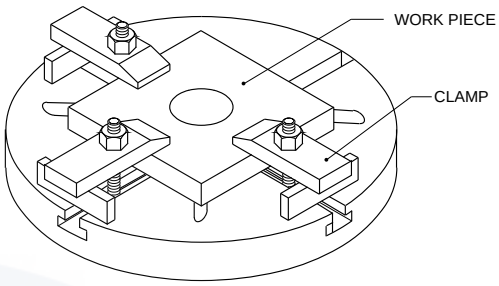
The application of the face plate with the accessories in different set ups is shown in the sketches below.(Figs 7,8 and 9)

Fig 7



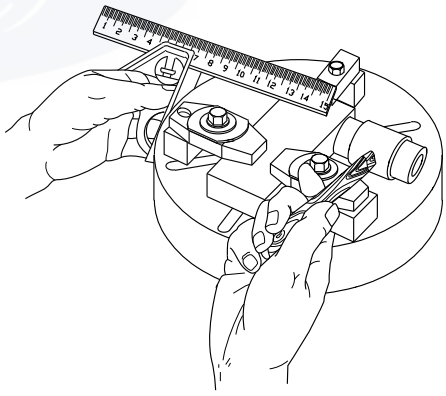
WORK HELD BY AN ANGLE PLATE

Fig 8



WORK CLAMPED DIRECTLY TO FACE PLATE

Fig 9



LOCATING WORK ON A FACE PLATE

Lathe operation - taper turning

Objectives: At the end of this exercise you shall be able to
- **name the methods of turning tapers on lathes**
- **state how each method is performed**
- **state the advantages and disadvantages of each method.**

Methods of turning taper on a lathe

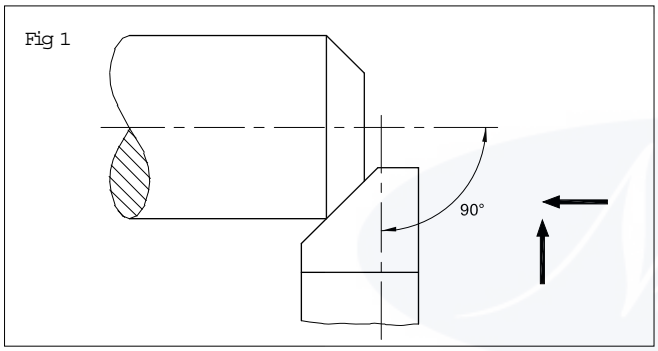
The different methods of taper turning on a lathe are:

- form tool method
- compound slide method
- tailstock offset method
- taper turning attachment method.

Form tool method (Fig 1)

This method is used in mass production for producing small lengths of taper. The form tool should be set at right angles to the axis of the work and feed.

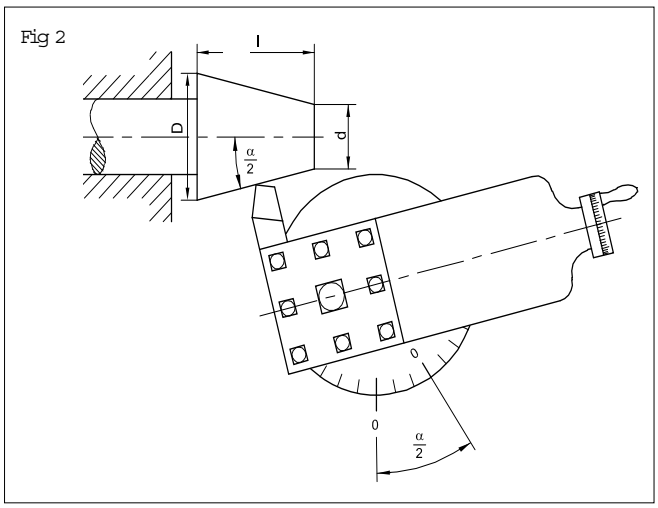
Fig 1



The carriage should be locked while turning taper by this method.

Compound rest method (Fig 2)

Fig 2



In this method, the compound rest is swivelled to half the included angle of the taper, and the taper is turned by feeding the top slide.

The angle '$\frac{\alpha}{2}$' to which the compound rest is set is found by the formula

$$\tan \frac{\alpha}{2} = \frac{D - d}{2l}$$

where

D = big dia.
d = small dia.
l = length of taper

$\frac{\alpha}{2}$ = 1/2 included angle in degrees.

Advantages

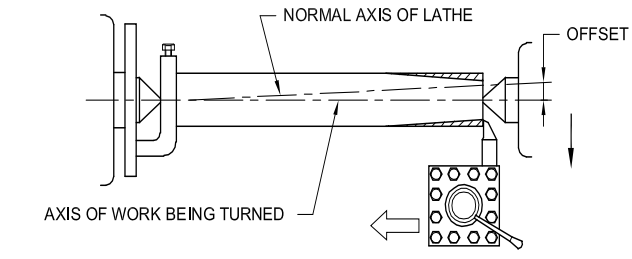
- Both internal and external tapers can be produced.
- Steep tapers can be produced.
- Easy setting of the compound rest.

Disadvantages

- Only hand feed can be given.
- Threads on the taper portion cannot be produced.
- The taper length is limited to the movement of the top slide.

Tailstock offset method (Fig 3)

Fig 3



IF CENTRES ARE NOT IN LINE TAPERED WORK WILL RESULT.

In this method the job is held at an angle, and the tool moves parallel to the lathe axis. The body of the tailstock is shifted on its base to an amount corresponding to the angle of the taper.

These tapers can be turned between centres only, and this method is not suitable for producing steep tapers. The amount of offset is found by the formula

$$\text{offset} = \frac{(D - d)\, L}{2l}$$

where

D = big dia. of taper
d = small dia. of taper
l = taper length
L = total length of the job.

Advantages

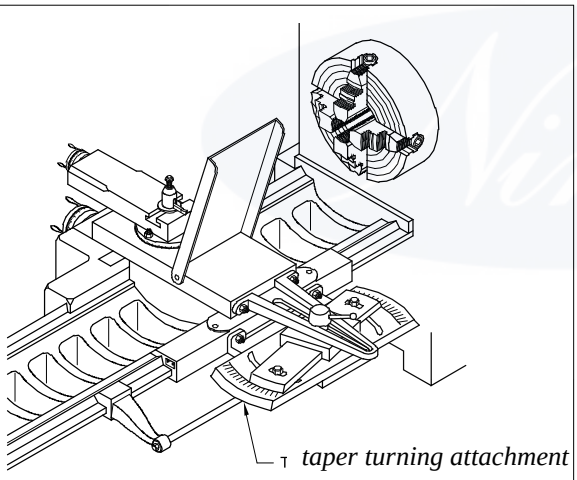
- Power feed can be given.
- Good surface finish can be obtained.
- Maximum length of taper can be produced.
- External thread on taper portion can be produced.
- Duplicate tapers can be produced.

Disadvantages

- Only external taper can be turned.
- Accurate setting of the offset is difficult.
- Taper turning is possible when the work is held between centres only.
- Damages the centre drilled holes of the work.
- The alignment of the lathe centres will be disturbed.

Taper turning by attachment (Fig 4)

Fig 4



A special attachment is provided on a few modern lathes. Here the job is held parallel to the axis and the tool moves at an angle. The movement of the tool is guided to the required angle by the attachment.

Advantages

- Both internal and external tapers can be produced.
- Threads on both internal and external taper portions can be cut.
- Power feed can be given.
- Lengthy taper can be produced.
- Good surface finish is obtained.
- The alignment of lathe centres is not disturbed.
- It is most suitable for producing duplicate tapers because the change in length of the job does not affect the taper.
- The job can be held either in chuck or in between centres.

Disadvantage

- Use is limited to turning of slow taper angles only.

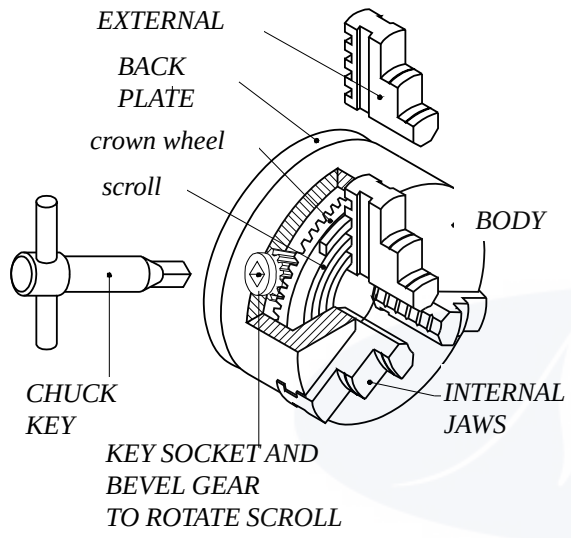
Lathe accessories : work-holding devices - 3-jaw chuck

Objectives: At the end of this lesson you shall be able to
- **name the parts of a 3-jaw chuck**
- **state the constructional features of a 3-jaw chuck**
- **distinguish between a 3-jaw chuck and a 4-jaw chuck**
- **state the merits and demerits of a 4-jaw chuck over a 3-jaw chuck**
- **specify a chuck.**

3-jaw chuck (Fig 1)

The 3-jaw chuck is also known as a self-centering chuck. The majority of the chucks have two sets of jaws for holding internal and external diameters. Only a perfect round work with equally spaced flats divisible by three should be held in a 3-jaw chuck.

Fig.1



THREE-JAW CHUCK

From the construction of a 3-jaw chuck it is seen that the scroll not only clamps a component in place but also locates the component. This is fundamentally a bad practice, since any wear in the scroll and/or the jaws impairs the accuracy of location. Further there is no means of adjustment possible to compensate for this wear.

Jaws of this type of chuck are not reversible, and separate internal and external jaws have to be used.

The parts of a 3-jaw chuck are:

- backplate
- body
- jaws
- crown wheel, and
- pinion.

Back plate (Fig 1)

The back-plate is fastened at the back of the body by means of Allen screws. It is made out of cast iron. Its bore is tapered to suit the taper of the spindle nose. It has a keyway which fits into the key provided on the spindle nose. There is a step in the front on which the thread is cut. The threaded collar, which is mounted on the spindle, locks the chuck by means of the thread and locates by means of the taper and the key.

Body (Fig 1)

The body is made out of cast steel, and the face is hardened. It has three openings 120° apart to assemble the jaws and operate them. Three pinions are fixed on the periphery of the body to operate the jaws by means of a chuck key. It is hollow in its cross-section. A crown wheel is housed inside the body.

Jaws (Fig 1)

The jaws made out of high carbon steel, hardened and tempered, slide on the openings of the body. Generally there are two sets of jaws viz. 1) external jaws and 2) internal jaws. External jaws are used for holding solid works. Internal jaws are used for holding hollow works. Steps on the jaws increase the clamping range. The back side of the jaws is cut with scroll thread. Each jaw is numbered in a sequential manner, which helps in fixing the jaws in the corresponding numbered slots.

Crown wheel (Fig 1)

The crown wheel is made out of alloy steel, and is hardened and tempered. On one side of the crown wheel, a scroll thread is cut to operate the jaws, and the other side is tapered on which the bevel gear teeth are cut to mesh with the pinion. When the pinion is rotated by means of the chuck key, the crown wheel rotates, thus causing the jaws to move inward or outward, depending upon the rotation.

Pinion (Fig 1)

The pinion is made out of high carbon steel, hardened and tempered. It is fitted on the periphery of the body. On the top of the pinion a square slot is provided to accommodate the chuck key. It has a tapered portion on which bevel gear teeth are cut, which match with the crown wheel.

COMPARISON BETWEEN 3-JAW CHUCK AND 4-JAW CHUCK

3-jaw chuck	4-jaw chuck
Only cylindrical, hexagonal works can be held.	A wide range of regular and irregular shapes can be held.
Separate internal and external jaws are available.	Jaws are reversible for external and internal holding.
Setting up of work is easy.	Setting up of work is difficult.
Has less gripping power.	More gripping power.
Depth of cut is comparatively less.	More depth of cut can be given.
Heavier jobs cannot be turned.	Heavier jobs can be turned.
Workpieces cannot be set for eccentric turning	Workpieces can be set for eccentric turning.
Concentric circles are not provided on the face.	Concentric circles help for approximate setting of jaws.
Accuracy decreases as the chuck gets worn out.	There is no loss of accuracy as the chuck gets worn out.

To specify a chuck, it is essential to provide the following :

Specification of a chuck	*Example*
Type of chuck	3-jaw self-centering chuck
Capacity of the chuck	Gripping capacity 450 mm.
Diameter of the body	Diameter of the body 500 mm.
Width of the body	Width of the body 125 mm.
Method of mounting to the spindle nose.	Tapered and or threaded method of mounting

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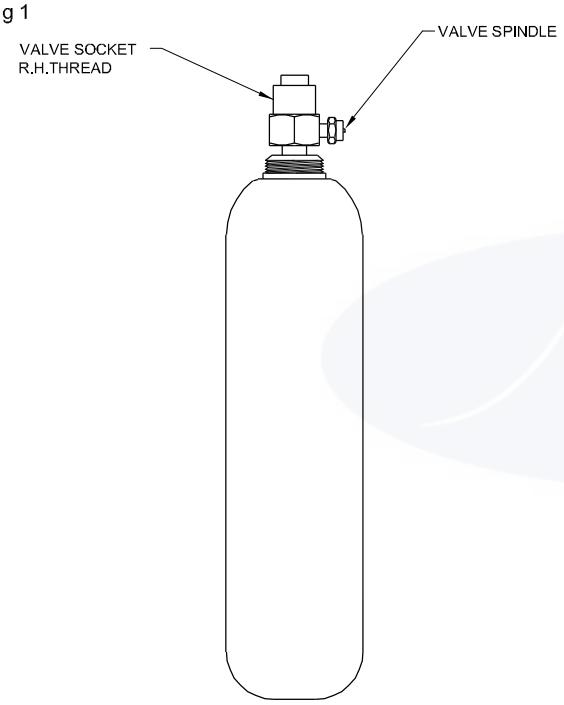
Tools and Equipment used in oxy-acetylene gas welding

Objectives : At the end of this lesson you shall be able to
- **compare the features of oxygen and acetylene regulators**
- **state the features of hose-pipes used in gas welding**
- **distinguish between the hose connections for oxygen and acetylene regulators and blowpipe**
- **identify the features of a blowpipe and state their functions**
- **state the features of a spark lighter**
- **state the use of a cylinder trolley.**

Oxy-acetylene gas welding

The essential requirement for a beginner dealing with oxy-acetylene gas welding is to identify the tools and equipment required and know their uses.

Fig 1



OXYGEN CYLINDER (COLOUR BLACK)

Oxygen gas cylinders (Fig 1)

The gas cylinder is a steel bottle, painted black with 7m^3 capacity for storing gas.

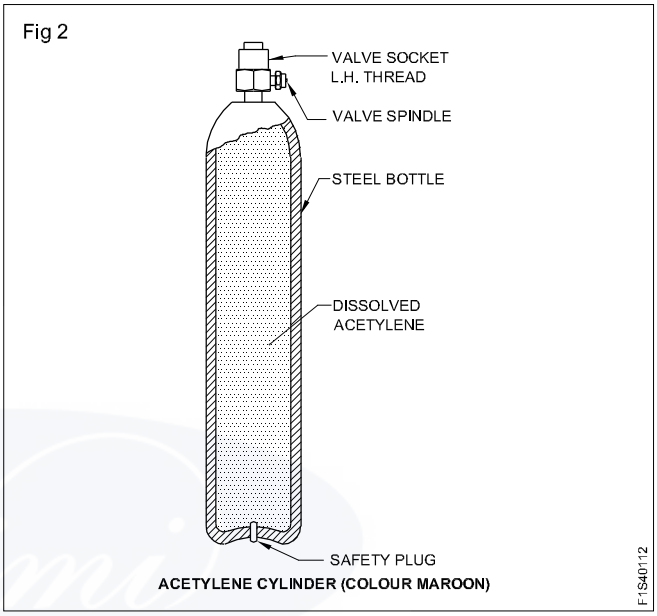
The valve socket has right hand threads.

The cylinder is used to store oxygen gas with a pressure of 120 to 150 kg/cm^2.

Dissolved acetylene cylinders (Fig 2)

This is painted maroon and has a storing capacity of 6m^3. The valve socket has left hand threads. It is used to store acetylene gas in a dossolved state with a pressure of 15-16 kg/cm^2.

Fig 2

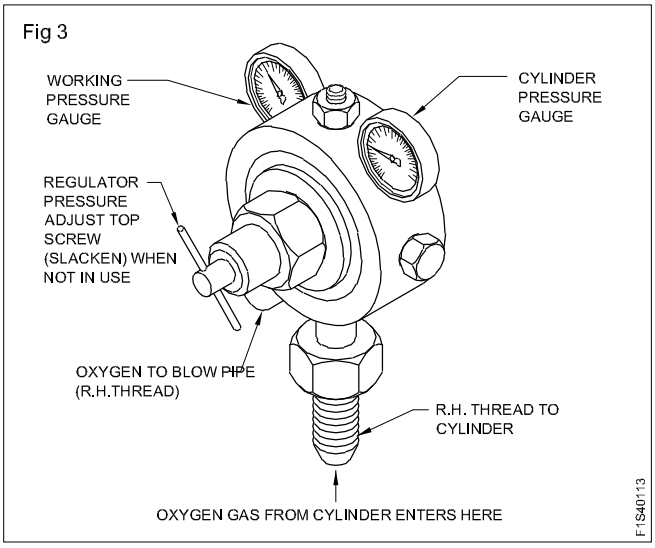


ACETYLENE CYLINDER (COLOUR MAROON)

Pressure regulators for oxygen

The regulator is meant to reduce and control the oxygen cylinder gas pressure to a suitable working pressure and maintain constant rate of flow for the blowpipe. This regulator has right hand threads. (Fig 3)

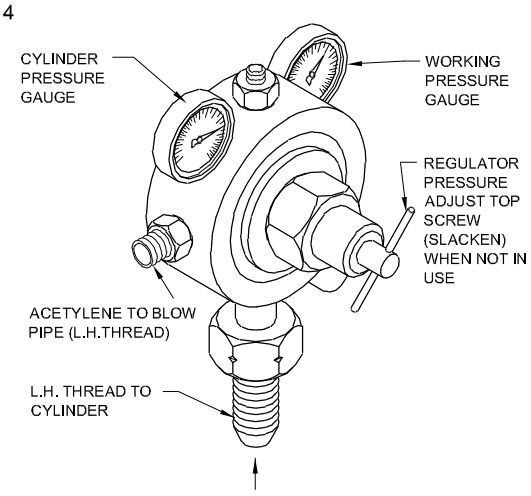
Fig 3



Pressure regulators for acetylene

This is to reduce and control the acetylene cylinder gas pressure to a suitable working pressure at a constant rate of flow for the blowpipe. This regulator has left hand screw threads. (Fig 4)

Fig 4

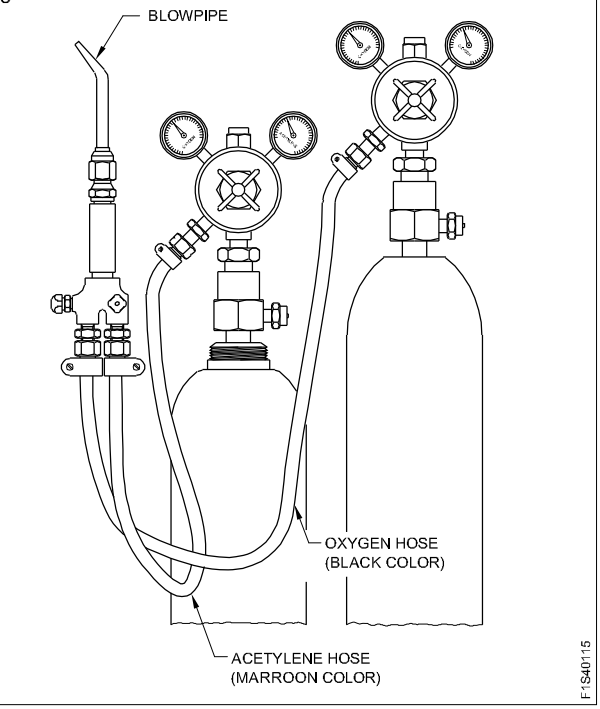


Note: Both oxygen and acetylene regulators have a cylinder pressure gauge to indicate the cylinder gas pressure and a working pressure gauge to indicate the working pressure required for the blowpipe. (Figs 3 & 4)

Rubber hoses

The hose carries the gases from the gas regulators to the blowpipe. The hoses are made of strong canvass rubber having good flexibility. The hose pipe for the oxygen line is black in colour while that for the acetylene line is of maroon colour. (Fig 5)

Fig 5

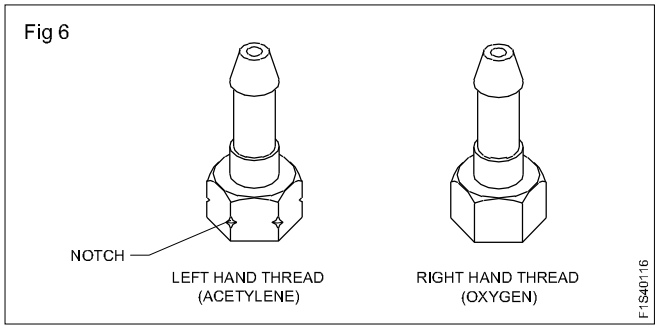


Hose pipe connections for regulators

This is a connecting union used to connect rubber hose pipes with the regulators.

Oxygen connection has right hand threads while the acetylene connection has left hand threads. (Fig 6). The nut used for the acetylene rubber hose connections will have a notch at its corners.

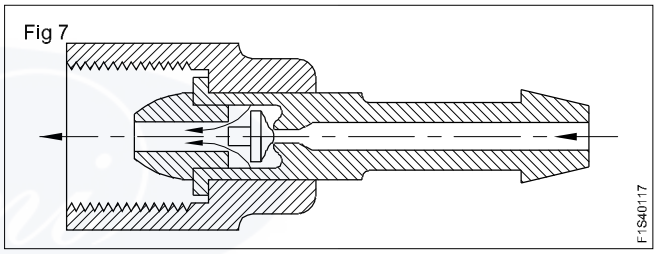
Fig 6



Hose pipe connections for blowpipes

This has the shape of a connecting union and is fitted with a non-return disc to prevent flash-back and backfire during welding. (Fig 7)

Fig 7

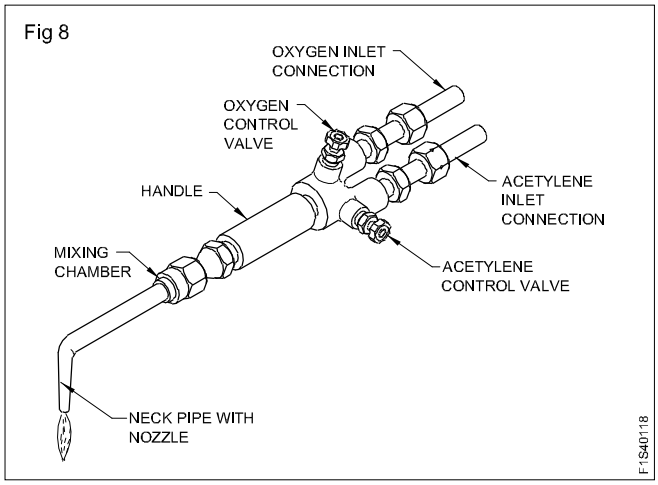


It is used to connect the rubber hose pipe with the blowpipe.

The oxygen connection has right hand threads while the acetylene one has left hand threads.

Blowpipe set with nozzle (Fig 8)

Fig 8



This is a device with a handle and inlet connection for acetylene (left hand threads) and oxygen (right hand threads). It has control valves for acetylene and oxygen

gas flow, a gas mixing chamber, and a neck-pipe with a nozzle.

This is used to control and mix the acetylene and oxygen gases in the required proportion to make a perfect oxy-acetylene gas flame.

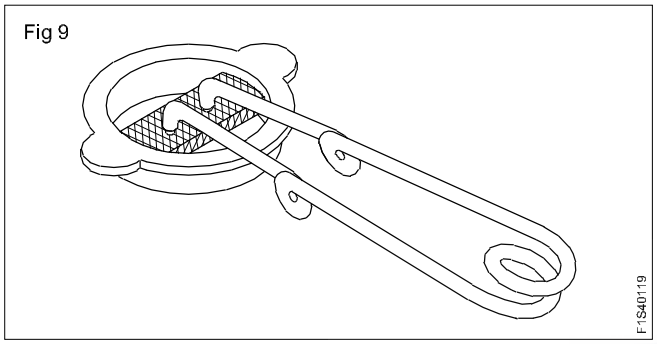
A set of interchangeable nozzles of different sizes are used to produce smaller or bigger flames.

Spark lighter (Fig 9)

This is used to ignite the flame.

The spark is produced by rubbing the flint over a metal surface with cuts like those in a file.

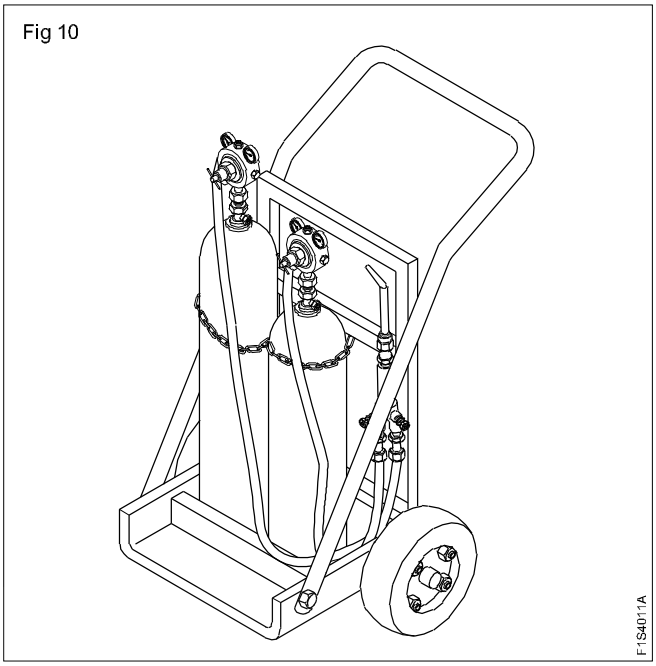
Fig 9



Trolley for cylinder (Fig 10)

The trolley is used to keep both oxygen and acetylene cylinders in an upright position. The trolley helps to transport the cylinders - safely and easily.

Fig 10



Safety precautions in handling gas welding plant

Objectives : At the end of this lesson you shall be able to
- **state the general safety precautions in oxy-acetylene plants.**
- **state the safety rules for handling gas cylindedrs**
- **state the safety practices for handling gas regulators and hose-pipes.**
- **state the safety precautions related to blowpipe operations.**

To be accident-free, one must know the safety rules first and then practise them as well. As we know can 'accident starts when safety ends'.

Ignorance of rules is no excuse!

In gas welding, the welder must follow the safety precautions in handling gas welding plants and flame-setting to keep himself and others safe.

Safety precautions are always based on good common sense.

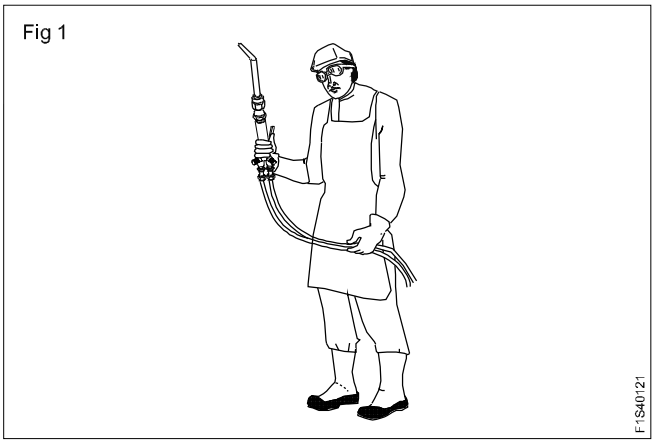
The following precautions are to be observed, to keep a gas welder accident-free.

General safety

Do not use lubricants (oil or grease) in any part or assembly of a gas welding plant. It may cause explosion.

Keep all flammable material away from the welding area. Always wear goggles with filter lens during gas welding. (Fig 1)

Fig 1



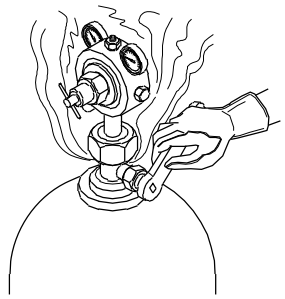
Always wear fire resistant clothes, asbestos gloves and apron.

Never wear nylon, greasy and torn clothes while welding.

Whenever a leakage is noticed rectify it immediately to avoid fire hazards. (Fig 2)

Even a small leakage can cause serious accidents.

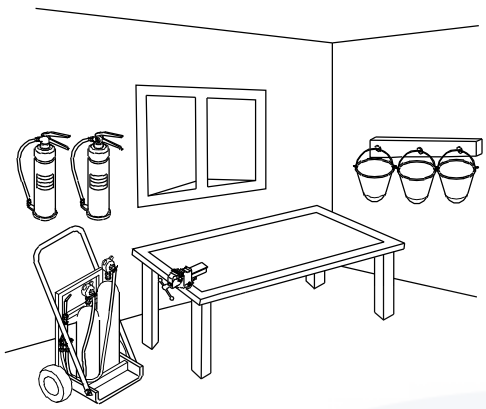
Fig 2



F1S40122

Always keep fire-fighting equipment handy and in working order to put out fires. (Fig 3)

Fig 3



F1S40123

Keep the work area free from any form of fire.

Safety gas cylinders

Do not roll gas cylinders or use them as rollers.

Use a trolley to the carry the cylinders.

Close the cylinder valves when not in use or empty.

Keep full and empty cylinders separately.

Always open the cylinder valves slowly, not more than one and a half turn.

Use the correct cylinder keys to open the cylinders.

Do not remove the cylinder keys from the cylinders while welding. It will help to close the cylinders QUICKLY in the case of a back-fire or flash-back.

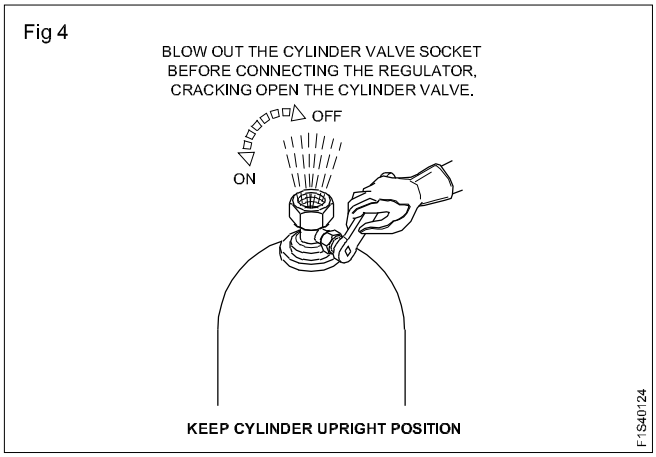
Always use the cylinders in an upright position for easy handling and safety.

Always crack the cylinder valves to clean the valve sockets before attaching regulators. (Fig 4)

Safety for rubber hose pipes (Fig 5)

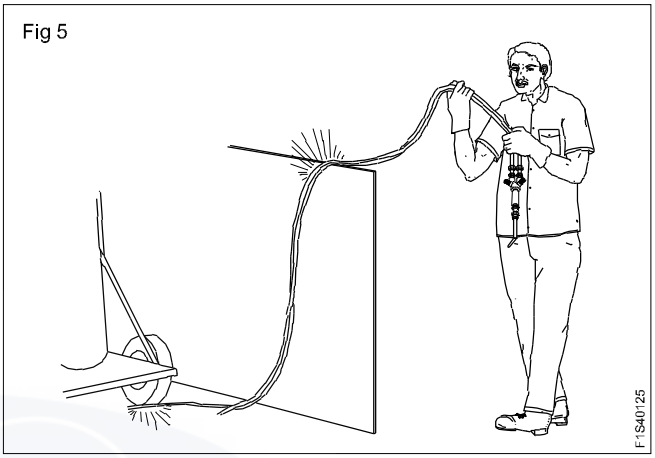
Inspect the rubber hose pipes periodically and replace the damaged ones.

Fig 4



F1S40124

Fig 5



F1S40125

Do not use odd bits of hose pipes / tubes.

Do not replace the hose pipes for acetylene with the ones used for oxygen.

Always use a black hose pipes for oxygen and maroon hosepipes for acetylene.

Safety for regulators

Prevent hammer blows to the gas cylinders and ensure that water, dust and oil do not settle on the cylinders.

One right hand threaded connection for oxygen and left hand threaded connection for acetylene.

Safety for blowpipes

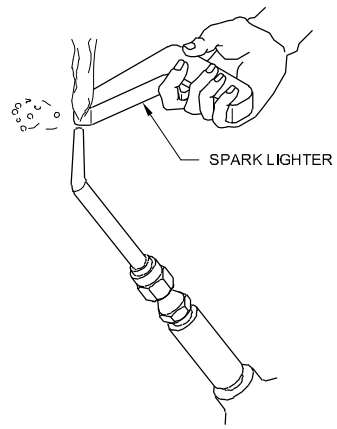
When a blowpipe is not in use put out the flame and place the blowpipe in a safe place.

When flame snaps out and backfires, quickly shut both the blowpipe valves (oxygen first) and dip in water.

While igniting the flame, point the blowpipe nozzle in a safe direction. (Fig 6)

While extinguishing the flame, shut off the acetylene valve first and then the oxygen valve to avoid a backfire.

Fig 6



POINT THE BLOWPIPE IN SAFE DIRECTION
TURN ON ACETYLENE. APPLY SPARK AT TIP

F1S40126

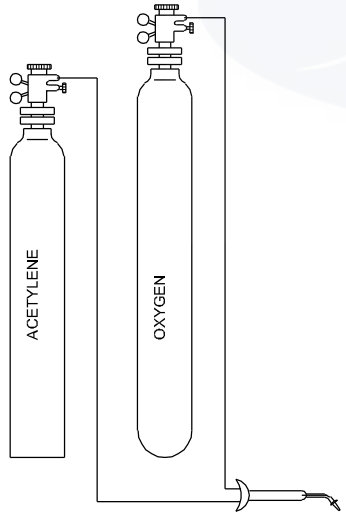
Systems of oxy-acetylene

Objectives : At the end of this lesson you shall be able to
- **distinguish between high pressure and low pressure acetylene plants**
- **distinguish the features of low pressure and high pressure blowpipes.**

Oxy-acetylene plants can be either high pressure or low pressure.

A high pressure plant utilizes acetylene under high pressure, upto 1 kg/cm^2. (Fig 1)

Fig 1



HIGH PRESSURE OXY-ACETYLENE PLANT

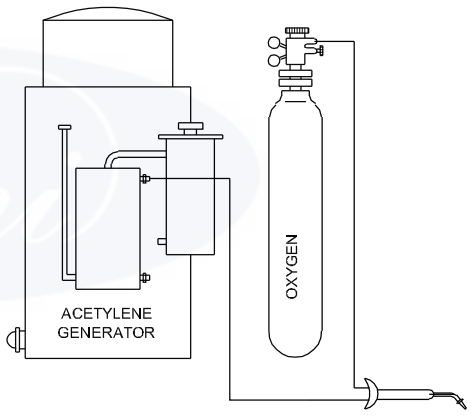
F1S40131

Dissolved acetylene (acetylene in cylinder) is a commonly used source.

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

High pressure and low pressure plants utilize oxygen gas in compressed high pressure cylinders only.

Fig 2



LOW PRESSURE OXY-ACETYLENE PLANT

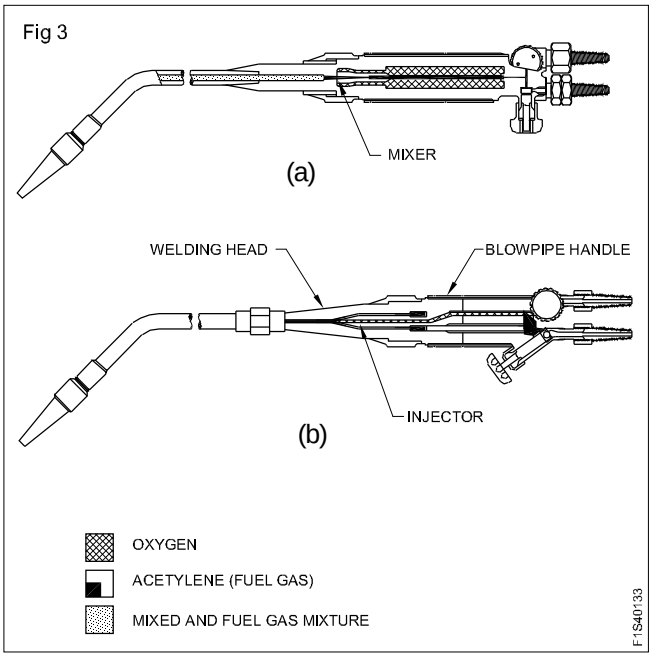
F1S40132

The high or low pressure systems used in oxy-acetylene welding refer only to the acetylene pressure.

Distinguishing features of blowpipes

For low pressure systems, a specially designed injector type blowpipe is required. This can be used for high pressure also. (Fig 3a)

In a high pressure system, a mixer type high pressure blowpipe is used, this is not suitable for the low pressure system. (Fig 3b)


Fig 3
MIXER
(a)
WELDING HEAD
BLOWPIPE HANDLE
INJECTOR
(b)
OXYGEN
ACETYLENE (FUEL GAS)
MIXED AND FUEL GAS MIXTURE
F1S40133

Gases used in gas welding

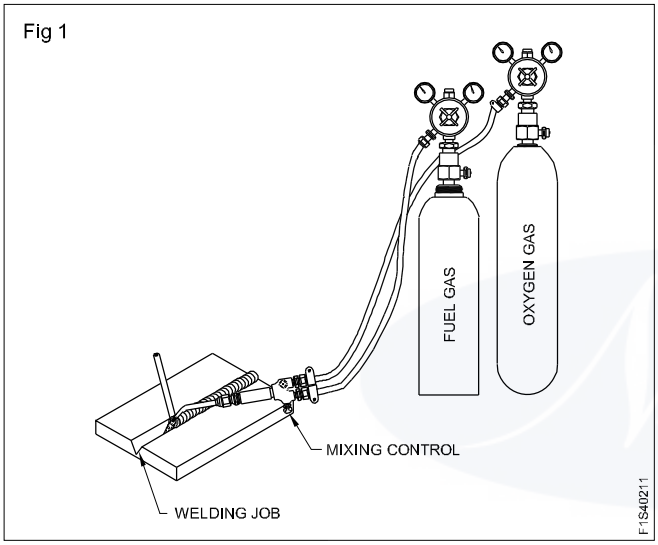
Objectives: At the end of this lesson you shall be able to
- **name the different types of gases used in gas welding**
- **state the different types of gas flame combinations**
- **state the temperatures and uses of the different gas flame combinations.**

In the different gas welding processes, the welding heat is obtained from the combustion of the fuel gases.

All the fuel gases require oxygen to support combustion.

As a result of the combustion of the fuel gases and oxygen, a flame is obtained. This is used to heat the metals for welding. (Fig 1)

Fig 1



Fuel gases used in welding

The following are the gases used as fuel for welding.

- Acetylene gas
- Hydrogen gas
- Coal gas
- Liquid petroleum gas (LPG)

Supporter of combustion gas

All gases burn with the help of oxygen. Hence it is known as the supporter of combustion.

Different gas flame combinations

Oxygen + Acetylene = Oxy-acetylene gas flame

Oxygen + Hydrogen = Oxy-hydrogen gas flame

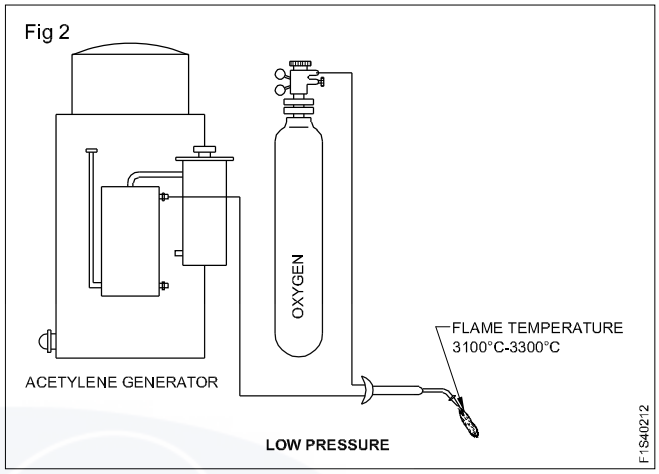
Oxygen + Coal = Oxy-coal gas flame

Oxygen + LPG = Oxy-LP gas flame

Temperature and uses of gas flame combinations

Oxy-acetylene gas flame (Fig 2)

Fig 2

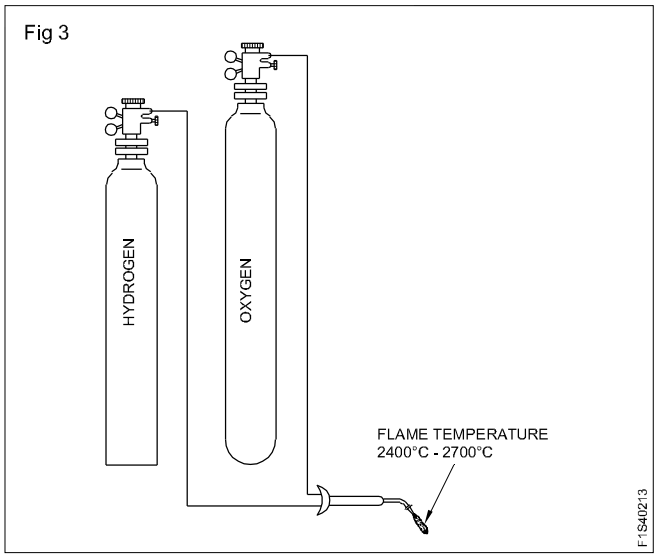


Flame temperature : 3100° C to 3300° C

The oxy-acetylene gas flame is used for welding all ferrous and non-ferrous metals and their alloys, gas cutting, gouging, steel brazing, bronze welding, metal spraying and powder spraying.

Oxy-hydrogen gas flame (Fig 3)

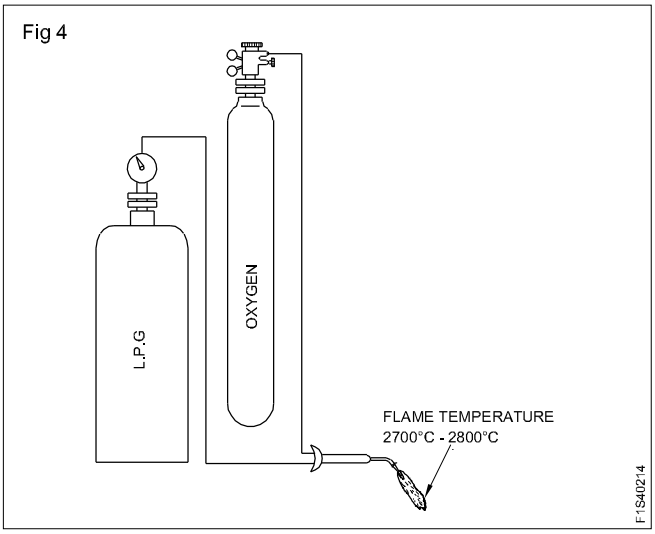
Fig 3



Flame temperature : 2400°C to 2700°C

It has carbon and moisture effect in the flame. It is used only for brazing, silver soldering and underwater gas cutting of steel.

Oxy-liquid petroleum gas flame (Fig 4)

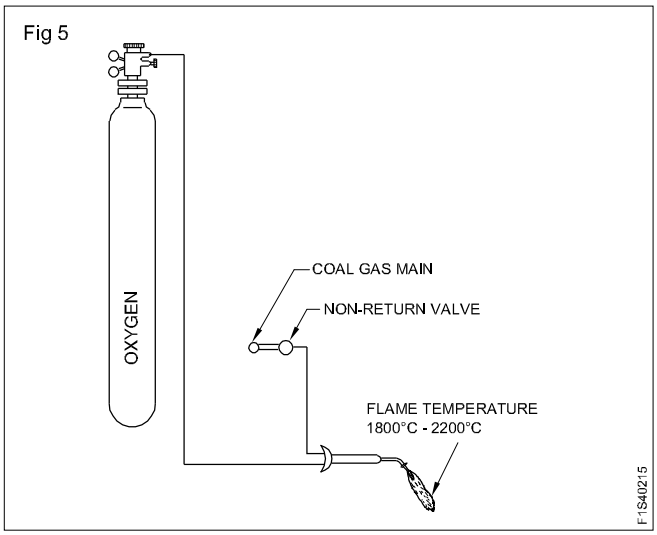


Flame temperature : 2700°C to 2800°C

This flame has carbon and moisture effect.

It is only used for gas cutting of steel, and for heating.

Oxy-coal gas flame (Fig 5)



Flame temperature : 1800°C to 2200°C

This flame has carbon effect in the flame and is used for silver soldering and brazing.

The most commonly used gas flame combination is OXY-ACETYLENE.

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 oxy-acetylene flame**
- **explain the uses of each type of oxy-acetylene flame.**

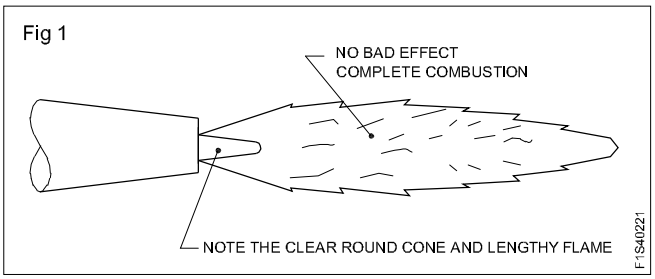
The essential requirement for oxy-acetylene welding is a well controlled flame with sufficient heat, which can be easily manipulated to heat and melt metals without altering the chemical composition of the metal/weld.

Flame types

The different flame types are

- Neutral flame
- Oxidising flame
- Carburising flame.

Neutral flame (Fig 1)



Characteristics

The neutral flame is formed with oxygen and acetylene in equal proportion.

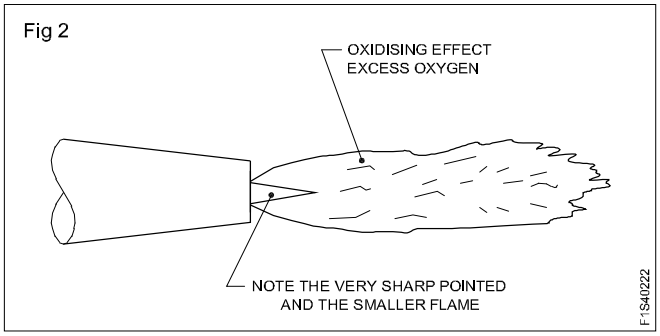
Complete combustion takes place in this flame.

This flame does not have bad effect on metals/weld.

Uses

A neutral flame is used to weld most of the common metals, i.e. mild steel, cast iron, stainless steel, copper and aluminium.

Oxidising flame (Fig 2)



Characteristics

The oxidising flame is formed with excessive oxygen.

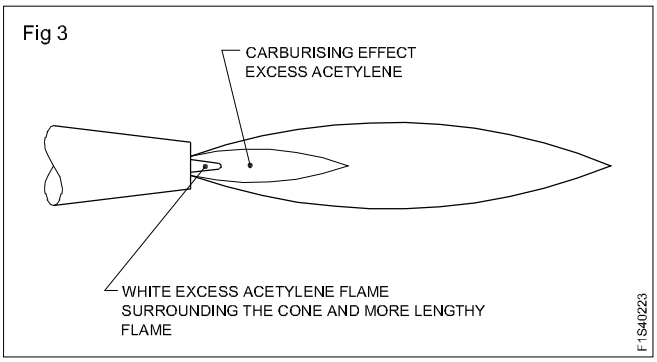
The flame has oxidising effect on metals.

Uses

The oxidising flame is useful only for the welding of brass and to control the burning of zinc.

Carburising flame (Fig 3)

Fig 3



This flame contains excess of acetylene .

The flame has a carburising effect on steel, causing hard, and brittle weld.

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.

Neutral flame is the most commonly used.

Acetylene gas generation

Objectives : At the end of this lesson you shall be able to
- **state the composition of acetylene gas**
- **state the principle of acetylene gas generation**
- **name the methods of acetylene generation**
- **identify the types of acetylene generators.**

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 an acetylene gas generator

Actylene gas is the product of a chemical reaction between calcium carbide and water.

Calcium Carbide + Water = Acetylene Gas + Slaked Lime

Calcium carbide is composed of calcium metal, 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 the water forming acetylene gas.

Calcium combines with the oxygen to form slaked lime.

Methods of acetylene generation

Acetylene is produced in ACETYLENE GENERATORS based on two methods.

- Water to carbide method. (Fig 1)
- Carbide to water method (Fig 2)

Water to carbide means,

water falls on the carbide in the process.

Carbide to water means carbide falls into water in the process.

Fig 1

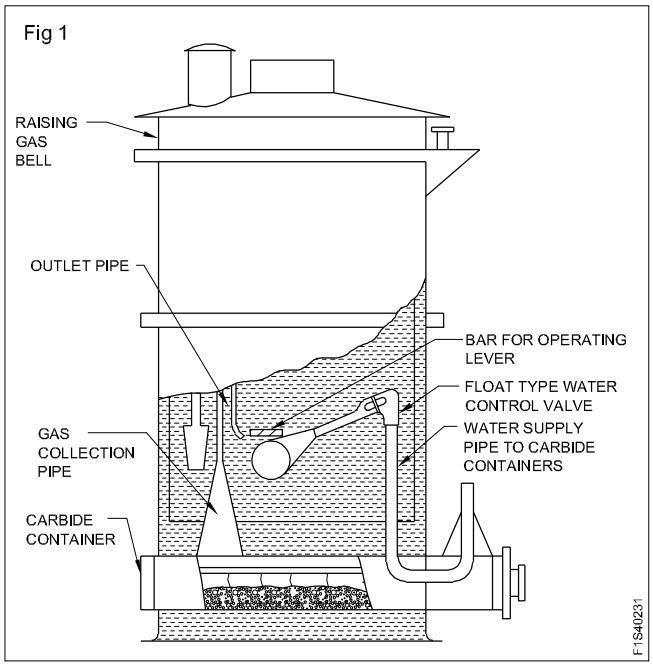
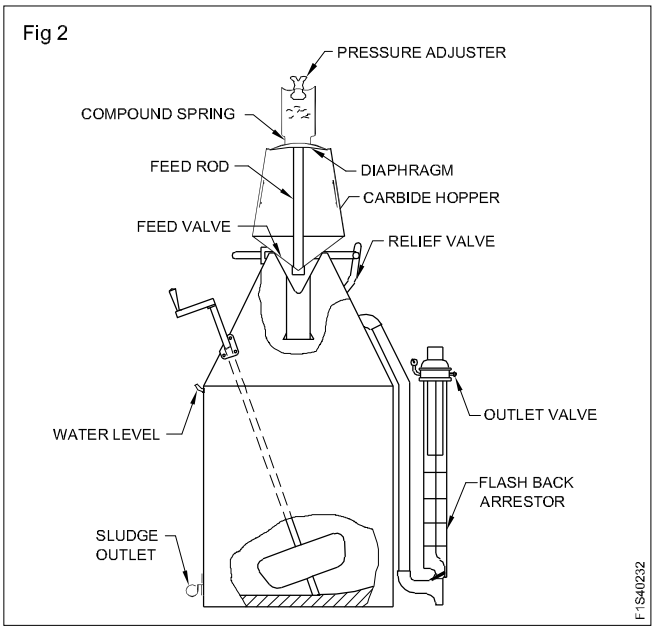

RAISING GAS BELL
OUTLET PIPE
BAR FOR OPERATING LEVER
FLOAT TYPE WATER CONTROL VALVE
WATER SUPPLY PIPE TO CARBIDE CONTAINERS
GAS COLLECTION PIPE
CARBIDE CONTAINER
F1S40231

Fig 2


PRESSURE ADJUSTER
COMPOUND SPRING
FEED ROD
DIAPHRAGM
CARBIDE HOPPER
FEED VALVE
RELIEF VALVE
WATER LEVEL
OUTLET VALVE
FLASH BACK ARRESTOR
SLUDGE OUTLET
F1S40232

Method of cleaning before welding

Objectives: At the end of this lesson you shall be able to
- **state the importance of cleaning before welding**
- **name the different methods of cleaning.**

Importance of cleaning

The basic requirement of any welding process is to clean the joining edges before welding in order to obtain a sound weld.

The joining edges or surface may have oil, paint, grease, rust, moisture, scale or 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 condition of the surfaces to be joined.

Methods of cleaning

Chemical cleaning

This includes washing the joining surface with solvents such as kerosene, paraffin, thinners, turpentine or petrol for removing oil, grease etc. (Fig 1 & 2)

Fig 1

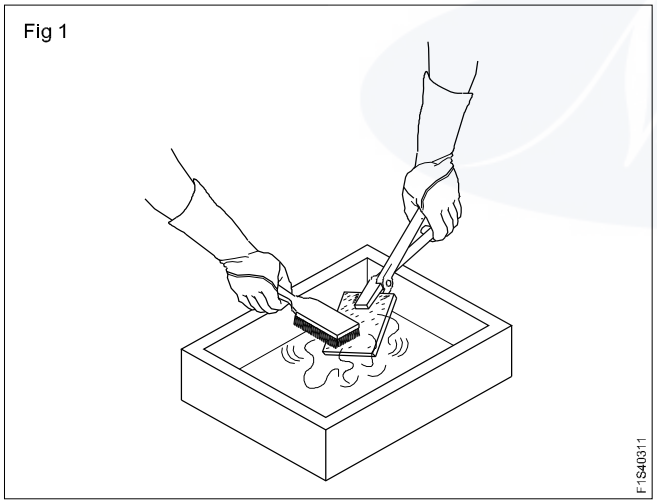
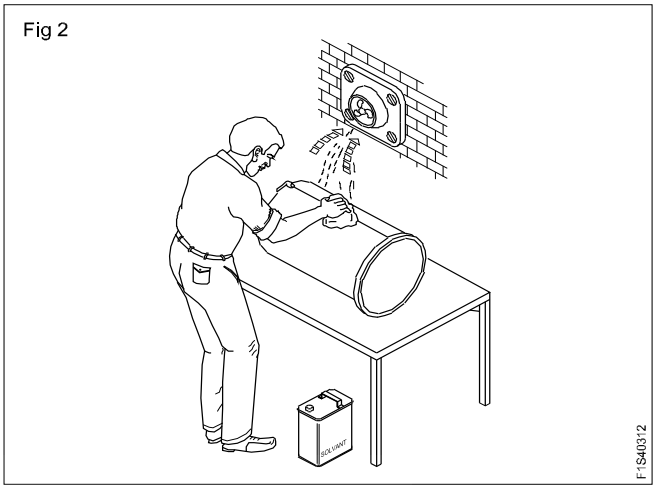


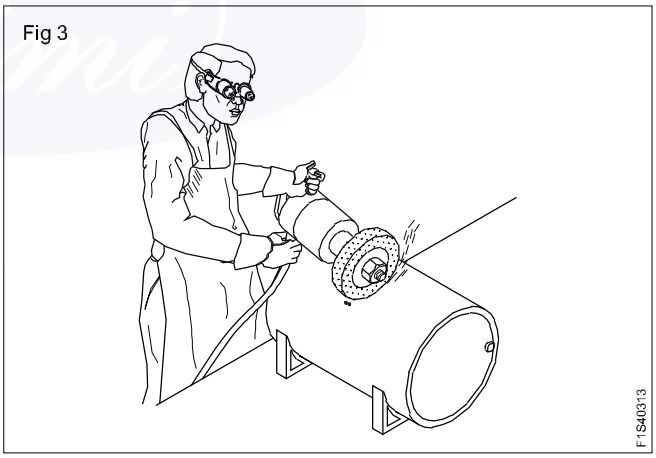
Fig 2



Mechanical cleaning

Mechanical cleaning include wire brushing, grinding, chipping, sand blasting, scraping, metal gritting, machining or cleaning with emery paper. (Fig 3)

Fig 3



Welding Nozzles - sizes and selection

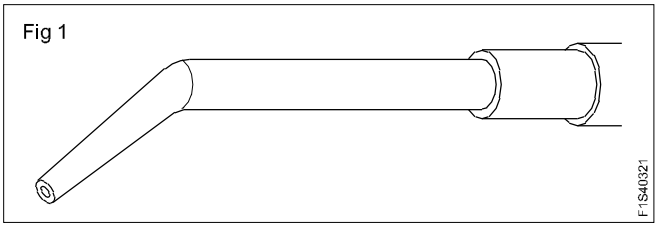
Objectives : At the end of this lesson you shall be able to
- **identify the different sizes of nozzles**
- **select the correct nozzle for the job**
- **select the correct gas pressure for the nozzles.**

The welding nozzle is a part of the welding blowpipe (made of copper with a small orifice) fitted at the end where the flame is ignited. (Fig 1)

Nozzle sizes

The size of the nozzle is determined by the diameter of its orifice.

Fig 1



Smaller orifice nozzles make a smaller flame useful for welding thin metals, whereas larger hole nozzles make a larger flame useful for welding thick metals, where more heat is required.

The common nozzle sizes are

1,2,3,4,5,7,10,13,18,25,35,45, 55,70 and 90.

The selection of a nozzle is determined by the

- Thickness of the metal to be welded
- Mass of the metal to be welded
- Kind of the metal to be welded.

Selection of gas pressure for nozzles

Smaller size nozzles require less pressure whereas the larger size nozzles require more pressure (Table 1).

Selection of Nozzle

Table 1

Plate thick-ness (mm)	Nozzle size	Oxygen Acetylene pressure (kg/cm)
0.8	1	
1.2	2	
1.6	3	0.15
2.4	5	
3.2	7	
4.0	10	
5.0	13	0.20
6.5	18	
8.2	25	0.25
10.0	35	
13.0	45	0.30
19.0	55	
25.0	70	0.40
Over 25.0	90	0.45

Welding Terms (Fusion, Molten Pool, Penetration)

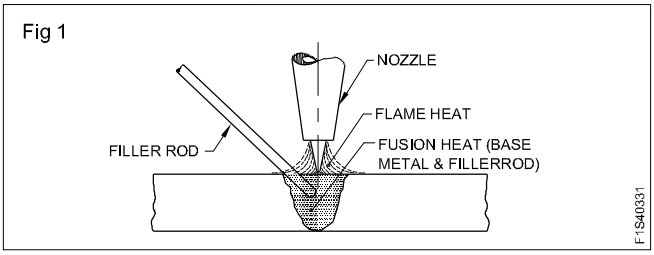
Objectives : At the end of this lesson you shall be able to
- **explain the welding terms, fusion, molten pool, and penetration**
- **identify them from graphic illustrations.**

Fusion

The joining edges or the surfaces of similar metals, when heated to the melting point, become fluid, flow together and make a homogeneous bond when cooled or frozen.

Fusion may be formed between the base metal (job) and the filler rod during welding or between the base metals only. (Fig 1)

Fig 1



Lack of fusion results in poor weldment.

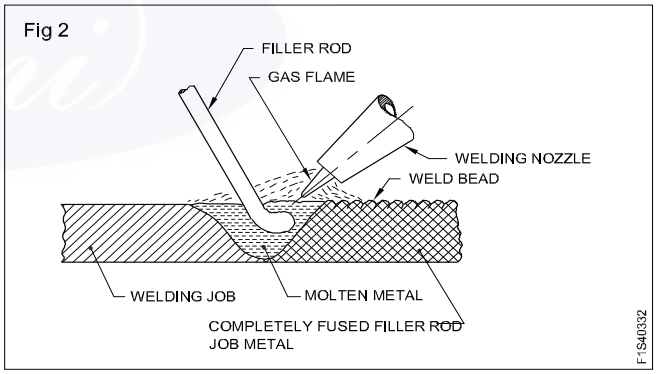
Molten pool

This is the pool of molten metal formed on the job during fusion welding.

This is also called molten weld puddle. (Fig 2)

The molten pool controls the size of the weld (width of the bead).

Fig 2

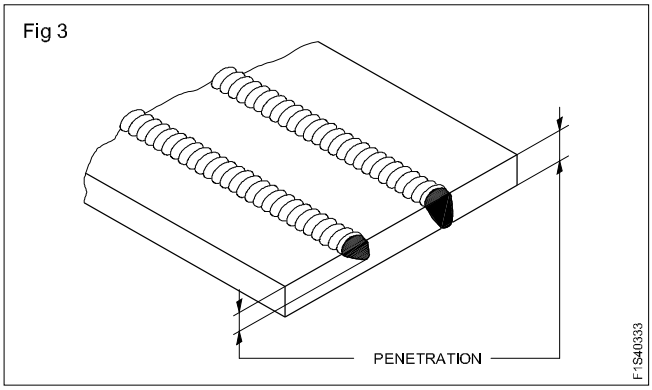


Penetration

Penetration is the depth of fusion of a weld in the job or the joined surface. (Fig 3)

Complete penetration and good fusion are conditions very essential for successful welds.

Fig 3



Filler rods for gas welding

Objectives : At the end of this lesson you shall be able to
- **state the function of filler rods**
- **name the various types of filler rods and their sizes**
- **select a proper filler rod for a job to be welded by gas.**

Filler rods

Pieces of wires or rods used as filler metal in a joint during the gas welding process are called filler rods or welding rods.

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

Unsuitable welding rods lead to unsatisfactory welds.

It is uneconomical to buy and use welding filler rods which are cheap and substandard.

Good quality filler rods help to :

- Reduce oxidation (effect of oxygen)
- Control the mechanical properties of the deposited metal
- Make up for the loss of certain elements in the weld metal caused by heat.

Types of filler rods

Each metal requires filler rods suitable for it. (Refer to Table 1)

Sizes

The size of the filler rods is specified by their diameter.

Examples

1.60,3.15,5.00 and 6.30mm.

Selection of filler rods

Filler rods are selected according to the

- Type of the metal to be welded
- Thickness of the metal to be welded (including joint edge preparation)
- Nature of the joint to be made (i.e.) fusion welding or braze welding (non-fusion)
- Strength requirement
- Welding technique to be used (leftward or rightward).

Refer to Table 2 for the sizes of the filler rods according to the thickness of plate the type of edge preparation and the root gap.

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

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

Common metals, alloy and their melting points

Objectives: At the end of this lesson you shall be able to
- **distinguish between ferrous & non-ferrous metals**
- **name the common metals and alloys**
- **determine the melting points of common metals and alloys.**

Engineering metals may be ferrous, non-ferrous or alloys.

Ferrous metals are those which have iron as their base.

They include iron and alloys of iron such as steel,cast iron and alloy steels.

If two or more metals are chemically combined, they form an alloy.

Non-ferrous metals do not contain iron as the base. (Iron may be present in a small percentage in some cases.)

Non-ferrous metals include copper, aluminium, zinc, tin etc.

The table1 gives the melting points of different metals.

Table 1

Metal	Melting Point
Mild steel	1500 to 1530°C
Cast iron	1150°C
Copper	1083°C
Aluminium	659°C
Brass and bronze	850°C to 950°C
Zinc	419°C
Tin	232°C
Lead	327°C

Related welding terms, flashback, backfire

Objectives: At the end of this lesson you shall be able to
- **distinguish between 'backfire' and 'flashback'**
- **state the causes of backfire**
- **state the method of controlling the 'flashback'.**

Back fire

At certain times, during flame lighting or gas welding a small explosion of the flame occurs at the tip of the torch.

The flame may or may not go off. This explosion is called backfire.

The causes for backfire are

- The pressure setting is low
- The nozzle is overheated
- The nozzle orifice has carbon or spark deposits
- The nozzle touches the molten pool
- There is leakage near the nozzle.

Eleminate the causes before proceeding further to avoid backfire.

Flashback

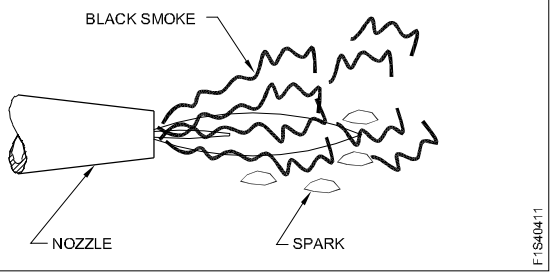
Sometimes, during backfire, the flame goes off and the burning gases travel backward in the blowpipe,towards the regulator or cylinders. This is known as 'flashback'.

Indications of flashback

- A sharp squealing sound inside the blowpipe.

- Heavy black smoke and spark may come out of the nozzle. (Fig 1)
- The blowpipe handle starts heating.

Fig 1



Precautions

Close the blowpipe valves (oxygen first).

Immerse the blowpipe in water and close the cylinder valves.

If the backfire or flashback is not checked in time, it may cause serious accidents to men and equipment.

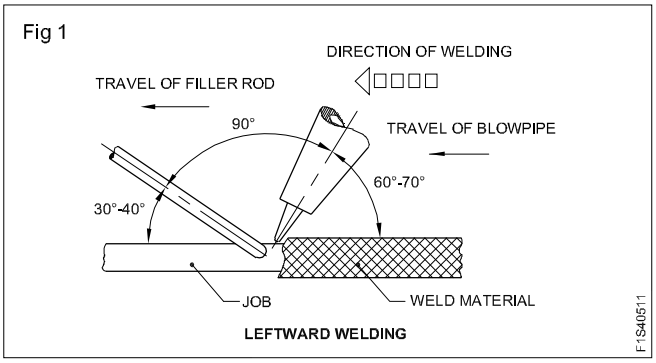
Leftward and Rightward welding techniques

Objectives: At the end of this lesson you shall be able to
- **distinguish between the leftward and the rightward techniques**
- **state the application of the leftward and the rightward techniques.**

Leftward technique (Fig 1)

This is a technique of gas welding in which the welding is carried out from the right side to the left side of the joint.

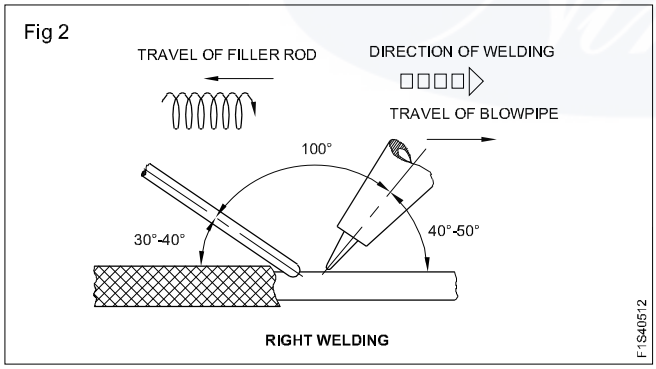
Fig 1



Rightward technique (Fig 2)

The technique of gas welding in which the welding is carried out from the left side to the right side of the joint is knopwn as the rightward technique.

Fig 2



Characteristics of leftward and rightward techniques

In leftward technique :

- The flame is directed toward the unwelded part
- The filler rod, if used, is directed toward the welded part of the joint.
- There less heat concentration for fusion, and hence, it is used for welding thin jobs.

In the rightward technique :

- The flame is directed toward the welded part
- The filler rod is directed toward the unwelded part of the joint
- There is more heat concentration for fusion, and hence, useful for welding thick jobs.

Blowpipe and filler rod angles

In the leftward technique, the blowpipe and filler rod angles are 60° and 30° respectively with the welding line.

In the rightward technique the blowpipe and filler rod angles are 50° and 40° respectively with the welding line.

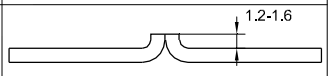
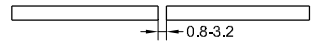
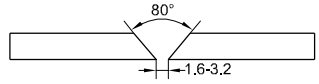
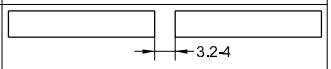
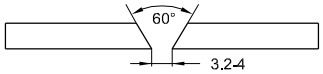
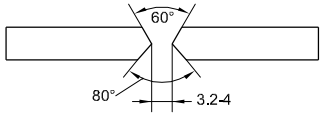
Application

The leftward technique is used for welding steel having thickness up to 5 mm and for all other metals in a flat position.

The rightward technique is used for welding steel having thickness above 5 mm and for welding of steel pipes.

The rightward technique is economical for welding thick steel plates as more heat is concentrated for fusion.

APPLICATION OF WELDING TECHNIQUES WITH DIFFERENT PARAMETERS

THICKNESS OF METAL	DIAMETER OF FILLER ROD (IN MM)	JOINT EDGE PREPARATION
LESS THAN 0.9 mm	UP TO 1.6 mm	 FLANGED EDGE COUPLING
0.9 mm TO 3.2 mm	1.6 TO 3.2 mm	 OPEN SQUARE BUTT
3.2 mm TO 5.0 mm	3.2 TO 4.0 mm	 SINGLE "V"BUTT
5.0 mm TO 8.2 mm	3.2 TO 4.0 mm	
8.2mm 16.2 mm	4.0 TO 6.5 mm	
16.2 mm AND OVER	6.5 mm	

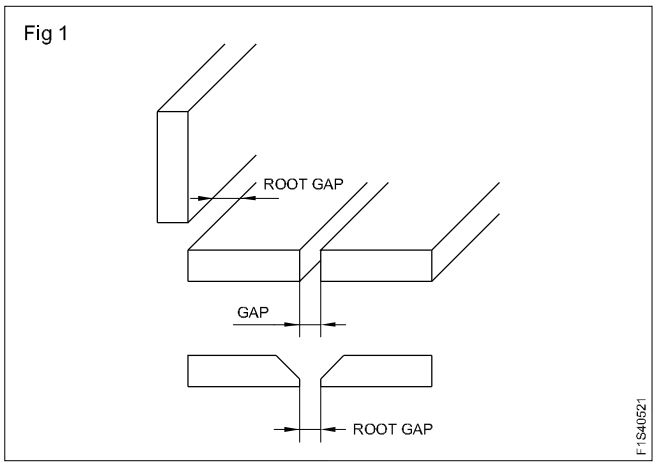
Purpose of root gap and tacking the job before welding

Objectives : At the end of this lesson you shall be able to
- **state the purpose of the root gap kept in the joint before welding**
- **state the purpose of tacking the job-pieces before welding.**

Root gap or root opening in welding joints.

Before welding, the joining parts of the assembly are kept apart at some specific distance. (Fig 1)

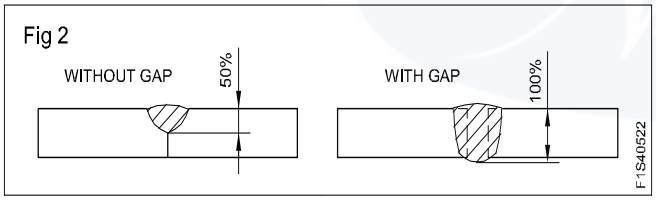
Fig 1



Purpose

The purpose is to obtain the required depth of fusion or complete penetration to the entire depth of the joint during welding. (Fig 2)

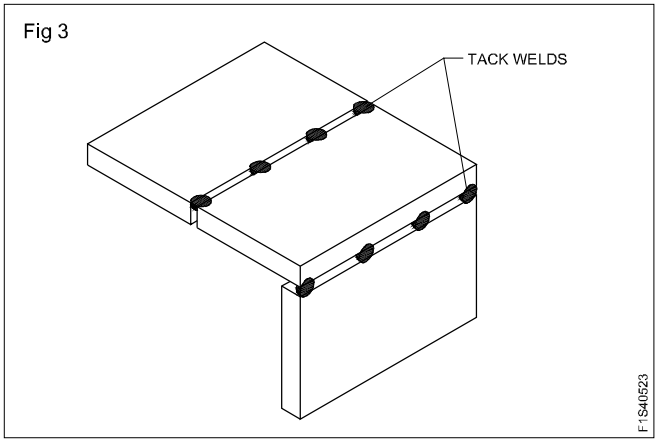
Fig 2



Tack welding the assembly

Small welds of short distance are used to assemble the joining pieces before welding. (Fig 3)

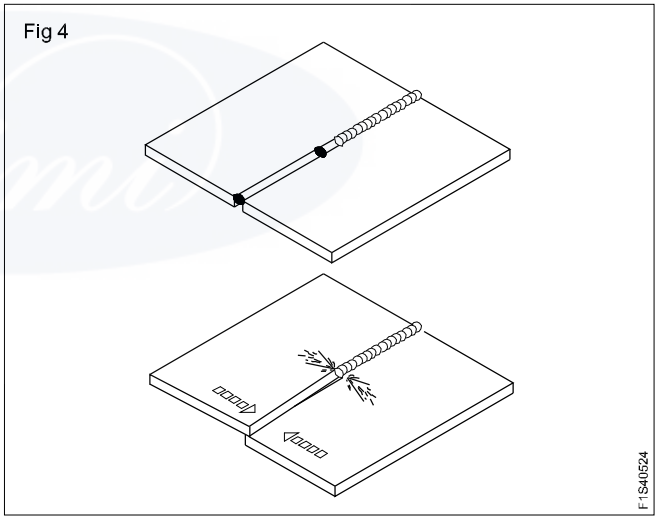
Fig 3



Purpose

The purpose of welding is to maintain the gap and alignment of the assembly for the desired depth of fusion and to control distortion during welding. (Fig 4)

Fig 4



Basic welding joints and position

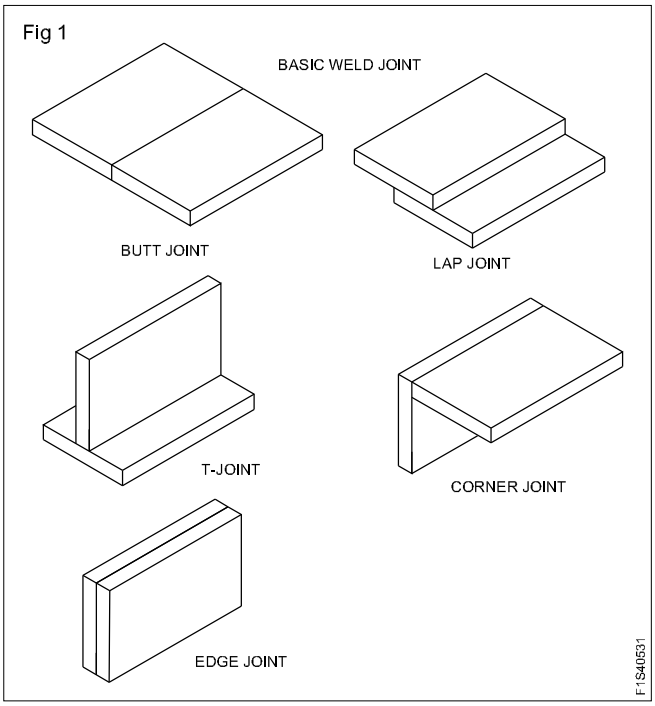
Objectives : At the end of this lesson you shall be able to
- **identify the basic welding joints from drawings**
- **identify the basic welding positions from drawings.**

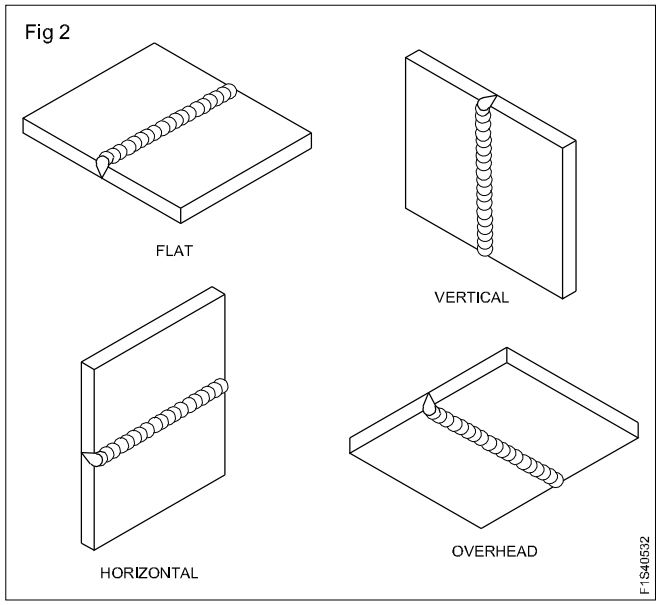
Basic welding joints (Fig 1)

The following are the basic welding joints.

- Butt joint
- Lap joint
- Tee joint
- Corner joint
- Edge joint

The above types indicate the shape of the joints and how the joining edges of parts are placed together. (Joint designs are very important in fabrication work).





Basic welding positions (Fig 2)

The following are the important basic welding positions

- Flat or downhand position
- Horizontal position
- Vertical position
- Overhead position

Welding action takes place in the molten pool,formed in the welding joint or the welding line.

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

All joints can be welded in all positions.

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

Sl. No.	Fuel gas	Supporter of combustion	Name of the gas flame combination	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 and 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.

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 temperature: Heat is a form of energy, capable of flowing between two bodies which are at different temperatures. The addition of heat energy to a body increases the kinetic energy of motion of its molecules. Temperature is the degree of hotness or coldness of a body measured, usually centigrade or 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. 40^0C, 50^0C, 150^0F etc.

Temperature measurement: There are two basic scales for measuring changes in 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 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. The 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 degree (°F).

Conversion of temperature from °C to °F

The formula used for temperature conversion is

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

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

$$F = (100 \times \frac{9}{5}) + 32 = 212°.$$

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

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

$$= 90 \times \frac{5}{9} = 50°$$

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 gases 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 gases 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

Properties of metals

Objectives: At the end of this lesson you shall be able to
- **describe the effects of heat on the properties of metals**
- **explain the main properties of metals like chemical, physical and mechanical properties.**

Effect of welding heat on the properties of metals

During welding the properties of the weld metal may be affected.

- Important alloying elements may be destroyed.
- Brittle, hard or cracked welds may be produced.
- There may be reduction in the corrosion resistance properties of the welds.

- Main properties of the base metal and weld metal will get affected.

Properties of metals can be classified mainly into:

- chemical properties
- physical properties
- mechanical properties.

Chemical properties are those which involve chemical effect such as:

- corrosion
- oxidation
- reduction.

CORROSION will spoil the metal surface due to the effect of various elements in the atmosphere and water.

OXIDATION is the formation of metal oxides which occur when oxygen combines with the metals.

REDUCTION refers to the removal of oxygen from the surrounding molten puddle to reduce the effect of ATMOSPHERIC CONTAMINATION.

PHYSICAL PROPERTIES are those, which affect metals when they are subjected to heat generated by welding such as:

- melting point
- thermal conductivity
- thermal expansion
- grain growth.

MELTING POINT is the degree of temperature, when a solid metal changes into LIQUID. Copper melts at 1083°C and aluminium melts at 659°C.

THERMAL CONDUCTIVITY is the rate at which a metal conducts heat to the adjacent area of the heated job.

Copper conducts heat faster than aluminium. Aluminium conducts heat faster than iron.

Thermal expansion: Whenever metals are heated there will be increase in its dimensions due to their thermal expansion property. Depending on the nature of metal, different metals will have different thermal expansion.

Grain structure: Like salt or sugar, the metal is also a crystalline substance. In metals the crystals are called grains. Grains are composed of atoms. Atomic structure determines the grain structure just as the arrangement of bricks determines the shape of the building.

During welding (due to heating effect) the grain size increases resulting in loss of strength.

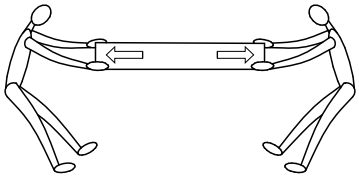
MECHANICAL PROPERTIES are those which determine the behaviour of metals under applied load such as:

- tensile strength
- ductility
- hardness
- toughness
- brittleness.

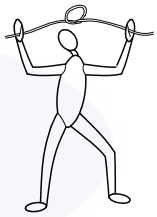
TENSILE STRENGTH is the property of the metal which resists forces acting to pull it apart. (Fig 1)

DUCTILITY is the ability of the metal to stretch, bend or twist without breaking or cracking or to draw into fine wires. (Fig 1)

Fig 1



A METAL WITH TENSILE STRENGTH RESISTS PULLING FORCES



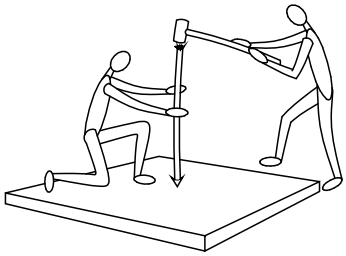
A DUCTILE METAL CAN EASILY BE SHAPED/BENT

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HARDNESS is the ability of the metal to withstand abrasions, cutting action by a tool. Usually any hard metal will resist the compressive forces. Normally a hard metal will also be brittle.

TOUGHNESS is the ability of a metal to withstand sudden force without breaking. (Fig 2)

Fig 2



TOUGHNESS



A BRITTLE METAL FAILS (BREAKS) SUDDENLY WHEN SUBJECTED TO A HEAVY LOAD OR SHOCK

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BRITTLENESS is the property of the metal which is opposite of ductility and is applied to a metal which cracks suddenly if placed under pressure or load to bend or twist. (Fig 2)

Types of welds

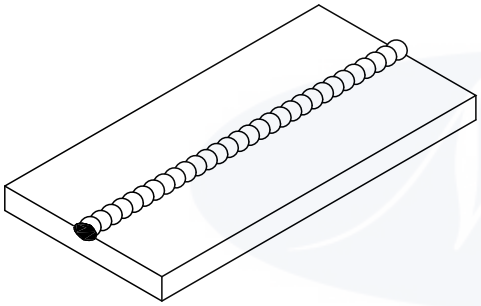
Objectives: At the end of this lesson you shall be able to
- **illustrate the different types of weld**
- **explain butt weld, its nomenclatures and types**
- **describe fillet weld, its nomenclatures and types.**

Weld types: We have studied different welding joints. To get these joints done the following types of weld are used.

- Bead weld
- Groove or butt weld
- Fillet weld
- Plug or slot weld

Bead weld (Fig 1) is a type of weld composed of one or more stringer or weave beads deposited on an unbroken surface to obtain the desired properties and dimensions.

Fig 1



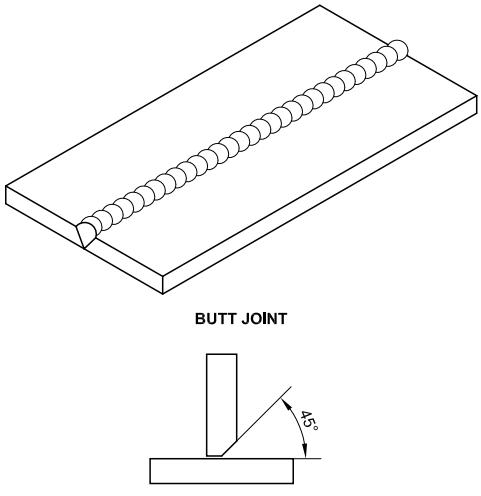
BEAD WELD

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Example: Practice for a beginner on laying beads on a plate. Hard facing, building up of worn out parts.

Butt weld or groove weld (Fig 2) is a weld made in the groove between two members to be joined as butt joint. Groove welds are also done on T fillet joints if the plate thickness is more than 12mm.

Fig 2



BUTT JOINT

TEE JOINT

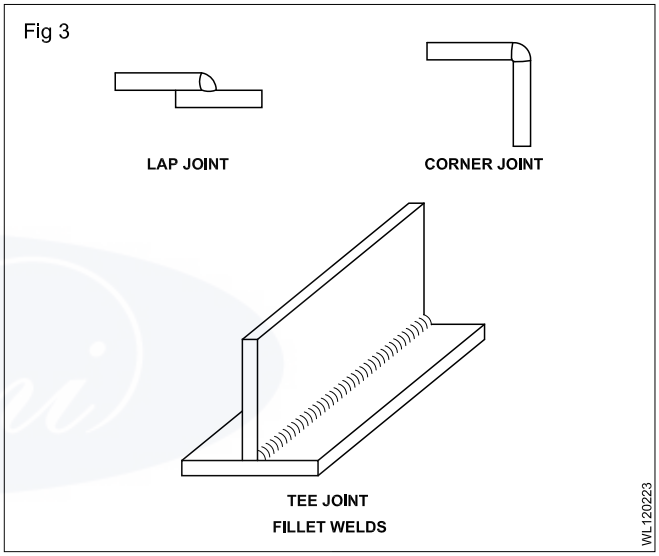
GROOVE WELDS

WL120222

Fillet weld (Fig 3) is a weld, having a triangular cross-section, joining two surfaces at right angle to each other such as:

- Lap joint
- Tee joint
- Corner joint.

Fig 3



LAP JOINT

CORNER JOINT

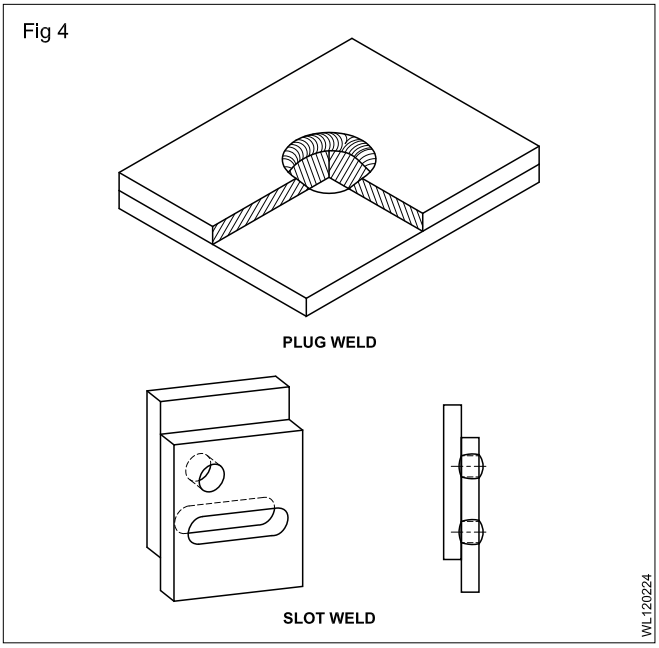
TEE JOINT

FILLET WELDS

WL120223

Plug or slot welds (Fig 4) are welds used to join two over–lapping pieces of metal by welding through circular holes or slots. These welds are often used in the place of rivets.

Fig 4



PLUG WELD

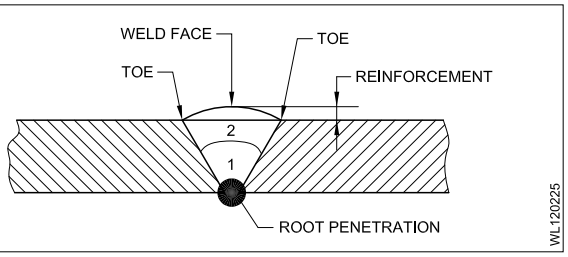
SLOT WELD

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Weld nomenclatures

Butt or groove welds (Fig 5)

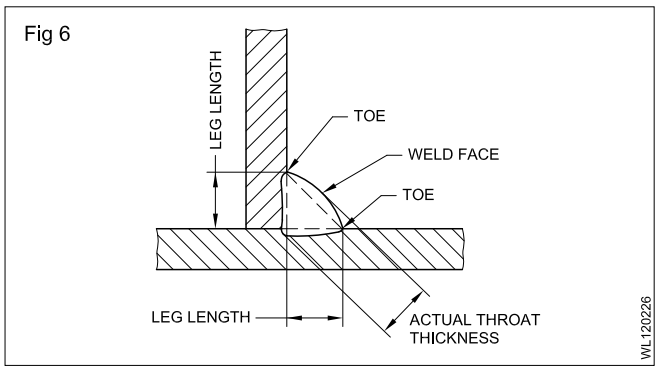
Fig 5



Information of the terms shown in the Fig 5 and 6 are to be added.

Fillet welds (Fig 6)

Fig 6



Welding method of low carbon steel and medium 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 carbon 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.

Edge preparation : As explained for mild steel in Ex.2.01/G-1 (Refer Fig.1 given below)

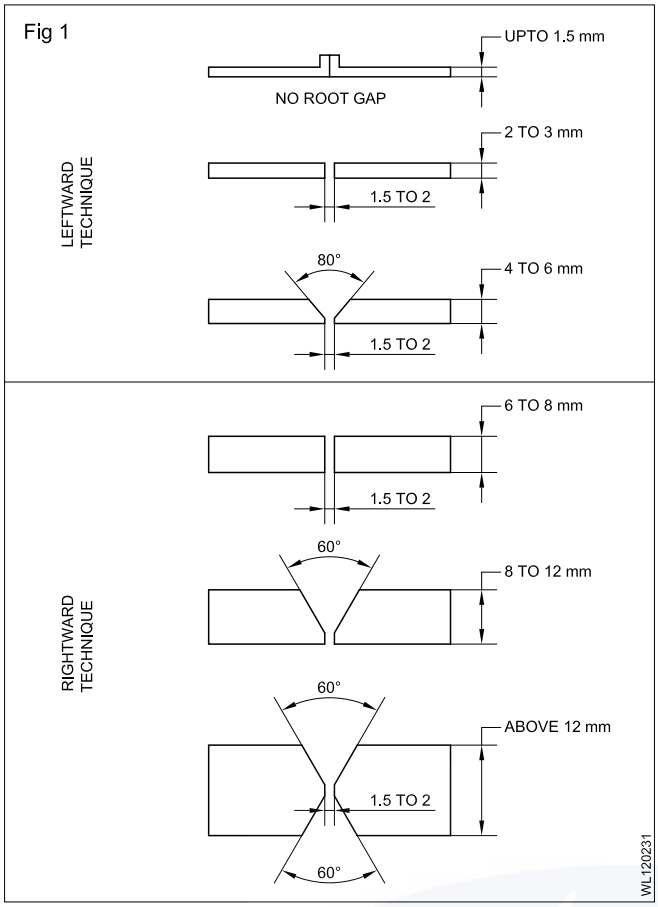
Type of flame : Neutral flame to be used.

Application of flux : No flux is required.

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

Medium carbon steel: These steels 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 heat). 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.

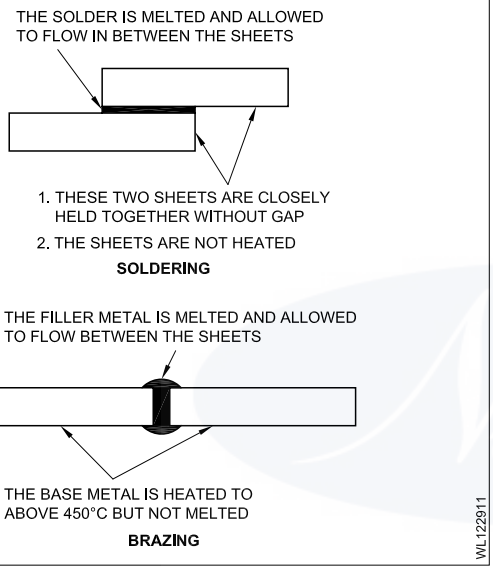
High carbon steels contain 0.6% to 1.2% carbon. This type of steel is not weldable by gas welding process because it is difficult to avoid cracking of base metal and the weld.

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 silver brazing**
- **describe the difference between brazing and soldering**
- **explain the various methods of brazing**
- **explain the problems in brazing and the remedies.**

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

Fig 1



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

The alloys used for soft soldering are:

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

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

Composition of soft solder

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

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

TYPES OF FLUXES

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

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

Suitable fluxes for various materials

Steel - zinc chloride

Zinc and galvanized iron - hydrochloric acid

Tin - zinc chloride

Lead - tallow resin

Brass, copper, bronze - zinc chloride, resin.

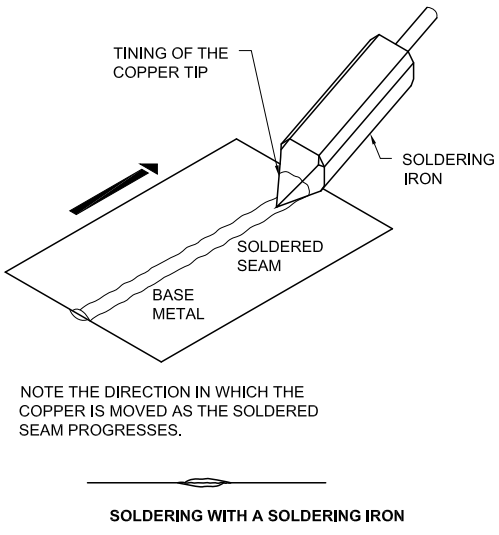
Basic operations in soldering

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.

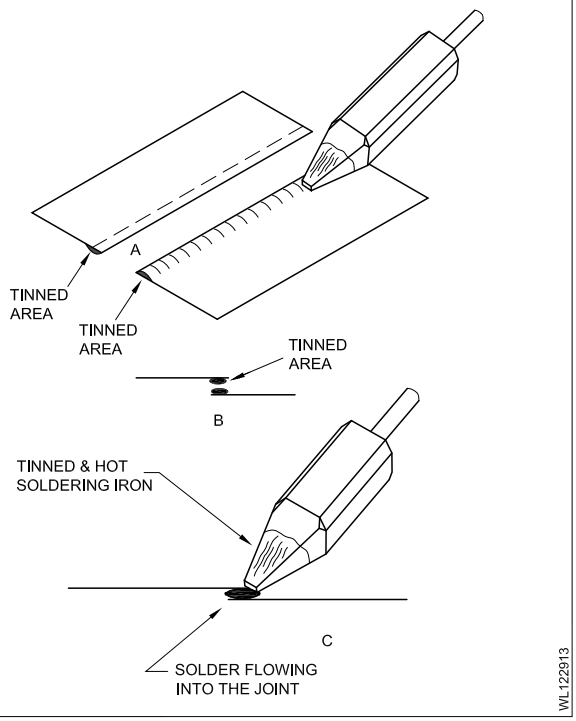
The surfaces to be soldered are coated with flux to remove the films of oxide. (Fig 2)

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 joint by 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^{0}C as compared to soldering which is done at below 450^{0}C.

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

- 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 0.08mm)
- 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, fluroborates, boric acid, wetting agents and water. So suitable flux combination is selected based on metal being used.

Brazing is employed where a ductile joint is required.

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

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

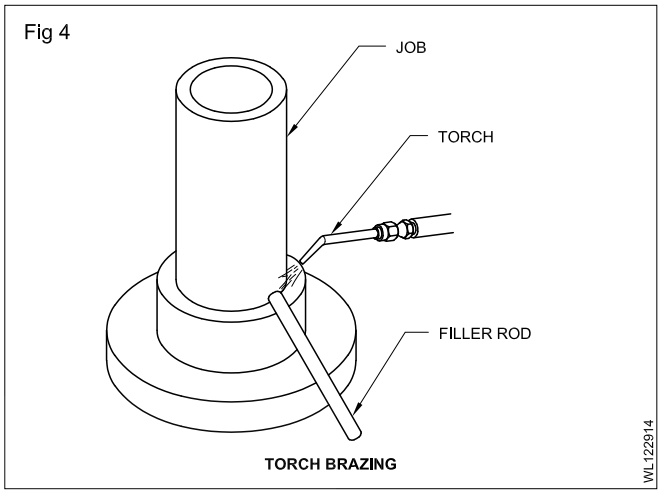
It is applied on the joint in the form of a paste made by mixing up with water.

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

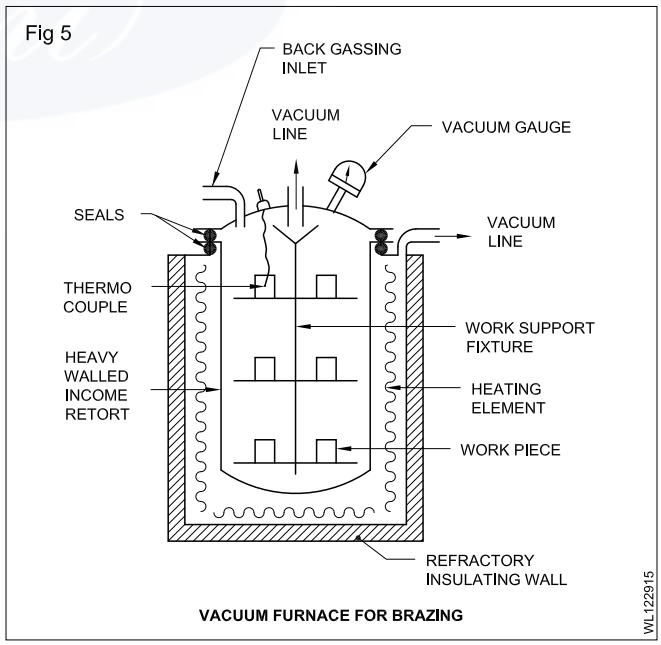
Torch brazing: The base metal is heated to the required temperature by the application of the oxy-acetylene flame. (Fig 4)

Fig 4



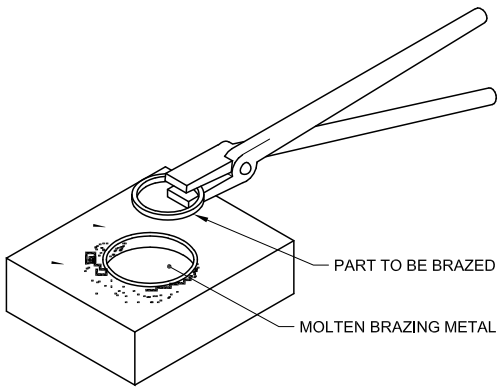
Furnace brazing: The parts to be brazed are aligned with the brazing material placed in the joint. The assembly is kept in the furnace. The temperature is controlled to provide uniform heating. (Fig 5)

Fig 5



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

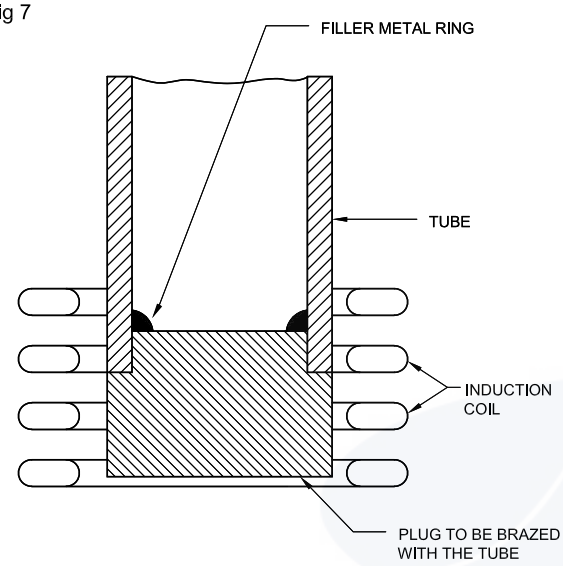
Fig 6



DIP BRAZING PROCESS

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Fig 7



INDUCTION BRAZING

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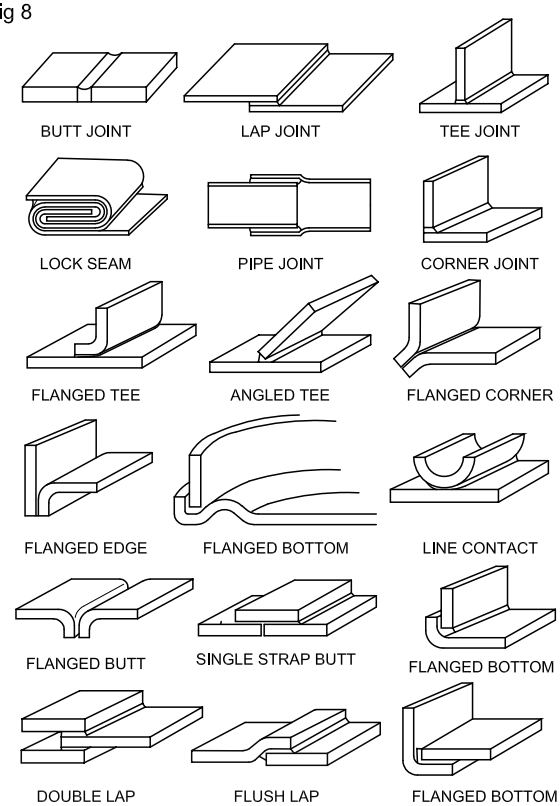
Conditions to obtain satisfactory brazed or soldered joint

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.

Fig 8



SUGGESTED JOINT DESIGNS FOR SOLDERED AND BRAZED JOINTS

WL122918

Advantages of brazing

The completed joint requires little or no finishing.

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

There is no flash or weld spatter.

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

The process can be easily mechanised.

The process is economical owing to the above advantages.

Disadvantages of brazing

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

All the brazing alloys loose strength at an elevated temperature.

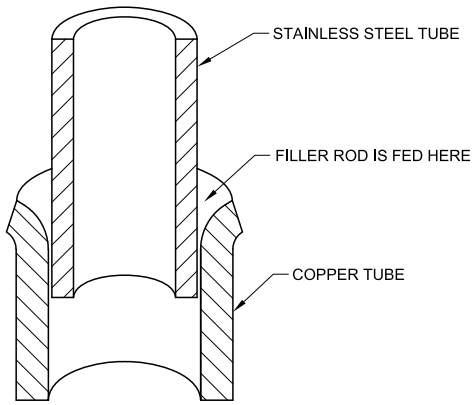
The colour of the brazing alloy which ranges from silver white to copper red may not match the base metal very closely.

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' grinder wheels 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 of, instead of 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^{0}C which is always less than that of the base metals joined. Fig.1 shows silver brazing of stainless steel tube with a copper tube.

Fig 1



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^{0}C to 800^{0}C. Use an ocy-acetylene blow pipe for heating.

– Apply the silver brazing filler rod coated with the pasty flux at the joint using leftward technique. Heat the filler rod to the "flow temperature" which is usually 10 to 15^0 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 15^0 more than its melting temperature.

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

Clean the joint thoroughly to remove all residual flux.

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

Brazing and braze welding: Both brazing and braze welding are metal joining processes which are performed at temperatures above 840^{0}F (450^{0}C) as compared to soldering which is performed at temperatures below 840^{0}F (450^{0}C).

The American Welding Soceity defines these processes as follows:

Brazing - "A group of welding processes which produces coalescence of materials by heating them to a suitable temperature and by using a filler metal having a liquidus above 840^{0}F (450^{0}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 840^0F (450^0C) and below the solidus of the base metal, is used. Unlike brazing, in braze welding the filler metal is not distributed in the joint by capillary action".

Brazing has been used for centuries. Blacksmiths, jewelers, armorers and other crafters used the process on large and small articles before recorded history. This joining method has grown steadily both in volume and popularity. It is an important industrial process, as well as jewelry making and repair process. The art of brazing has become more of a science as the knowledge of chemistry, physics and metallurgy has increased.

The usual terms Brazing and Braze welding imply the use of a nonferrous alloy. These nonferrous alloys consist of alloys of copper, tin, zinc, aluminum, beryllium, magnesium, silver, gold and others.

Brass is an alloy consisting chiefly 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 840^0F (450^0C). 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 leakproof 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 join 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.

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 dimensions 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 store 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 surfaces before welding.

Different methods used to cut metals

1 By chiselling 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 90^0 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.

Methods of cleaning the base metals before welding

Objectives: At the end of this lesson you shall be able to
- **state the importance of cleaning before welding**
- **explain the different methods of cleaning.**

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

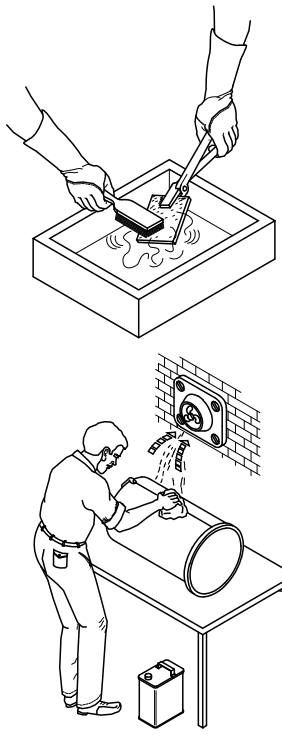
Importance of cleaning: The basic requirement of any welding process is to clean the joining edges before welding. The joining edges or surface may have oil, paint, grease, rust, moisture, scale or any other foreign matter. If these contaminants are not removed the weld will become porous, brittle and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

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

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

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

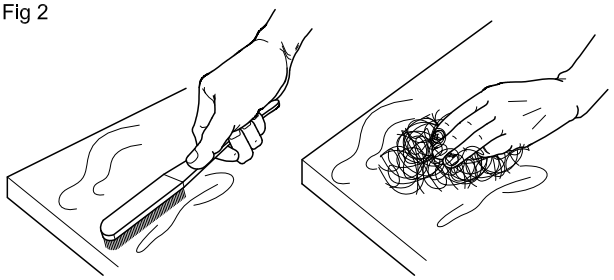
Fig 1



CHEMICAL CLEANING

CA130111

Fig 2



WIRE BRUSH

WIRE WOOL

WL130112

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**
- **distinguish between conductors and insulators**
- **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.

a by creating an arc

b by electrical resistance of materials

It is dangerous to play with electricity.

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

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

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

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

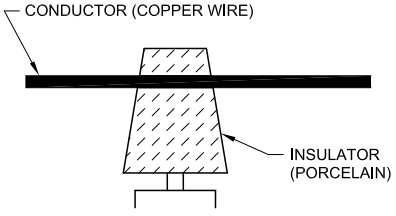
Its measuring unit is ohm and the measuring instrument is ohmmeter or Megger.

Resistance of a metal changes as given below:

- if the length is more the resistance will also be more.
- if the diameter is more the resistance will be less.
- the resistance will increase or decrease depending on the nature of the material.

Conductors: Those substances through which electricity passes are called conductors. (Fig 3)

Fig 3



CA130113

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 3)

Glass, mica, rubber, Bakelite, plastic, dry wood, dry cotton, porcalien 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 circuits are:

- series circuit
- parallel circuit.

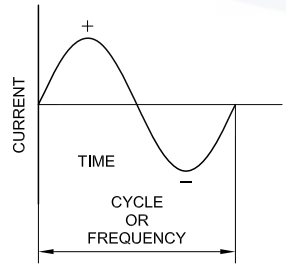
Series circuit: The resistances of a circuit are connected in a series end- to-end making only one path in which the current flows.

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

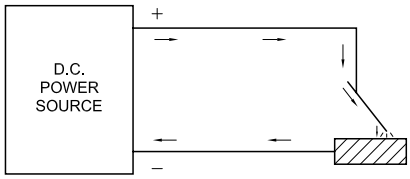
Its rate of change is called frequency i.e. hertz (Hz). (Fig.4)

Fig 4



Direct current (DC) (Fig.5): Electric current which always flows in a particular direction is known as direct current. (i.e.) Negative to positive (electronic direction). Positive to negative (conventional direction).

Fig 5



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

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

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.

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.

$C = \frac{E}{R}$ where C = current in amps

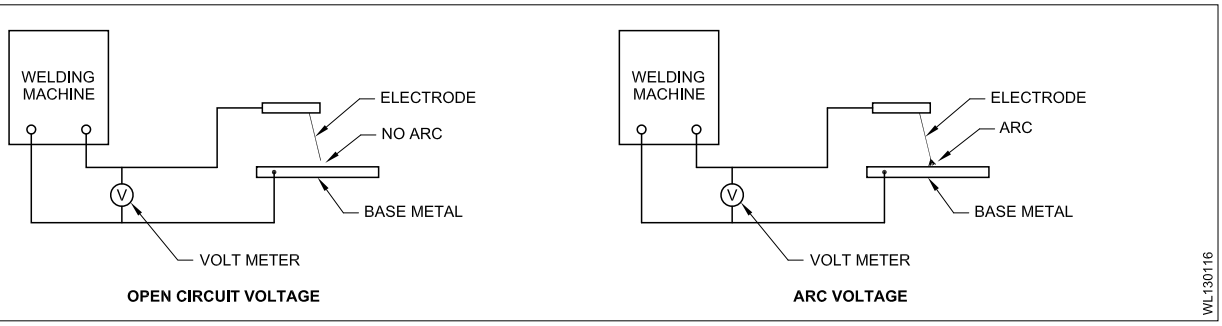
E = C x R where E = EMF = Electromotive in volts

$R = \frac{E}{c}$ wgere R = Resistance in ohms

Open circuit voltage and arc voltage: Fig.6 show an electric circuit used in arc welding. After switching on the welding machine, when there is no arc created/struck between the electrode tip and the base metal then the voltage "V" shown by the voltmeter in the circuit is called "Open circuit voltage".

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

Fig 6



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

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

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

- created a high temperature (4500^{0}C) arc between the electrode and the work using electric voltage and high current. (All types of arc welding)
- heating the work to red hot condition by using the resistance property of the metal and passing a very high current for a fraction of a second and then applying a very heavy pressure. (All types of resistance welding)
- using highly concentrated electron beam on the joint of the 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.

Electric welding processes

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 generation depends upon:

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

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

Formula for converting electrical energy to heat energy

$H = I^2 RT$

H is the amount of heat produced in 'joules'.

I is the amount of current passing in amps.

R is the resistance of medium in ohms.

T is the time during which the current flows.

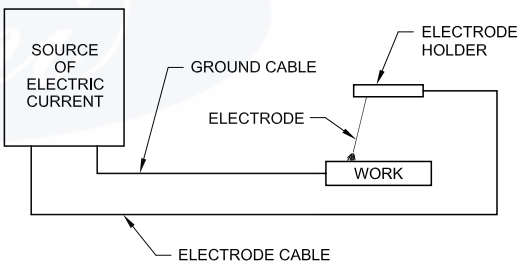
This is useful only in the resistance welding process.

TYPES OF ELECTRIC WELDING

There are many types of electric welding process classified as follows.

Electric arc welding: It is a fusion-welding (non-pressure) process in which the welding heat is obtained from an arc, formed between an electrode and the welding job connected to a suitable welding machine. (Fig 7)

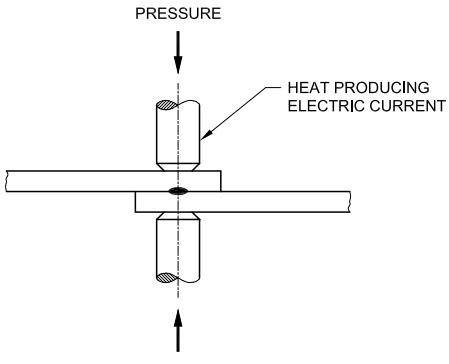
Fig 7



SIMPLE WELDING CIRCUIT

Electric resistance welding: It is a pressure-welding process in which the heat is obtained by passing a heavy momentary electric current through the inherent electric resistance of the joint to be welded. (Fig 8)

Fig 8



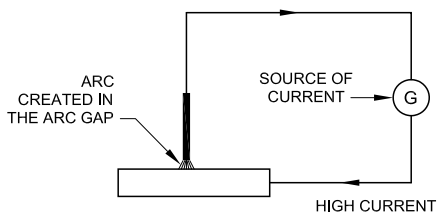
When the joint reaches a plastic state, sufficient pressure is applied to produce fusion and get a homogeneous weld.

Principle of arc welding

Electric arc is formed when both the terminals of an electric circuit are brought together and then separated by a small gap.

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 9)

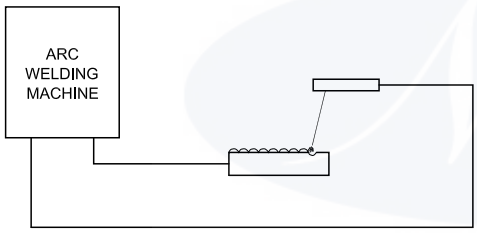
Fig 9



Metallic arc welding (Fig 10): This is an arc welding process in which the welding heat is obtained from an arc, formed between a metallic (consumable) electrode and welding job.

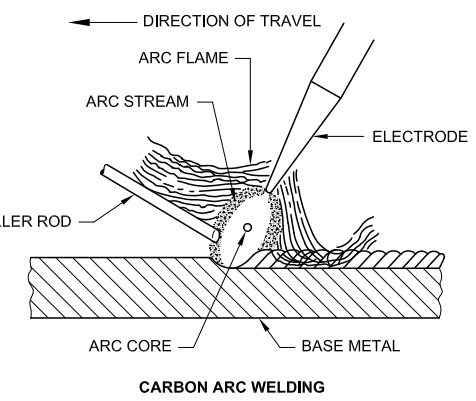
The metal electrode itself melts and acts as a filler metal.

Fig 10



Carbon arc welding (Fig 11): Here the arc is formed between a carbon electrode (non-consumable) and the welding job.

Fig 11



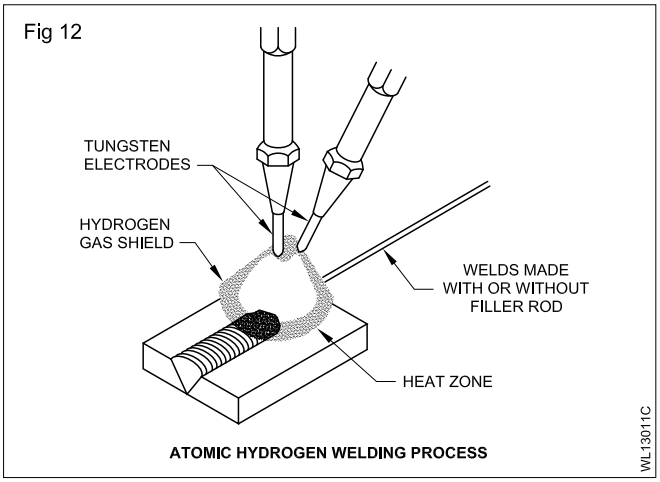
A separate filler rod is used since the carbon electrode is a non-metal and will not melt.

Atomic hydrogen arc welding (Fig 12): 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 12

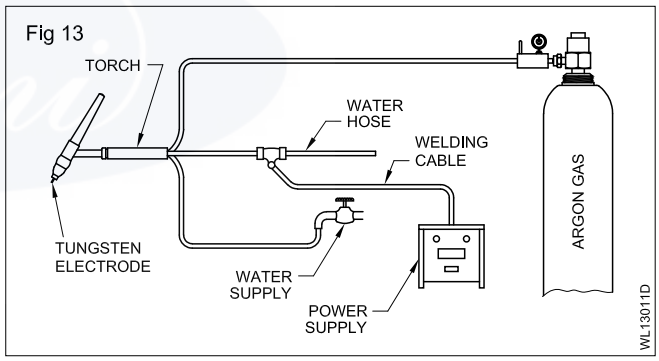


Tungsten inert gas arc welding (TIG) (Fig 13): In this case the arc is formed between the tungsten electrodes (non-consumable) and the welding job in an atmosphere of an inert gas (argon or helium).

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

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

Fig 13



Gas metal arc welding (GMAW) or Metal inert gas arc welding (MIG) (Fig 14): 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).

Metal transfer across the arc (Characteristics of arc)

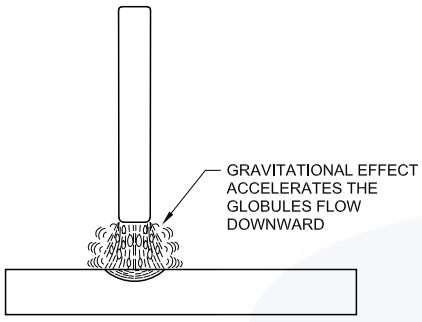
Objectives: At the end of this lesson you shall be able to
- **explain the factors involved in the transfer of metal across the arc due to arc characteristics.**

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

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

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

Fig 1



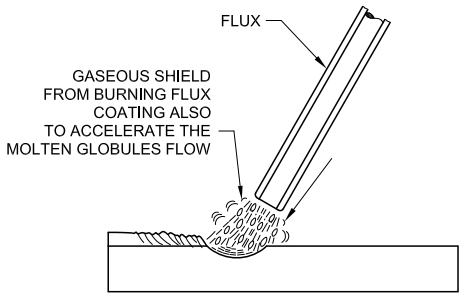
GRAVITY FORCE

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

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

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

Fig 2



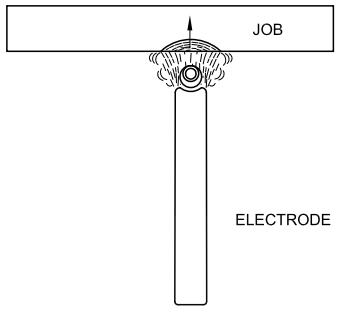
GAS EXPANSION EFFECT

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

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

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

Fig 3

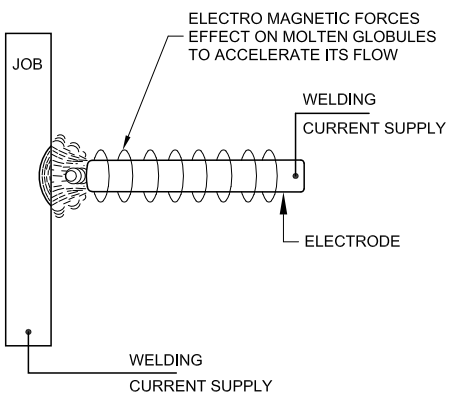


SURFACE TENSION EFFECT

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

This effect is more useful in positional welding.

Fig 4



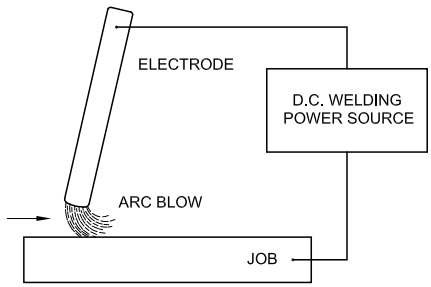
ELECTRO MAGNETIC EFFECT

Arc blow in DC arc welding

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 5)

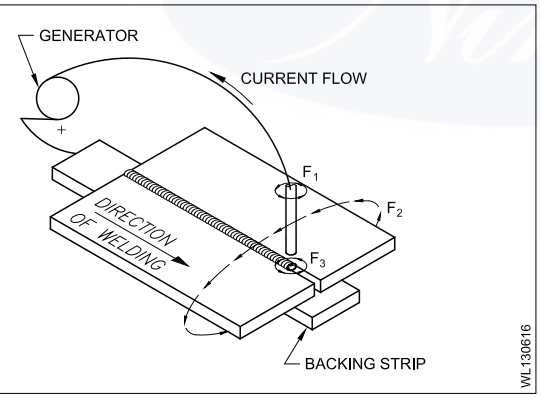
Fig 5



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.6). Likewise a similar magnetic field is also formed around the base metal F_2 (Fig.6). 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.7

Fig 6



Due to this the following effects occur.

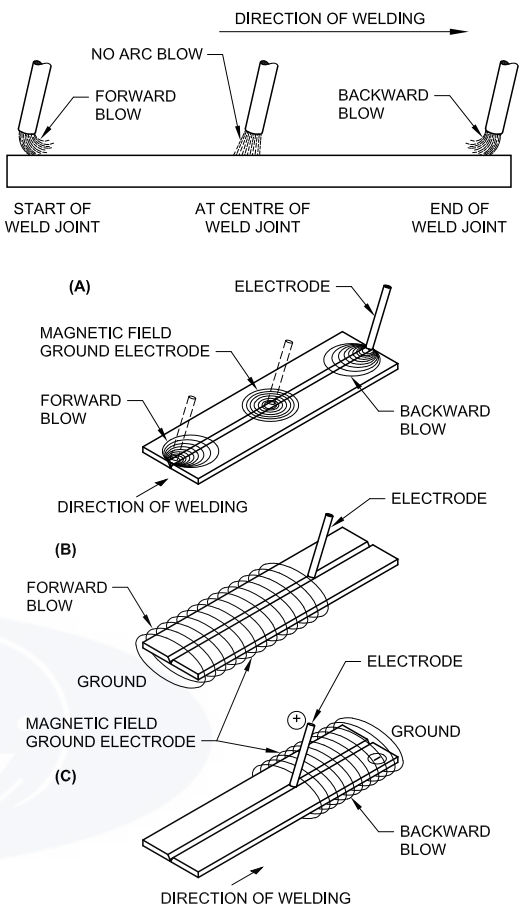
- More spatters with less deposition of weld metal.
- Poor fusion/penetration.
- Weak welds.
- Difficulty in depositing weld metal at the required place in the joint.
- The bead appearance will be poor and slag inclusion defect will also takes place.

Methods used to control the arc blow

The arc blow can be controlled by:

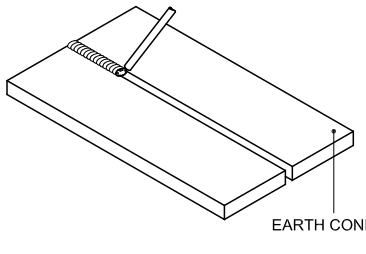
- place the earth connection as far from the weld joint as possible (Fig 8)

Fig 7



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

Fig 8



- 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 9)
- welding towards a heavy welding tack or a weld already made
- keeping a magnetic bridge on the top of the groove joint
- holding the correct electrode angle with a short arc.

Fig 9

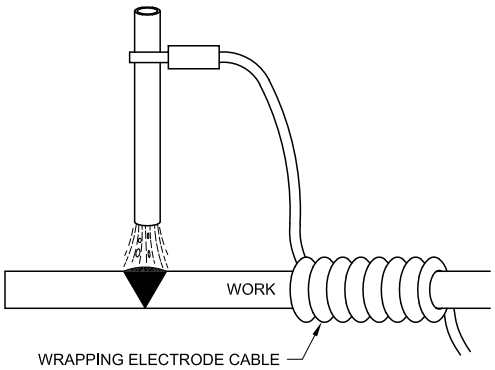
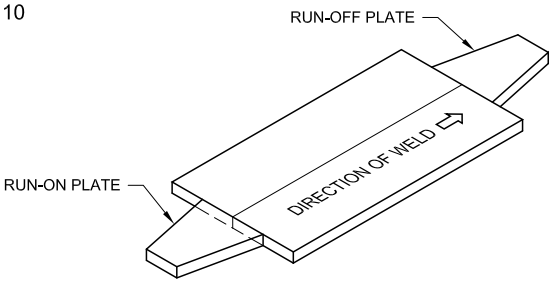


Fig 10



Use ‘run on’ and ‘run off’ plates.Fig.10

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

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.**

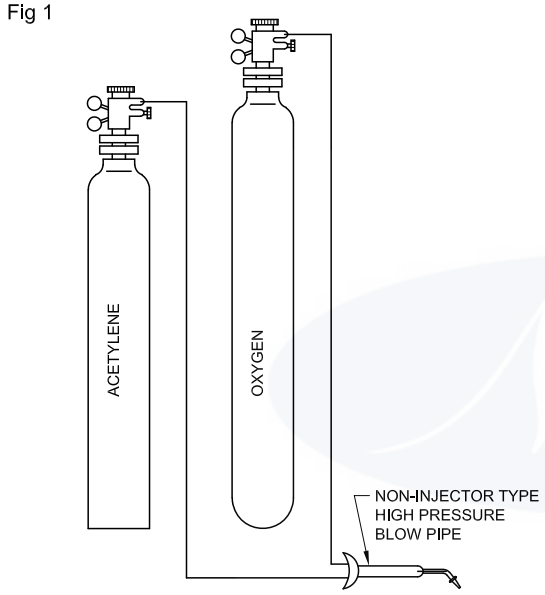
Oxy-acetylene plants: An oxy-acetylene plant can be classified into:

– 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.

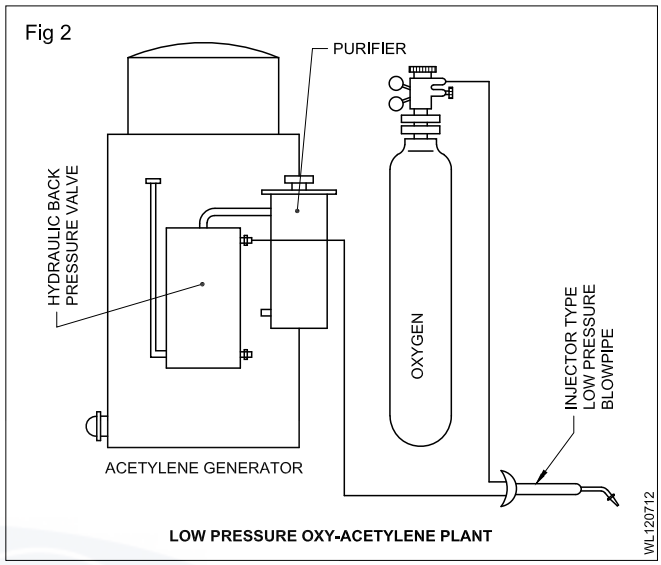
A low pressure plant utilizes acetylene under low pressure (0.017 kg/cm^2) produced by the acetylene generator only. (Fig 2)

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.

A low pressure acetylene plant with a low pressure acetylene generator and a high pressure oxygen cylinder is called a low pressure system.

Fig 2



LOW PRESSURE OXY-ACETYLENE PLANT

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

Types of blowpipes: For the low pressure system, a specially designed injector type 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 and accurate, hence working efficiency is more. The gases being in cylinder are perfectly under control. The D.A cylinder is portable and can be taken easily from one place to another place.

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

Disadvantages of high pressure system: Dissolved acetylene cylinder costs more and the rental charges to be paid to the suppliers for holding the cylinders are high. Hence it is expensive.

Advantages of low pressure system: Acetylene gas generation is less expensive. No rent is to be paid to the gas company, as the acetylene generator is the property of the welder/owner. The low pressure welding/cutting blowpipe (injector type) can be used in high pressure system also.

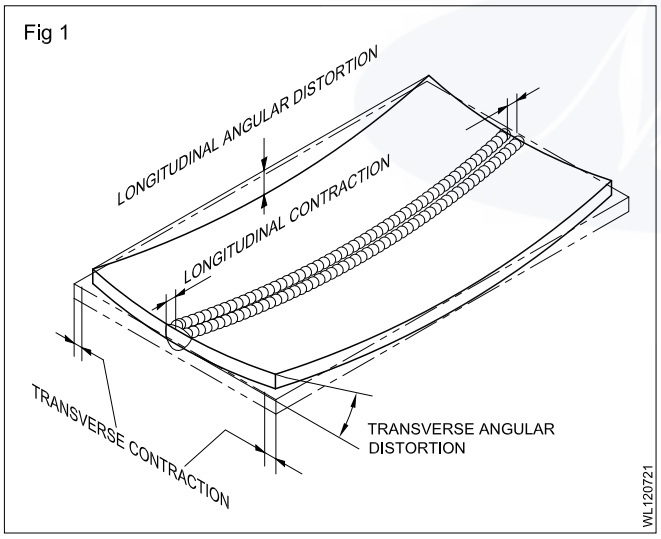
Disadvantages of low pressure system: The working on low pressure equipment i.e. acetylene generator poses more danger, hence the chances of accidents are more. The pressure adjustment of acetylene gas is not accurate, as it is controlled by oxygen pressure, hence the working efficiency is low. It is difficult to move the equipment from one place to another. Charging and cleaning of calcium carbide residue in the acetylene generator is difficult. The generated acetylene gas can reduce the flame temperature if it is not purified, which badly affects the welding quality. It requires an injector type blowpipe which is costlier. A license is required to store more than 100 kgs of calcium carbide at a time.

Distortion in gas welding

Objectives: At the end of this lesson you shall be able to
- **define distortion**
- **state and describe different types of distortion**
- **explain the causes of distortion in gas welding**
- **state the methods of controlling distortion**
- **describe the edge preparation done for gas welding.**

Definition: Any permanent change in the shape and size of the joining pieces from the original shape and size caused due to welding is called distortion. (Fig.1)

Fig 1



There are three types of distortion which are generally taking place in a welded joint. They are.

1 Longitudinal distortion

2 Transverse distortion

3 Angular distortion

Longitudinal distortion: Distortion taking place along the direction of weld is called longitudinal distortion. (Fig.2)

Transverse distortion: Distortion taking place in a direction perpendicular to the direction of welding is called transverse distortion. (Fig.3)

Fig 2

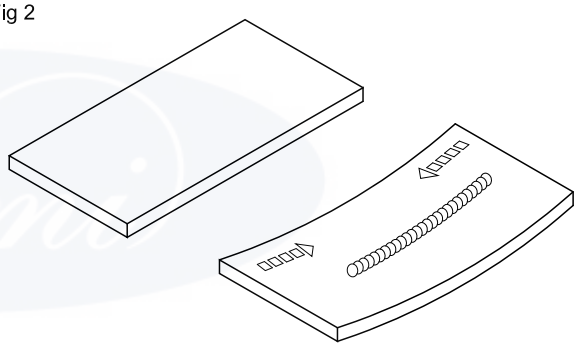
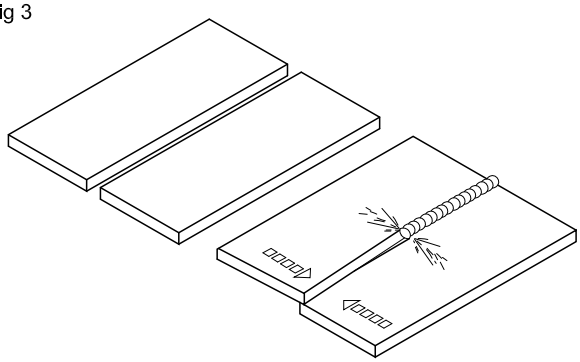
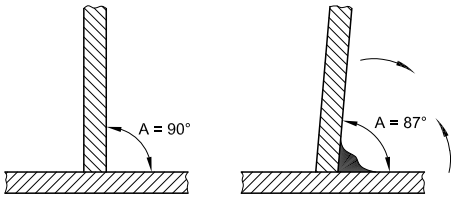


Fig 3

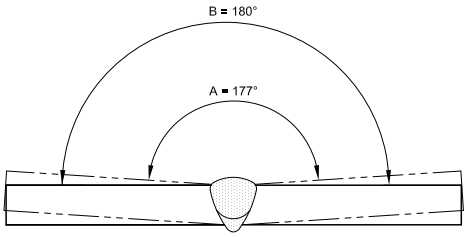


Angular distortion: If the plates which are welded are pulled towards each other due to welding and the angle between the plates changes from the originally set angle, then it is called angular distortion. (Fig.4)

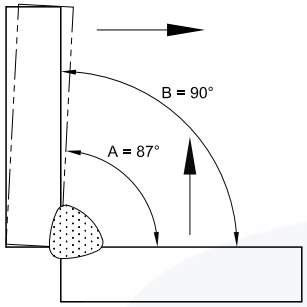
Fig 4



ANGULAR DISTORTION (FILLET JOINT)



ANGULAR DISTORTION (BUTT JOINT)



ANGULAR DISTORTION IN AN INSIDE CORNER JOINT

A = ANGLE AFTER WELDING
B = ANGLE BEFORE WELDING

ARROW INDICATE PULLING FORCES DUE TO WELDING

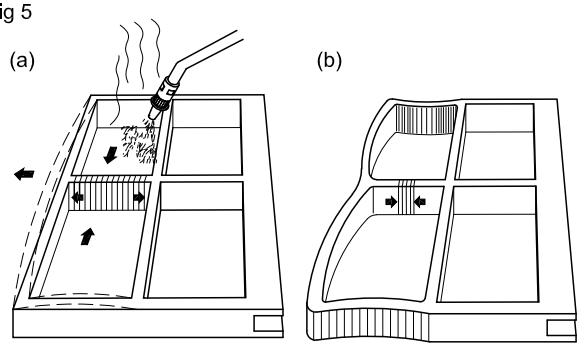
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The welding heat can cause stresses and distortions in a joint if the welding sequence is wrong.

The illustration (Fig.5a) shows how the heat produced during welding can cause damage and build up tension in a rigid job. This can spoil the quality, and perhaps, even cause cracks in the job.

Local distortion, as shown here (Fig.5b) is caused by heating or welding a beam of a rigid part. Residual stress has been created by the heating.

Fig 5



WL120725

Causes of distortion in gas welding: Main disadvantage of gas welding is it takes more time to deposit the weld metal on thicker plates.

Therefore generally thin sheets and pipes upto 3.15mm thick ferrous and non-ferrous metals are joined by oxy-acetylene gas welding.

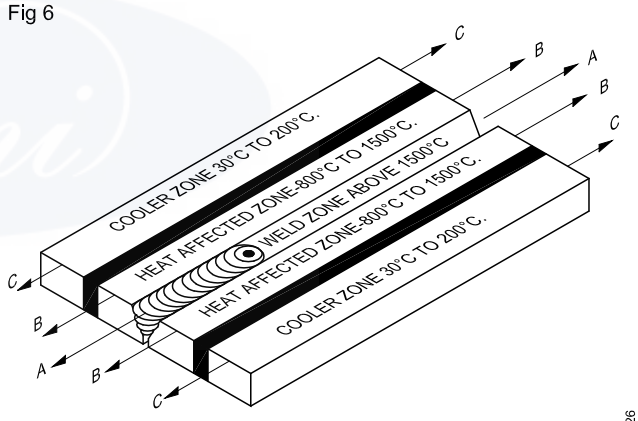
In view of thin sheets are being welded and the heat input into the joint by the inner cone and the outer envelope of the flame is more. Also the outer envelope is in contact with a larger/wider area of the joint. Hence distortion like bending buckling, twisting, while welding mild steel, stainless steel, aluminium etc. take place. In addition, cracks are created in cast iron, copper etc. due to high heat input.

In a welded joint, the fusion zone is heated to the melting point of the metal. The zone adjacent to the fusion zone called the heat affected zone (HAZ) is heated to about 100 to 600^{0}C less than the melting point.

The remaining portions of the joint called cooler zones are heated to a very low temperature of 30^{0}C to 200^{0}C.Fig.6.

So there will be more expansion at the fusion zone, less expansion at the HAZ and negligible expansion at other cooler portion of the joint during welding. Fig.6

Fig 6



TEMPERATURE IN DIFFERENT AREAS OF A WELDED JOINT (MILD STEEL)

WL120726

Similarly, during cooling of the joint after welding, all the above three zones have to be cooled to the room temperature of 30^{0}C. Therefore there will be excessive contraction at the fusion zone a little less contraction at the HAZ and negligible contraction at the cooler zone.

So the uneven heating and cooling as well as the uneven expansion and contraction of the joint is taking place during and after welding. But the base metal atoms will resist this and the stress and strain developed in the base metal due to this resistance causes the joint to be distorted.

Control of distortion and residual stresses by proper welding technique/method

The distortion or residual stress in a welded joint is caused by the uneven expansion and contraction in the weld and the base metal. As this will create very high shrinkage forces it is necessary to control them by one or more of the following methods.

Rule-1: Reduction of the effective shrinkage force

Rule-2: Making the shrinkage force work to reduce distortion.

Rule-3: Balancing one shrinkage force with another shrinkage foce.

Under each of the above 3 rules different method of controlling distortion are used depending on the type of weld, sheet or plate thickness used, the welding process etc. Refer Related Theory of Arc welding Exercise No.3.12/E-24 to know the various methods of controlling distortion.

Edge preparation (Gas welding): For a Tee fillet, lap fillet and corner fillet joints a square edge preparation for thickness upto 3.15mm is used.

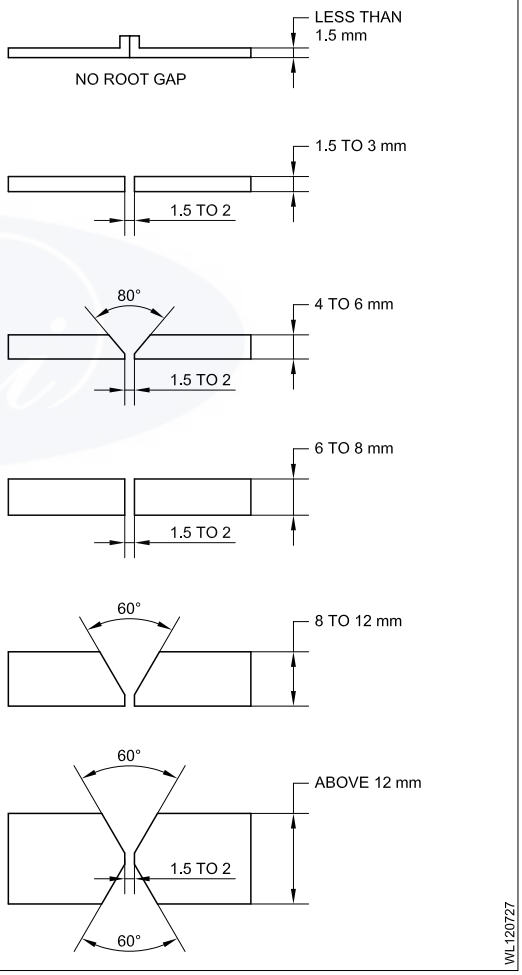
For butt joints, the edges are prepared as given below.

Plate edge preparation

Fig.7 shows the plate edge preparation depending on the thickness of the material to be welded.

Metal thickness	Diameter of filler	Edge preparation
Upto 1.6mm	None to 1.6mm	
1.6mm to 2.5mm	1.6mm to 2.5mm	
2.5mm to 4.0mm	2.5mm to 3.15mm	
4.0mm to 6.0mm	3.15mm	
6.0mm to 15mm	3.15mm	
15mm and over	5.0mm	

Fig 7



Belt tension

Objectives: At the end of this lesson you shall be able to
- **state the need for tensioning belts**
- **state the methods of adjusting belt tension**
- **state the importance of the arc of contact in a belt drive**
- **state the important factors for improving the efficiency in a belt drive**
- **calculate the deflection force necessary for a belt drive**
- **state the care and maintenance of belts.**

Belt tension

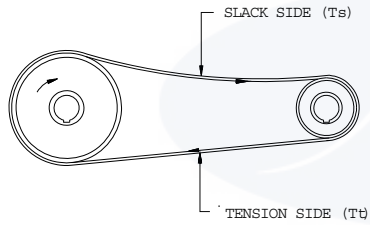
Belts must be tensioned correctly to transfer the torque from the driving pulley to the driven pully to prevent unnecessary wear.

Too much of belt tension curtails belt and bearing life. As the belts stretch in use, it is necesary to check and adjust the belt drive tension.

When a drive is transmitting power the belt pulls or the belt tensions. There is the tight side tension (Tt) and a slack side tension (Ts). (Fig 1)

Tension ratio

Fig 1



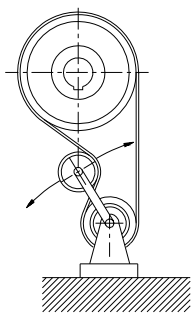
The ratio of the tight side to the slack side tension is commonly referred to as the tension ratio. A higher ratio between the tight side and slack side tension makes the belt loose and slip.

This causes lack of effective pull for transmitting the required power.

Adjustment of tension

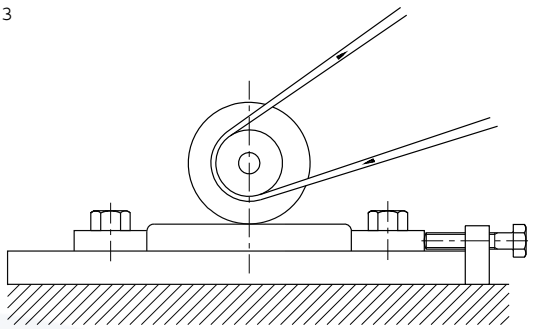
When the distance between two pulleys is fixed, the tension of a belt is adjusted by an idler. (Fig 2)

Fig 2



When the distance between two pulleys is not fixed, the tension of the belt is adjusted by the adjustment screw. (Fig 3)

Fig 3



Arc of contact

Tension is necessary to create friction between the pulleys and the belt. Torque transmission depends on the contact area of the belt over the pulleys. (Fig 4)

Fig 4

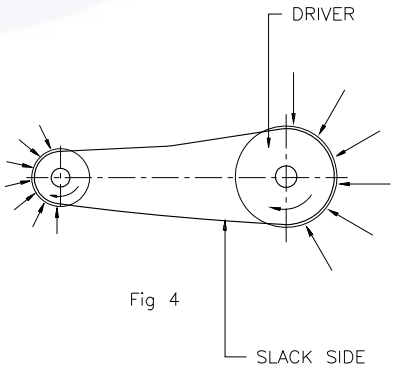
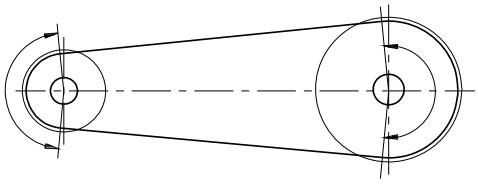


Fig 4

If the wrapping angle is big, the pulley can transmit high torque. (Fig 5)

Fig 5

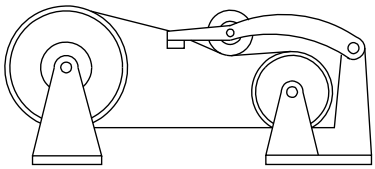


Belt efficiency

To provide maximum arc of contact the following points should be considered.

- Heavy belts of multi ply construction should not be used on small diameter pulleys.
- If the arc of contact is insufficient because of the short centre distance between the pulleys, a jockey pulley should be introduced as near to the small pulley as possible. (Fig 6)

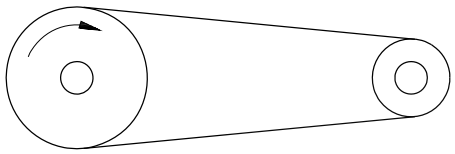
Fig 6



THE USE OF A JOCKEY PULLEY TO MAINTAIN CORRECT BELT TENSION

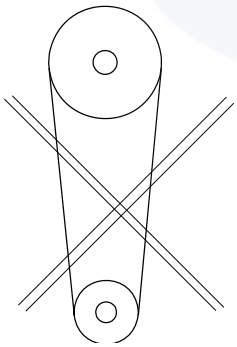
Excessive tension in the belt reduces the arc of contact, and introduces additional stresses which drastically reduce the life of the belt and bearings. (Fig 7)

Fig 7



Vertical drives should definitely be avoided because the belt tension necessary to withstand gravitational pull (Fig 8) and accompanying slippage would result in adverse effects.

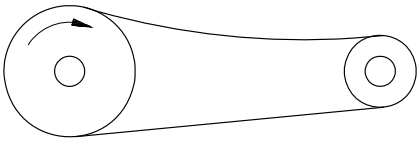
Fig 8



AVOID VERTICAL BELT DRIVE

On the open belt drive, the slack side (Fig 9) must be at the top and the centre distance between the pulleys should be the maximum.

Fig 9

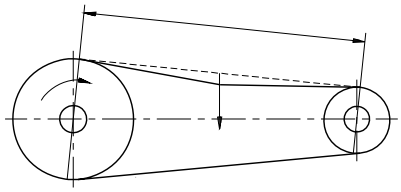


To measure tension of V-belt drives

To determine the force required to deflect one belt per 25 mm span length, apply a force perpendicular to the span at the centre of the belt large enough to deflect one belt to 0.5 mm span from its normal position. (Fig 10)

- Compare this deflection force with the range of forces given in Table 1.

Fig 10



- If it is less than the minimum recommended deflection force, the belts should be tightened.
- If it is more than the maximum recommended deflection force, the drive is tighter than it need be.

Care and maintenance

- Keep the pulley faces and belts free from foreign material which may cause slips.
- When the 'V' belts begin to show signs of wear they should be replaced. Replace all the belts in a multiple 'V' belt drive rather than a single one.
- Check and adjust drive tension periodically.
- Store belts in a cool, dark and dry place.

TABLE 1

Recommended deflection force per belt for classical 'V' belts

V-Belt cross-section	Small sheave dia. range cm	Speed ratio range	Recommended deflection force Kg Min.	Max.
A	7.62-8.13	2.0-4.0	1.08	1.54
	8.64-9.14		1.14	1.68
	9.65-10.67		1.32	1.91
	11.68-17.78		1.59	2.26
B	11.68	2.0-4.0	2.00	2.86
	12.67-13.71		2.22	3.22
	14.22-16.25		2.45	3.53
	17.27-23.87		2.81	4.08
C	17.78	2.0-4.0	3.4	5.00
	19.05-20.32		3.81	5.44
	21.59-25.4		4.30	6.36
	26.67-40.64		5.00	7.72
D	30.48-33.02	2.0-4.0	7.71	10.91
	34.29-39.37		8.6	12.27
	40.64-55.88		10.00	14.09
E	54.86-60.96	2.0-4.0	14.54	21.36

• The belt tension should be adjusted in such a way that the deflection force is in between the maximum and minimum.

Lubricating machines

Objective: At the end of this lesson you shall be able to
- **state the methods of applying a lubricant.**

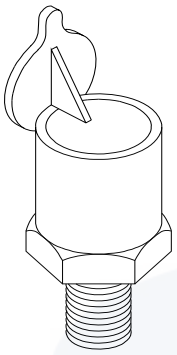
There are 3 systems of lubrication.

- **Gravity feed system**
- **Force feed system**
- **Splash feed system**

Gravity feed

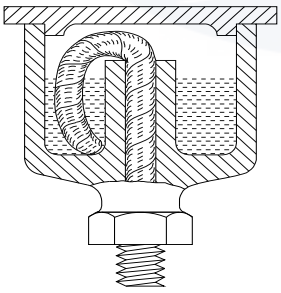
The gravity feed principle is employed in oil holes, oil cups and wick feed lubricators provided on the machines. (Figs 1 & 2)

Fig 1



OIL CUP

Fig 2



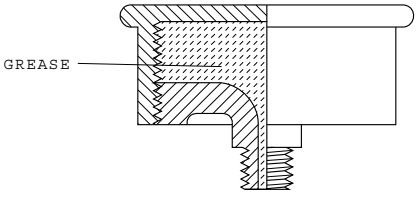
WICK FEED

Force feed/Pressure feed

Oil, grease gun and grease cups

The oil hole or grease point leading to each bearing is fitted with a nipple, and by pressing the nose of the gun against this, the lubricant is forced to the bearing. Greases are also force fed using grease cup. (Fig 3)

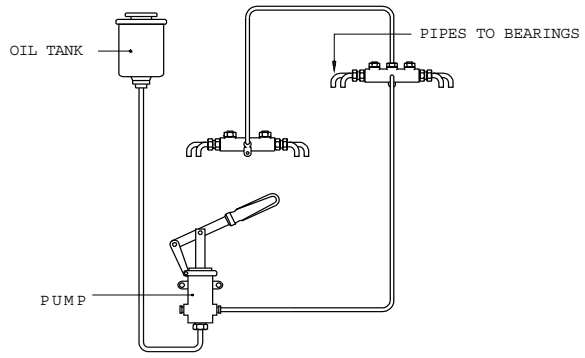
Fig 3



MANUAL SCREW DOWN GREASER

Oil is also pressure fed by hand pump and a charge of oil is delivered to each bearing at intervals once or twice a day by operating a lever provided with some machines. (Fig 4) This is also known as shot lubricator.

Fig 4



HAND PRESSURE FEED SHOT LUBRICATED

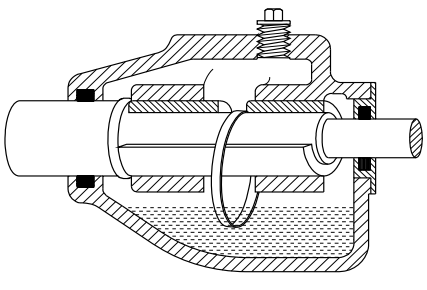
Oil pump method

In this method an oil pump driven by the machine delivers oil to the bearings continuously, and the oil afterwards drains from the bearings to a sump from which it is drawn by the pump again for lubrication.

Splash lubrication

In this method a ring oiler is attached to the shaft and it dips into the oil and a stream of lubricant continuously splashes around the parts, as the shaft rotates. The rotation of the shaft causes the ring to turn and the oil adhering to it is brought up and fed into the bearing, and the oil is then led back into the reservoir. (Fig 5) This is also known as ring oiling.

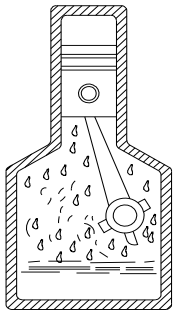
Fig 5



RING OILING

In other systems one of the rotating elements comes in contact with that of the oil level and splash the whole system with lubricating oil while working. (Fig 6) Such systems can be found in the headstock of a lathe machine and oil engine cylinder.

Fig 6



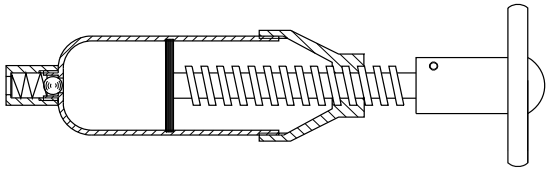
SPLASH-LUBRICATING SYSTEM

Types of grease guns

The following types of grease guns are used for lubricating machines.

- **'T' handle pressure gun (Fig 7)**

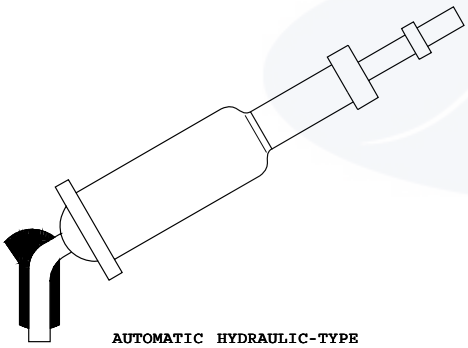
Fig 7



T-HANDLE PRESSURE GUN

- **Automatic and hydraulic type pressure gun (Fig 8)**

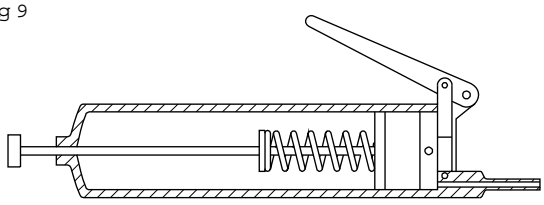
Fig 8



AUTOMATIC HYDRAULIC-TYPE PRESSURE GUN

- **Lever-type pressure gun (Fig 9)**

Fig 9



PRESSURE GREASE GUN

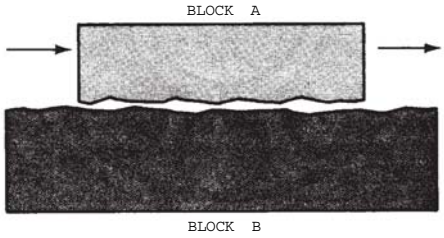
Lubrication to exposed slideways

The moving parts experience some kind of resistance even when the surface of the parts seems to be very smooth.

The resistance is caused by irregulartities which cannot be detected by the naked eyes.

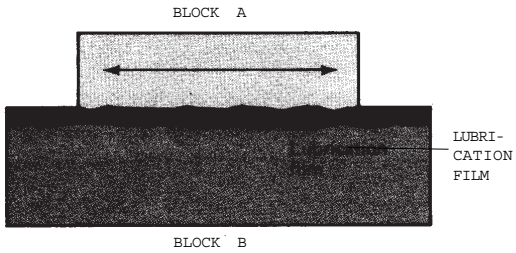
Without a lubricant the irregulartities grip each other as shown in the diagram. (Fig 10)

Fig 10



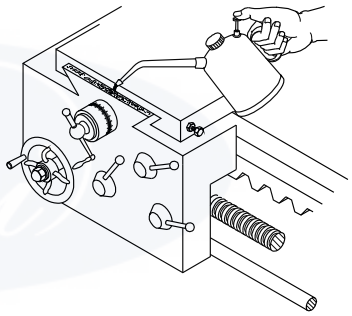
With a lubricant the gap between the irregularities fills up and a film of lubricant is formed in between the mating components which eases the movement. (Fig 11)

Fig 11



The slideways are lubricated frequently by an oilcan. (Fig 12)

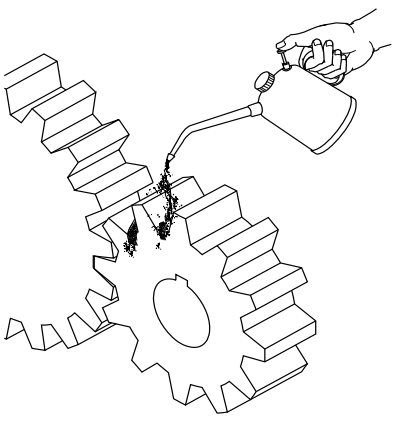
Fig 12



OIL THE SLIDES FREQUENTLY

After cleaning the open gears, oil them and repeat lubrication regularly. (Fig 13)

Fig 13

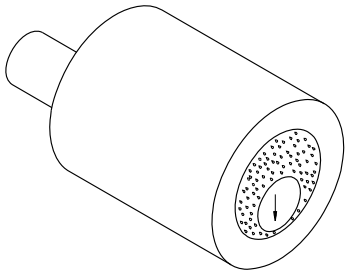


Lubricate bearings

A shaft moving in a bearing is also subjected to frictional resistance. The shaft rotates in a bush bearing or in ball/ roller bearing, experiencing friction.

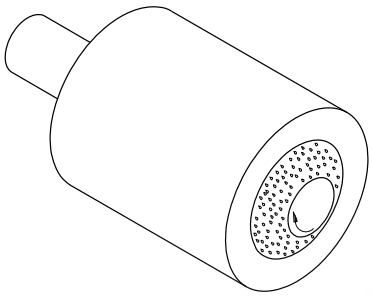
When the shaft is at rest on the bottom of the bush bearing, there is hardly any lubricant between the shaft and the bush. (Fig 14)

Fig 14



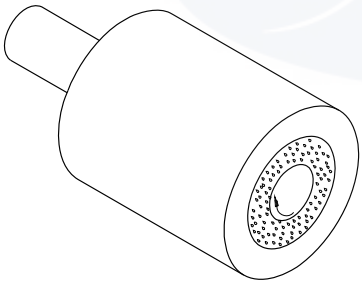
When the shaft starts rotation the lubricant maintains a film between the shaft and the bush and an uneven ring of lubricant builds up. (Fig 15)

Fig 15



When the shaft is rotating at full speed a full ring of lubricating film surrounds the shaft (Fig 16) which is known as hydro dynamic lubrication.

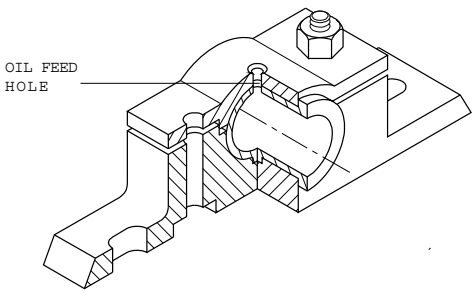
Fig 16



This lubrication ring decreases the frictional resistance very much and at the same time protects the mating members against wear and changes.

Some bush bearings have oil feeding holes over which the oil or grease cup is mounted and the lubricant is fed through the holes into the bearing by gravity feed system.(Fig 17)

Fig 17



Hints for lurbicating machines:

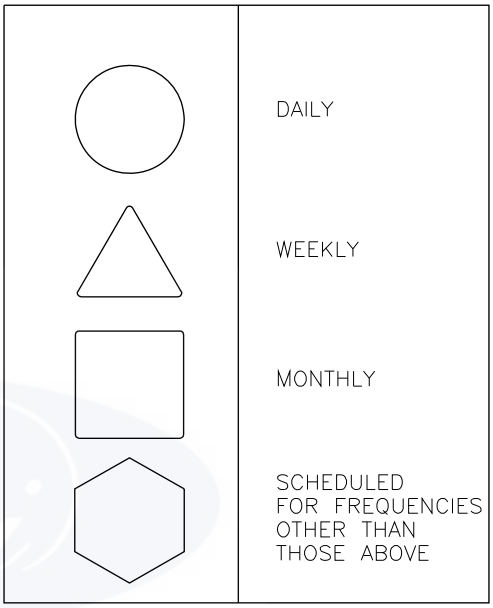
- identify the oiling and greasing points
- select the right lubricants and lubricating devices
- apply the lubricants.

The manufacturer's manual contains all the necessary details for lubrication of parts in machine tools. Lubricants are to be applied daily, weekly, monthly or at regular intervals at different points or parts as stipulated in the manufacturer's manual.

These places are indicated in the maintenance manuals with symbols as shown in Fig 18.

Fig 18

FREQUENCY CLASSIFICATION SYMBOLS



The best guarantee for good maintenance is to follow the manufacturer's directives for the use of lubricants and greases. Refer to the Indian Oil Corporation chart for guidance. The commonly used oils in the workshop is given in Annexure I.

The lubricant containers should be clearly labelled. The label must indicate the type of oil or grease and the code number and other details. Oil containers must be kept in the horizontal position while the grease container should be in the vertical position.

Product	Kinematic viscosity Cst at 40°C.	VI	Flash point COC°C	Description/Application
General Purpose Machinery Oils				
Lubrex 57	54.60	..	160	Lubrex oils are low viscosity index straight mineral lubricants having good inherent oxidation stability; they protect machine elements from excessive wear and provide economical lubrication. These oils are recommended for lubrication of bearings, open gears, lightly loaded slides and guideways of machine tools.
Lubrex 68	64.72	..	160	
Flushing Oil				
Lubrex Flush 22	19.22	..	150	Lubrex Flush 22 is a light coloured, low viscosity, straight mineral oil specially developed for slushing of automotive and industrial equipment. The characteristics of Lubrex Flush 22 make it possible to easily clean all inacessible internal surfaces of various equipments.
Circulating and Hydraulics Oils (Anti-wear Type)				
Servosystem 32	29.33	95	196	Servosystem oils are blended from highly refined base stocks and carefully selected anti-oxidant, anti-wear,anti-rust and anti-foam additives.These oils have long service life, and are recommended for hydraulic systems and a wid of circulation systems of industrial and automotive equipment. These oils are also used for compressor crankcase lubrication, but are not recommended for lubrication of turbines and equipment having silver coated components.
Servosystem 57	55.60	95	210	
Servosystem 68	64.72	95	210	
Servosystem 81	78-86	90	210	
Servosystem 100	95-105	90	210	
Servosystem 150	145-155	90	230	
Spindle Oils				
Servospin 2	2.0-2.4	..	70	Servospin oils are low viscosity lubricants containing anti-wear, anti-oxidant, anti-rust and anti-foam additives. These oils are recommended for lubrication of textile and machine tool spindle bearings, timing gears, positive displacement blowers, and for tracer mechanism and hydraulic systems of certain high precision machine tools.
Servospin 5	4.5-5.0	..	70	
Servospin 12	11-14	90	144	
Machinery Oils				
Servoline 32	29.33	..	152	Servoline oils provide good oiliness for general lubrication even under boundary lubrication conditions,protect parts against rust and corrosion and maintain thin film strength and anti-rust additives. Servoline oils are general purpose lubricants for all loss lubrication systems of textile mills, paper mills, machine tools.
Servoline 46	42.50	..	164	
Servoline 68	64-72	..	176	
Gear Oils				
Servomesh 68	64-72	90	204	Servomesh oils are industrial gear oils blended with lead and sulphur compounds. These oils provide resistance to deposit formation, protect metal components against rust and corrosion, separate easily from water and are non-corrosive to ferrous and non-ferrous metals. Servomesh oils are recommended for lubrication of industrial gears, plain and anti-friction bearings subjected to shock and heavy loads and should be used in systems were operating temperature does not exceed 90°C. These oils are not recommended for use in food processing units.
Servomesh 150	145-155	90	204	
Servomesh 257	250-280	90	232	

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Belt drives - creep & slip

Objectives: At the end of this lesson you shall be able to
- **state different types of belt drives**
- **distinguish between creep and slip**
- **state the effect of creep and slip.**

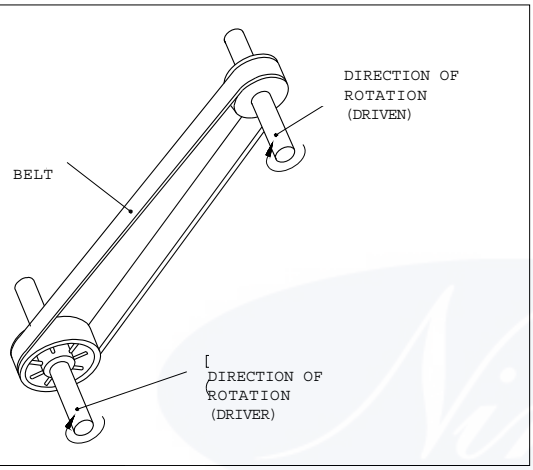
Belt drives

The belt drive is the most common method of power transmission. The belts are made from leather, cotton, rubber and synthetic materials. A flat belt drive is shown in Fig 1.

Types of Belt Drives (flat belts)

Open belt drive (Fig 1)

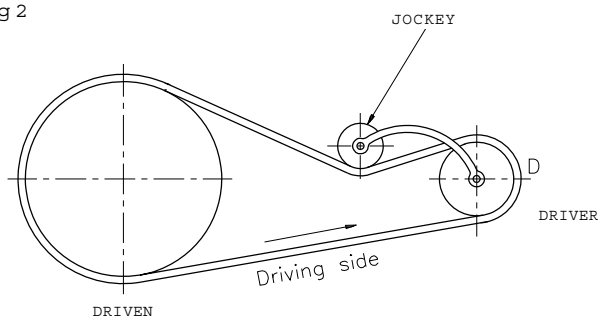
Fig 1



An open belt drive is used between parallel shafts in which the direction of rotation of driving and driven shafts is the same.

Jockey or idler pulley (Fig 2)

Fig 2

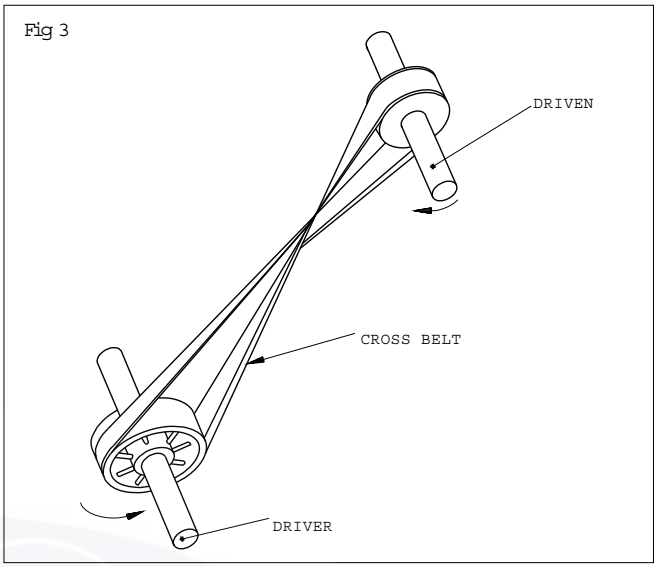


If the centre distance between the pulleys exceeds 3 times the larger pulley diameter and the ratio of the pulley diameters exceeds 6 to 1, a jockey or idler pulley is fitted near the driver pulley on the slack side of the belt to increase the arc of contact. This increases the wrapping angle and tension on the belt, necessary for the transmission of the torque.

Cross-belt drive (Fig 3)

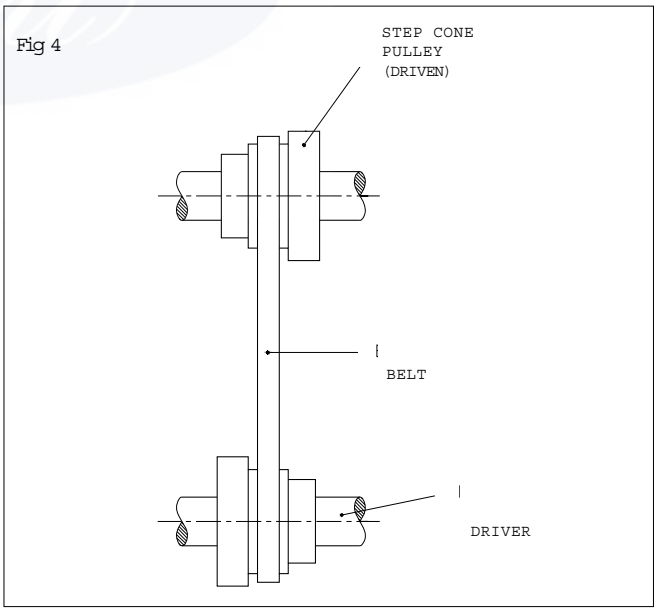
A cross-belt drive is shown in Fig 3 in which the direction of rotation of driving and driven shafts is opposite.

Fig 3



Stepped drives (Fig 4)
Stepped drives are used to obtain different speed ratios. Pulleys of different sizes are employed.

Fig 4

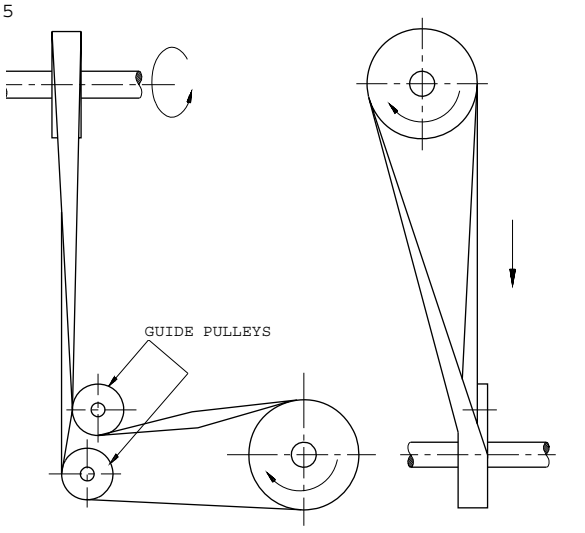


Three different speeds can be obtained by changing the belt position from one step to another.

Right angled drive (Fig 5)

This drive is employed between shafts at right angles using guide pulleys. In this the horizontal drive is converted into vertical drive with the help of the guide pulleys.

Fig 5



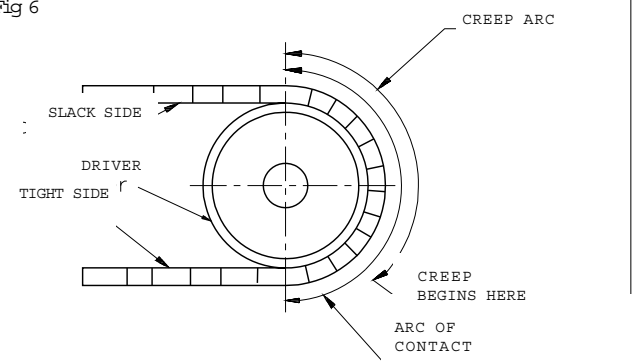
BELT DRIVE BETWEEN SHAFTS OF RIGHT ANGLES USING GUIDE PULLEYS

Creep and slip of belt (Fig 6)

As the belt turns on a pulley it tends to stretch on the contact area of the driving pulley and shorten on the driven pulley. This localised movement of the belt is a direct result of the elastic stretch and is known as creep. Greater the load more will be the creep. The figure shows the condition of belt as a result of creep.

Slip is the actual difference caused between the surface speed of the belt and pulley. The effect of slip may be

Fig 6



reduced by decreasing the pulley ratio and maintaining proper alignment. Creep, being the physical characteristic of the belt, cannot itself be controlled. Slip and creep jointly cause power loss.

Belt dressing

Due to the continuous rubbing of the belt on the surface of the pulley the belt gets dried up due to friction, and heat is generated. This causes the belt to slip.

To keep the belt supple and free from cracks, belt dressing is appliled. Tallow or powdered resin are good dressing materials which are applied on the inner face of the belt. This improves the gripping property of the belt.

Belts - types - belt fasteners

Objectives: At the end of this lesson you shall be able to
- **name the different types of belts**
- **state the advantages of 'V' belt drive**
- **state the classification of 'V'belts**
- **state the different types of belt fasteners.**

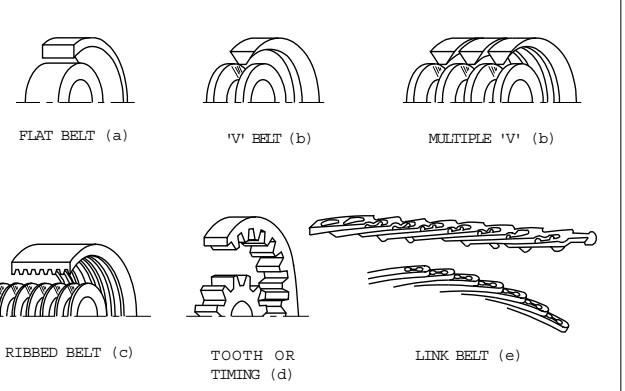
Types of belts

Basically five types of belts are used for the transmission of power.

- Flat belt (Fig 1a)
- V-belt and multiple V-belt (Fig 1b)
- Ribbed belt (Fig 1c)
- Toothed or timing belt (Fig 1d)
- Link belt (Fig 1e)

The choice of a particular belt depends upon speed ratio, centre distance, flexibility, strength, economy and maintenance consideration of the driving system.

Fig 1



V-belts

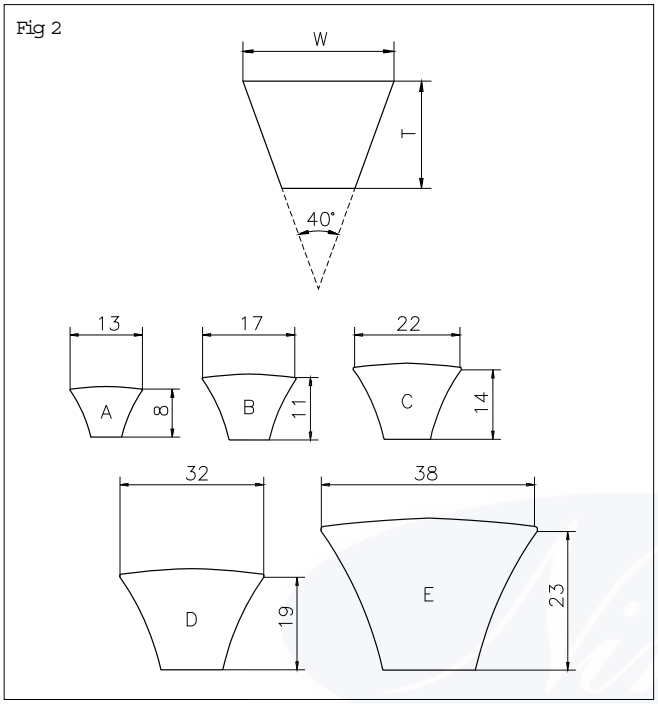
'V'belt drives are generally used when the distance between the shafts is too short for flat belt drives. Owing to the wedge action between the belt and the sides of the groove in the pulley, the V belt is less likely to slip, hence more power can be transmitted.

The endless V belt is shaped roughly like a trapezium in cross-section, and is made of cord and fabric, and is treated with rubber and moulded together in a uniform manner and shape. The cross-sectional symbol of a V-belt is shown in Fig 2.

Advantages of V-belt drive

- It is compact, so installation is possible in limited space.
- It is used when the centre distance between the driver and the driven pulleys is short.

Fig 2



- Less vibration and noise.
- Cushions the motor and bearing against load fluctuation.
- Easy replacement and maintenance.

Classification of 'V'belts

The 'V' belts are classified into 5 groups as per IS.2494-1974 namely A,B,C,D and E. The nominal included angle of the V-belt shall be 40°.

Table 1 given below lists the standard sizes of V-belts from Section A to E.

TABLE - 1

Cross-section Symbol	Nominal Top Width W (mm)	Nominal Thickness (T)
A	13	8
B	17	11
C	22	14
D	32	19
E	38	23

Individual manufacturer's belts may deviate slightly from these dimensions for various constructional reasons. Crowning, if any, in belts should be disregarded for the measurement of thickness.

Designation of V-belt as per IS.2494

The V belts conforming to this standard shall be designated by the cross-section symbol, nominal inside length and the number of IS: standard.

Example

C 3048 IS: 2494

C = V-belt cross-section

3048 = Nominal inside length in mm. in untensioned state.

Belt length calculation - (flat belts)

The best way to determine the correct length of a belt is by wrapping a steel tape around the pulleys and recording the measurement. If the belts are to be spliced and cemented, an additional amount of belt length must be provided for making the lap. The formula to determine the belt length is given below.

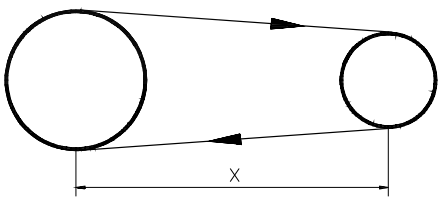
Calculation

Open belting (Fig 3)

If L = length of open belting
D = dia. of larger pulley
d = diameter of smaller pulley
x = centre distance between the pulleys

$$\text{then, } L = \frac{D + d}{2} \times 3\frac{1}{7} + 2x$$

Fig 3

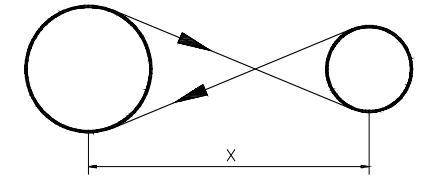


Cross-belting (Fig 4)

If L_C = length of cross-belting
C = circumference of larger pulley
c = circumference of smaller pulley
R = Radius of larger pulley
r = radius of smaller pulley
x = centre distance between the pulleys

$$\text{then, } L_c = \frac{C}{2} + \frac{c}{2} + 2\sqrt{x^2 + (R+r)^2}$$

Fig 4



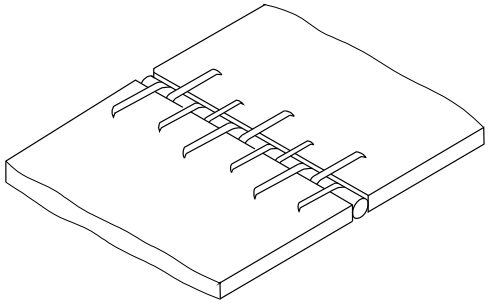
Types of Fasteners

The belt fasteners commonly used in addition to the alligator type are as follows.

Wire type belt fastener

Fig 5 shows the wire type fastener generally used on light duty machines.

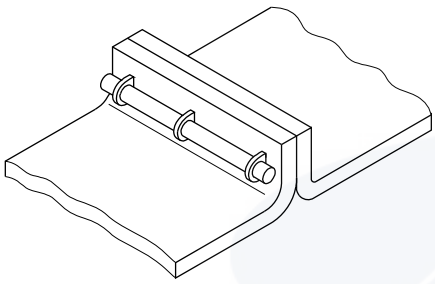
Fig 5



'Lagrelle' type belt fastener

Fig 6 shows a lagrelle type fastener used on heavy duty machines.

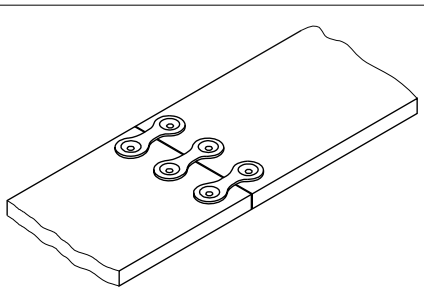
Fig 6



Jackson-type belt fastener

The Jackson-type fastener illustrated in Fig 7 is used on medium duty machines.

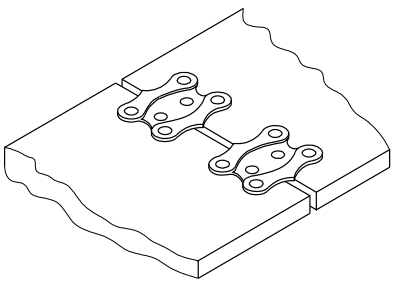
Fig 7



Crescent plate belt fastener

Fig 8 shows a mechanical type belt fastner which is used on medium duty machines.

Fig 8



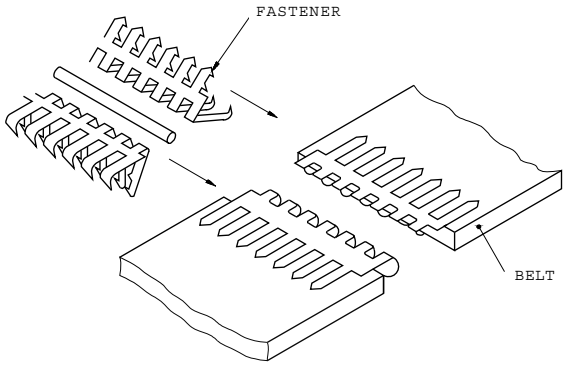
Belt fasteners (Alligator type)

Alligator type fasteners are used in joining belting for industrial purposes. The belt fastener is made of steel sheets conforming to IS:513-1973. The pins shall be made from mild steel wire conforming to IS: 280-1972. Belt fastners are shown in Fig 9 and the position of the pin in a joint is illustrated in Fig 10.

Specification

The fastener designation and pin size, thickness of belt and other dimensions are given in the table below as per IS: 5593-1980.

Fig 9



ALIGATOR TYPE BELT FASTENER

Fig 10

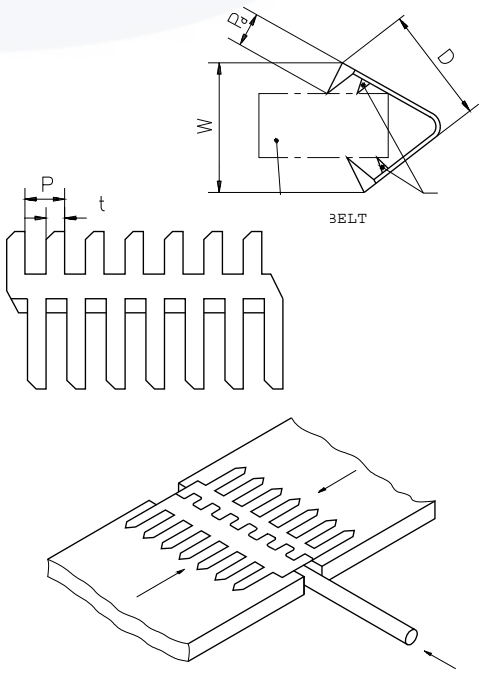


TABLE - 1

Fastener Designation	Thickness of belt	Metal thickness (Sheet)	Point depth P_d	Approx overall width W	Approx overall depth t_1 Min D	Width of bar prong P	Pitch of prong
15	3 to 4	1.0	5.0	18	13	2.5	6
20	4 to 5	1.1	6.5	22	17	3	8
25	5 to 5.5	1.2	7.0	25	21	3	8
27	5.5 to 7	1.2	8.0	29	24	3	8
35	7 to 8	1.8	9.5	32	30	4	10
45	8 to 9.5	1.8	11.0	38	31	5	12
55	9.5 to 11	2.0	14.0	48	40	6.5	16
65	11 to 13	2.0	16.0	54	41	6.5	16

PINS

Fastener designation	Pin size mm
15,20,25	2.64
27,35	3.25
45,55,65	4.06

Gears - types - care & maintenance

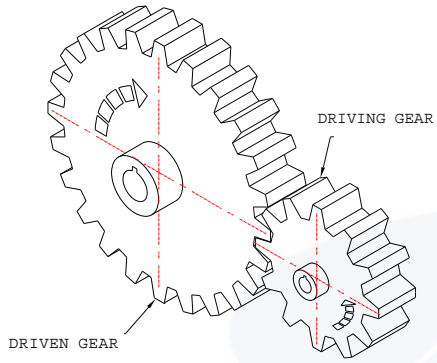
Objectives: At the end of this lesson you shall be able to
- **state the purpose of gears**
- **name the most common forms of gears and state their uses**
- **determine the velocity ratio of a gear train**
- **state the care and maintenance of gears.**

Purpose of gears

Gears are used to transmit torque/motion from the driving shaft to the driven/follower shaft:

- **to change the velocity ratio**
- **to change the direction of rotation. (Fig 1)**
- **to get a positive drive.**

Fig 1



Gears are made from cast iron, steel, non-ferrous, plastic or fibre material.

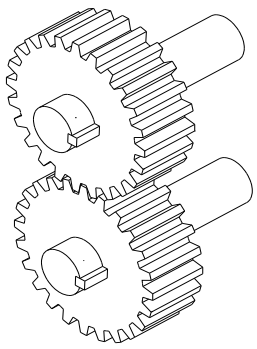
Types

Spur gear

The teeth are cut parallel to the axis of rotation. The spur gears are used to transmit power between two parallel shafts.

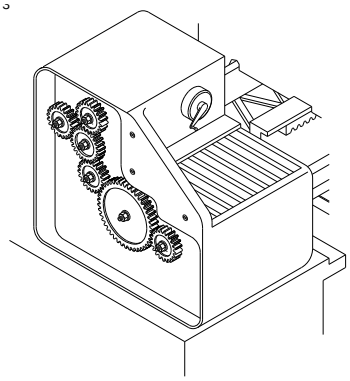
Fig 2 shows two spur gears mating each other and Fig 3 illustrates the application of gears in the centre lathe to transmit motion from the main spindle to the lead screw.

Fig 2



SPUR GEAR

Fig 3



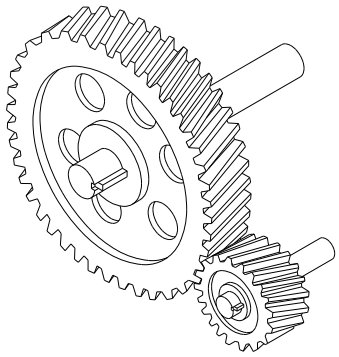
SPUR GEAR

Helical gear

In a helical gear, the teeth are cut at an angle to the axis of rotation. It may be used to transmit power between two parallel shafts. Helical gears run more silently than a spur gear.

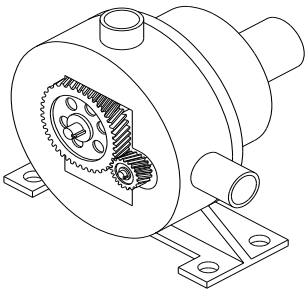
Fig 4 shows a set of helical gears mounted on two parallel shafts. These are widely used in automobile vehicles. The application of helical gears in an oil pump is illustrated in Fig 5.

Fig 4



HELICAL GEARS

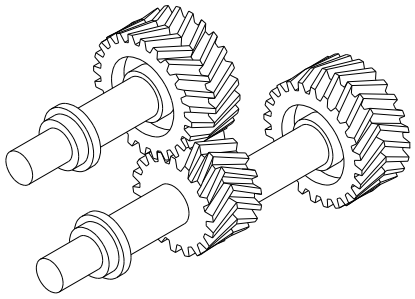
Fig 5



HELICAL GEARS

The end thrust is exerted by the driving and driven gears in the case of helical gears and the thrust may be eliminated by using double helical gears. These gears are called herring-bone gears. (Fig 6)

Fig 6

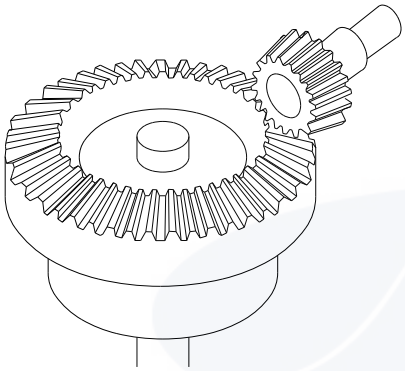


HERRING BONE GEARS

Bevel gear

The bevel gears shown in Fig 7 are used to transmit motion between shafts at various angles to each other. The teeth profile may be straight or spiral.

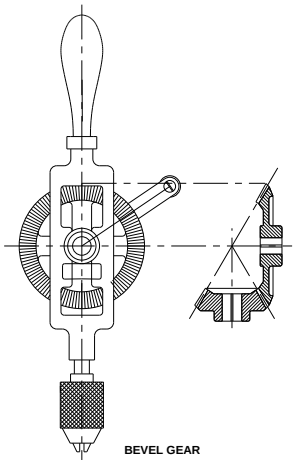
Fig 7



BEVEL GEAR

In a hand driller, the bevel gears transmit motion when the shafts are at right angles to each other. (Fig 8)

Fig 8

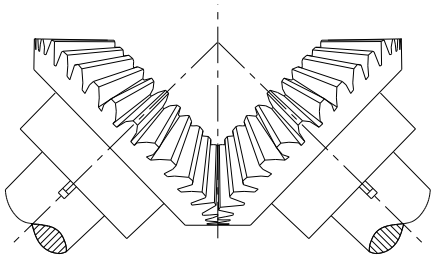


BEVEL GEAR

Mitre gears

If two bevel gears are symmetrical to each other and transmit motion at right angles, such gears may be called 'mitre gears'. (Fig 9)

Fig 9

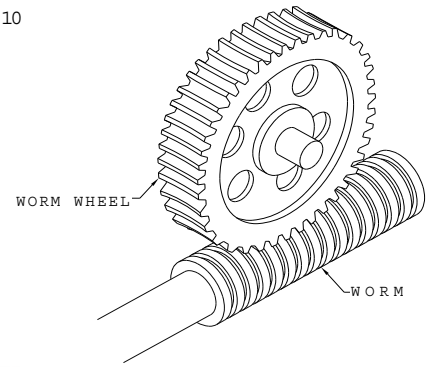


MITRE GEARING

Worm shaft and worm gear

The worm shaft has spiral teeth cut on the shaft and the worm wheel is a special form of gear teeth cut to mesh with the worm shaft. (Fig 10)

Fig 10

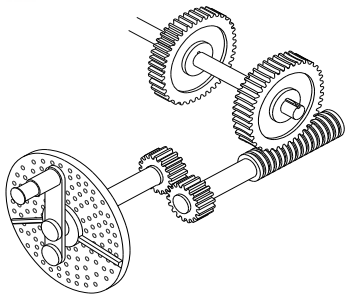


These are widely used for speed reduction purpose.

The application of worm and worm gear in the index-head gear mechanism is shown in Fig 11.

This system transmits motion at right angles to the axis of motion at different planes.

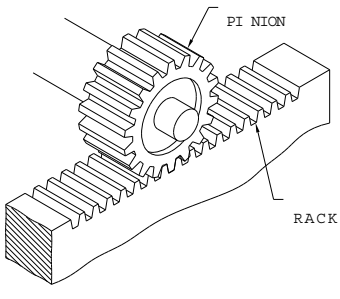
Fig 11



Rack and pinion

The rack and pinion can change rotary into linear movement and vice versa. (Fig 12)

Fig 12



This mechanism is used in drilling machines as illustrated in Fig 13.

Fig 13

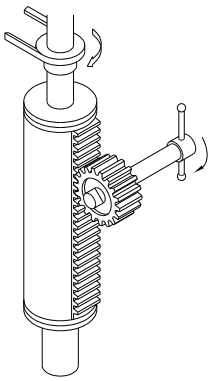
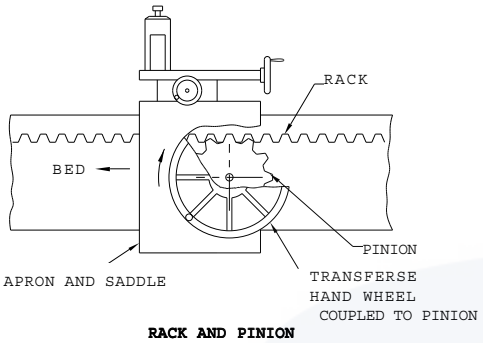


Fig 14 shows the application of the rack and pinion in lathe traverse mechanism.

Fig 14

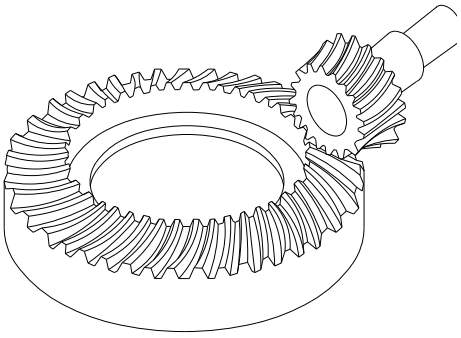


RACK AND PINION
(LATHE TRAVERSE MECHANISM)

Hypoid gears

The hypoid gears are used in automotive differential gearboxes. A pair of hypoid gears (illustrated in Fig 15) is similar to the spiral bevel gear but with the shafts offset. The tooth action between each gear is a combination of rolling and sliding action along a straight line. The pitch surfaces are hyperboloids of revolution; as such the gears are called hypoid gears.

Fig 15

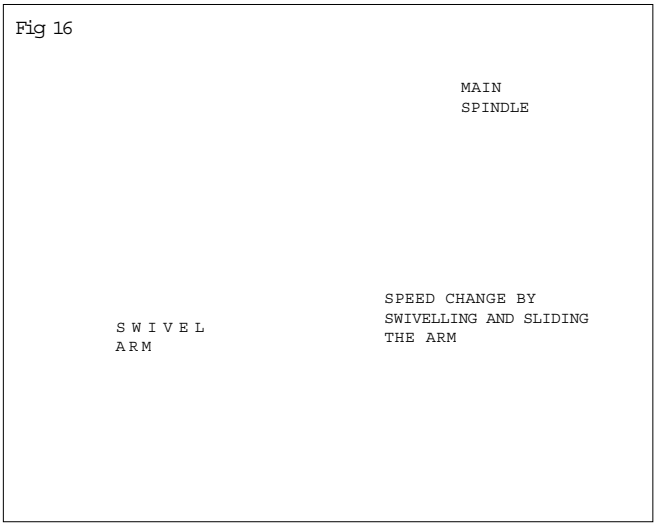


Velocity ratio of gear train

The gear train transmits motion without slip.

Different speeds can be obtained by shifting gear position in the gear- box. Fig 16 shows the feed change by swivelling and sliding the swivel arm in the Norton gearbox of lathes.

Fig 16



Formula for velocity ratio of gear train

$N_1 T_1 = N_2 T_2$

where

N_1 = RPM of driver gear

T_1 = number of teeth in the driver gear

N_2 = rpm of the follower/driven gear

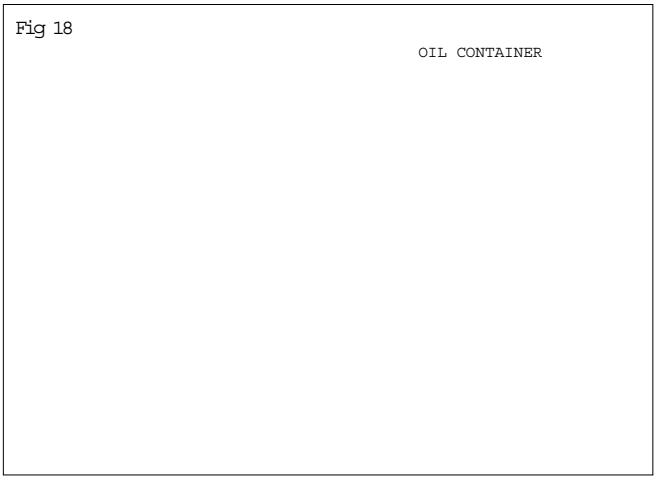
T_2 = number of teeth in the driven gear.

Lubrication of gear train

The low speed gears which are visible may be lubricated with an oilcan or brush. (Fig 17) The drop oil method of lubrication is shown in Fig 18.

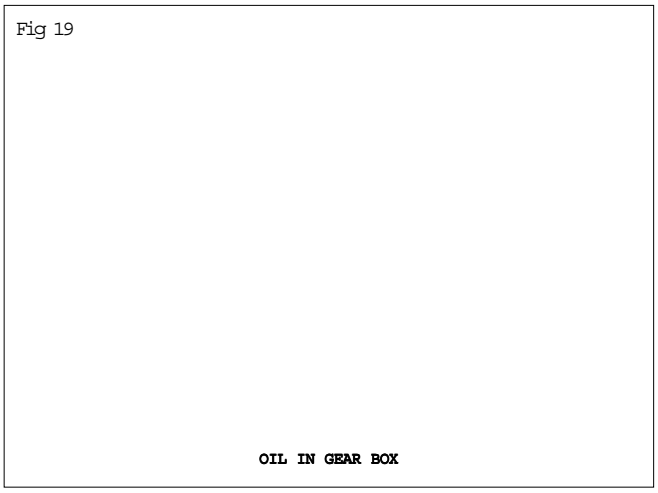
Fig 17

Fig 18



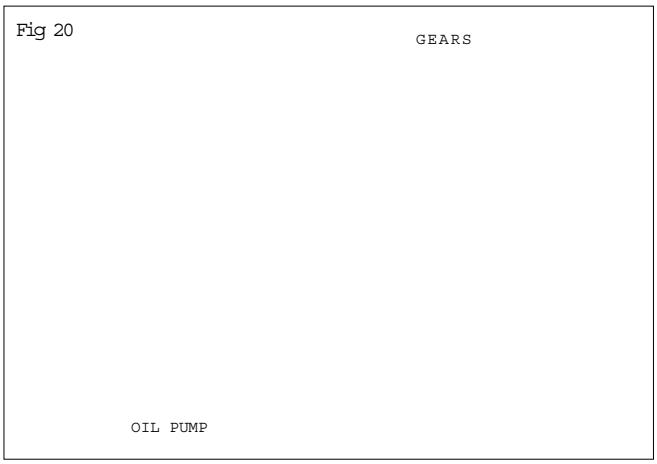
The enclosed gear trains should be packed in grease or run in an oil bath. (Fig 19)

Fig 19



In the case of big gearboxes mounted with different levels of gear sets,they are provided with oil pumps for lubrication purposes. (Fig 20)

Fig 20



Mounting the bearing

Objectives: At the end of this lesson you shall be able to
- **state the importance of bearing mounting**
- **state the methods of fitting the bearing.**

The function of a bearing in a machine is directly affected by the shaft and housing. When a bush bearing is over-tightened in a housing the bore becomes oval which will affet the free rotation of the shaft. Similarly incorrect squareness of shoulders and slots and deformation of the bore of bearing will result in inaccurate running of the shaft, increase in vibration level and premature bearing failure.

Bearings are precision made from hard and brittle materials. When force is applied to fit the bearings, the following care should be taken.

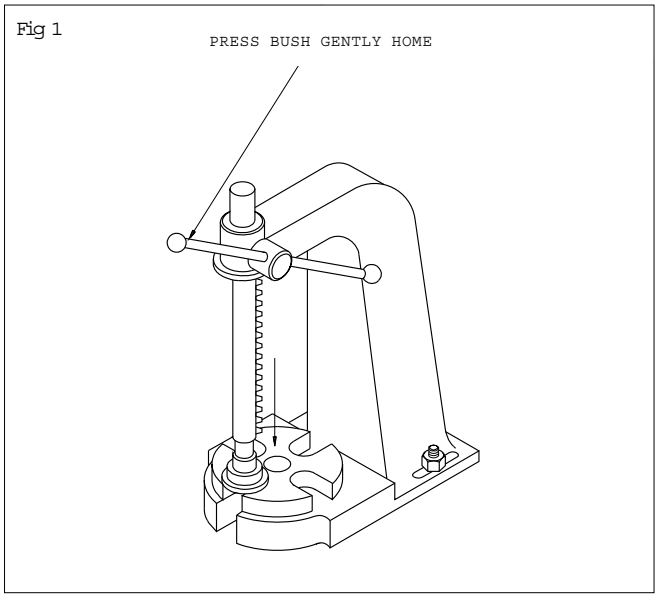
- Coat the journal or housing with clean, light oil.
- Apply force only on the race in contact with the housing or shaft.
- Keep the bearing square to the housing or shaft.
- After fitting, check the internal dimensions.

Method of fitting

Fitting a bearing using an arbor press

An arbor press (Fig 1) is used to fix a bearing square to the shaft on housing. It consists of a 'C' shaped casting body with a base, an index plate and head. The head portion is having a vertical bore to accommodate the quill. The quill can be moved up and down by the hand lever.

Fig 1



While pressing a bearing on to a shaft, use a tube to distribute the force evenly to keep the bearing square to the shaft. The tube must only touch the inner race and its ends must be machined square. (Fig 2) While pressing a shaft into a bearing, the bearing must be supported by the inner race only. (Fig 3)

Fig 2

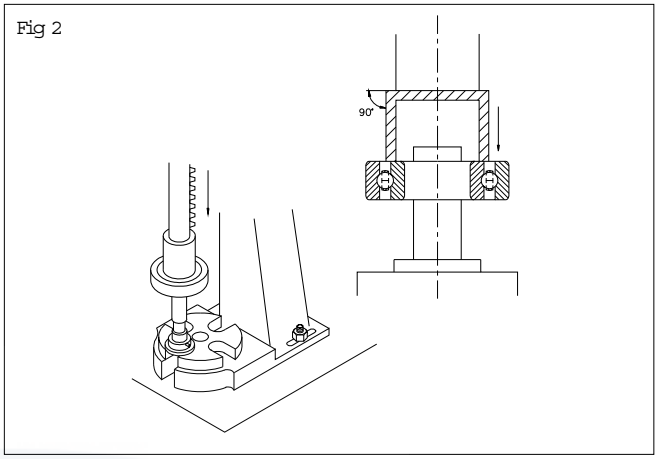
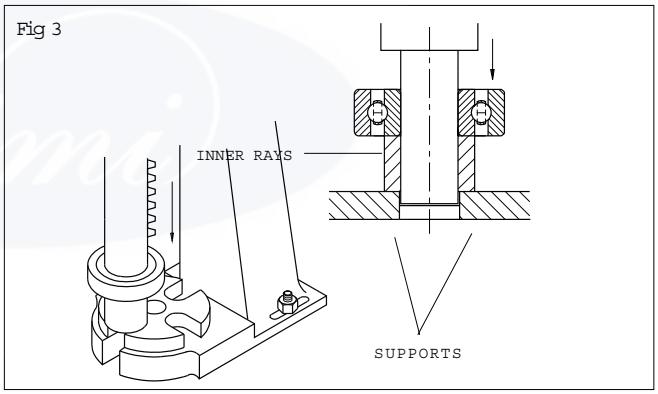
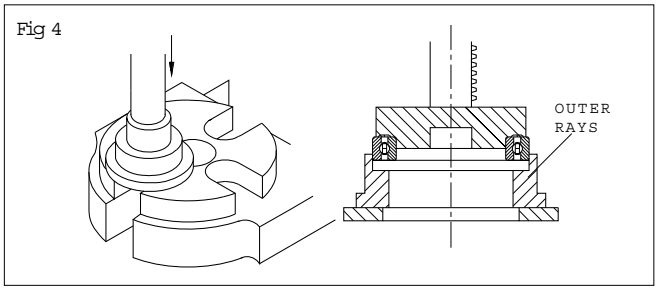


Fig 3



While pressing a bearing into a housing, a tube or flat block must be used so that the force is applied to the outer race only. (Fig 4)

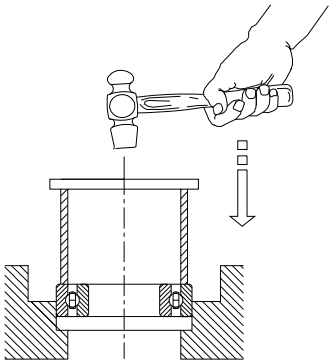
Fig 4



Hydraulically operated power presses are also used to press the bearing into the housing.

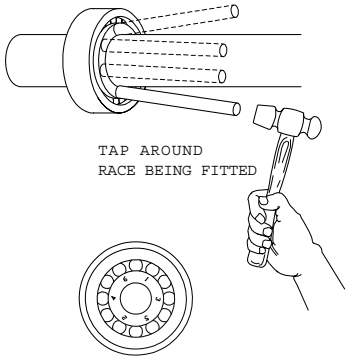
It is not always possible to press the bearing with an arbor press. When this is not possible, bearings are pressed using a tube and striking block. (Fig 5) This is the best method, since the bearing can more easily be kept square to its seating.

Fig 5



Using a drift (Fig 6)

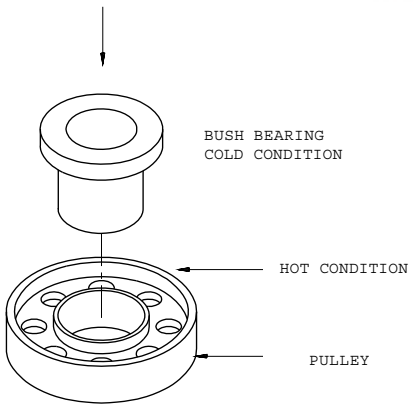
Fig 6



This method is useful when the bearing seating is in an awkward situation. The bearing is tapped evenly around the race being fitted. While setting the bearing ensure that the bearing is kept square to the seating. Care should be taken to prevent foreign matter from entering the bearing.

Shrinkage method (Fig 7)

Fig 7



In this method the housing is heated up in a heating chamber or on the hot plate to a temperature of 100 ^{o} to 140^{o} C and the bush is pushed in. In another method the housing is heated up while the bush is cooled in a dry ice chamber and is gently pushed inside the housing.

This is normally done when the amount of interference desired is more.

The common signs indicating trouble in a plain bearing installation are as follows.

Rapid wear

This may be due to overloading of bearing, improper lubrication or operating in extremely dirty conditions. Check the loading in the system against the bearings' capacity, properly lubricate the bearing and ensure all dust covers and seals are in place.

Pounding

This is due to the excessive wear in the bearing. Check the clearances between the shaft and the bearing bore.

Bearing runs hot

This is due to improper lubrication system and lubricant or may be due to shaft binding. Use correct lubricant in sufficient quantity.

Excessive oil leakage

This condition is a symptom of too much lubricant or faulty seals.

Bearing out of alignment

Check to see that the hold-down devices are properly installed and tightened.

Screeching

This indicates that the clearances are too light or lubrication is inadequate.

Conductors - insulators - wires, cables types - measurement of wire size - voltage grading

Objectives: At the end of this lesson you shall be able to
- **differentiate between conducting and insulating materials**
- **state the electrical properties of conducting materials**
- **state the terms used in electrical cables**
- **state the characteristics of copper and aluminium conductors**
- **state the properties of insulating materials**
- **state the different types of insulating materials.**

Conductors and insulators

Materials that contain many free electrons and are capable of carrying an electric current are known as conductors.

Examples - silver, copper, aluminium and most other metals.

Materials that have only a few electrons and are incapable of allowing the current to pass through them are known as insulators.

Examples - wood, rubber, PVC, porcelain, mica, dry paper and fibreglass.

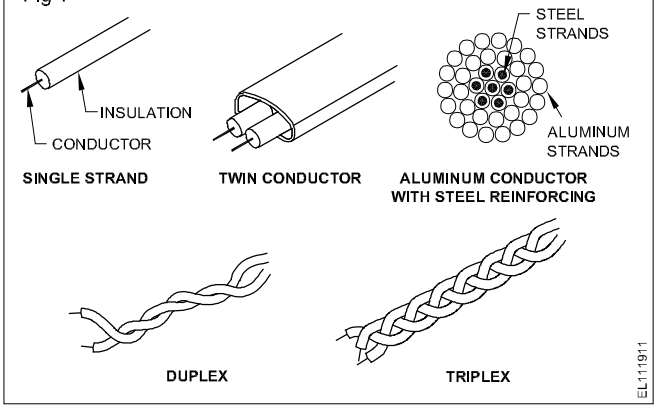
Conductors

The use of conductors and their insulation is regulated by I E regulations and B I S (ISI) Code of Practice.

The I E regulations and I S cover all electrical conductors listing the minimum safety precautions needed to safeguard people, buildings and materials from the hazards of using electricity.

Wires and cables are the most common forms of conductors. They are made in a wide variety of forms to suit many different applications. (Fig 1)

Fig 1



Conductors form an unbroken line carrying electricity from the generating plant to the point where it is used. Conductors are usually made of copper or aluminium.

Current passing through a conductor generates heat. The amount of heat generated depends on the square of the current that passes through the conductor and the resistance of the conductor.

As the heat developed in the conductor depends upon the resistance of the conductor the cross-sectional area of the conductor must have a large enough area to give it a low resistance. But the cross- sectional area must also be small enough to keep the cost and weight as low as possible.

The best cross-sectional area depends upon how much current the conductor can carry without much voltage drop in the line and heat generation in the conductor.

There is a limit to the temperature each kind of insulation can safely withstand and also the type of insulation which can withstand the physical chemical and temperature zones of the surroundings.

BIS (ISI) code specifies the maximum current considered safe for conductors of different sizes, having different insulation and installed in different surroundings.

Size of conductors

The size is specified by the diameter in mm or the cross-sectional area. Typical sizes are 1.5 sq.mm, 2.5 sq.mm, 6 sq.mm etc.

Still in India the old method of specifying the diameter by the standard wire gauge number is in use.

Classfication of conductors

Wires and cables can be classified by the type of covering they have.

Bare conductors

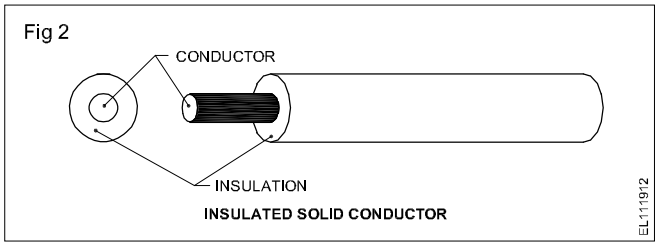
They have no covering. The most common use of bare conductors is in overhead electrical transmission and distribution lines. For earthing also bare conductors are used.

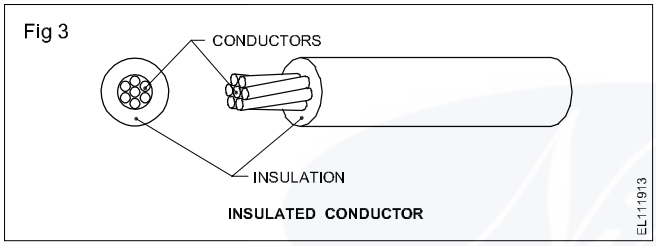
Insulated conductors

They have a coating of insulation. The insulation separates the conductor electrically from other conductors and from the surroundings. It allows conductors to be grouped without danger. Additional covering over the insulation adds mechanical strength and protection against weather, moisture and abrasion.

Solid and stranded conductors

A solid conductor is one in which there will be only one conductor in the core as shown in Fig 2. A stranded conductor is one in which there will be a number of smaller sized conductors twisted to form the core as shown in Fig 3. The number of conductors ranges from 3 to 162 and the conductor size varies from 0.193 mm to





3.75 mm diameter depending upon the current carrying capacity and also upon whether these conductors are used in cables or overhead lines.

Normally stranded conductors are designated as 10 sq. mm cable of size 7/1.40 where 10 sq.mm gives the area of the cross-section, in the size, numerator (7) gives the number of conductors and the denominator 1.40 gives the diameter of the conductor in mm. Alternatively 7/1.40 cable is the same as 7/17 whereas in the latter case the denominator is expressed in Standard Wire Gauge (SWG) number. Stranded conductors are more flexible and have better mechanical strength. According to recent stipulation, the cable size should be expressed in sq. millimetres or they can be expressed in terms of the number of conductors in the cable and the diameter of the conductor in mm.

Cable

A cable is a length of single, insulated conductor (single or stranded), or two or more such conductors - each provided with its own insulation, and are laid up together. The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering.

Cable (armoured)

An armoured cable is provided with a wrapping of metal (usually in the form of tape or wire), serving as a mechanical protection.

Cable (flexible)

A flexible cable contains one or more cores, each formed of a group of wires, the diameters of the cores and of the wires being sufficiently small to afford flexibility.

Core

All cables have one central core or a number of cores of stranded conductors farming high conductivity; generally there are one, two, three, three and half and four cores. Each core is insulated separately and there is overall insulation around the cores.

Wire

A solid substance (conductor) or an insulated conductor (solid or stranded) subjected to tensile stress with or without screen is called a wire.

Copper and aluminium

In electrical work, mostly copper and aluminium are used for conductors. Though silver is a better conductor than copper, it is not used for general work due to higher cost.

Copper used in electrical work is made with a very high degree of purity, say 99.9 percent.

Characteristics of copper

1 It has the best conductivity next to silver.

2 It has the largest current density per unit area compared to other metals. Hence the volume required to carry a given current is less for a given length.

3 It can be drawn into thin wires and sheets.

4 It has a high resistance to atmospheric corrosion: hence, it can serve for a long time.

5 It can be joined without any special provision to prevent electrolytic action.

6 It is durable and has a high scrap value.

Next to copper, aluminium is the metal used for electrical conductors.

Characteristics of aluminium

1 It has good conductivity, next to copper. When compared to copper, it has 60.6 percent conductivity. Hence, for the same current capacity, the cross-section for the aluminium wire should be larger than that for the copper wire.

2 It is lighter in weight.

3 It can be drawn into thin wires and sheets. But loses its tensile strength on reduction of the cross-sectional area.

4 A lot of precautions needs to be followed while joining aluminium conductors.

5 The melting point of aluminium is low, hence it may get damaged at points of loose connection due to heat developed.

6 It is cheaper than copper.

Table 1 shows the properties of copper compared with those of aluminium.

TABLE 1

Chararacteristics of conductor materials

Sl. No.	Properties	Copper (Cu)	Aluminium (Al)
1	Colour	Reddish brown	White
2	Electrical conductivity in MHO/metre	56	35
3	Resistivity at 20°C in ohm/metre (Cross-sectional area in 1 mm^2)	0.01786	0.0287
4	Melting point	1083°C	660°C
5	Density in kg/cm^3	8.93	2.7
6	Temperature coefficient of resistance at 20°C per °C	0.00393	0.00403
7	Coefficient of linear expansion at 20°C per °C	17×10^{-6}	23×10^{-6}
8	Tensile strength in Nw/mm^2	220	70

Properties of insulating materials

Two fundamental properties of insulation materials are insulation resistance and dielectric strength. They are entirely different from each other and measured in different ways.

Insulation resistance

It is the electrical resistance of the insulation against the flow of current. Megohmmeter (Megger) is the instrument used to measure insulation resistance. It measures high resistance values in megohms without causing damage to the insulation. The measurement serves as a guide to evaluate the condition of the insulation.

Dielectric strength

It is the measure of how much potential difference the insulation layer can withstand without breaking down. The potential difference that causes a breakdown is called the breakdown voltage of the insulation.

Every electrical device is protected by some kind of insulation. The desirable characteristics of insulation materials are:

– high dielectric strength
– resistance to temperature
– flexibility
– mechanical strength.

No single material has all the characteristics required for every application. Therefore, many kinds of insulating materials have been developed.

Insulating tapes

Various tapes are used for insulating electrical equipments, conductors and components. Some of these are adhesive. The tapes commonly used include friction, rubber, plastic and varnished cambric tapes.

Rubber tape

Rubber tapes are used for insulating joints. The tape is applied under slight tension. Pressure causes the layers to bend together. Application of this restores insulation but will not be mechanically strong.

Friction tape

This is used over rubber tape insulation. This is made up of cotton cloth impregnated with an adhesive. It does not stretch like the rubber tape. The friction tape does not have insulating qualities of the rubber tape, hence should not be used by itself for insulation.

Plastic tape (PVC tape)

This is used more than the other tapes. PVC tapes have the following advantages.

– High dielectric strength.
– Very thin.
– Stretches to conform to contours of joints.

Varnished cambric tapes

These tapes are made of cloth impregnated with varnish. It usually has no adhesive coating. Available in sheets and rolls and are ideal for insulating motor connecting leads.

Measurement of wire sizes - standard wire gauge - outside micrometer

Objectives: At the end of this lesson you shall be able to
- **state the necessity of measuring wire sizes**
- **state the method of using a standard wire gauge to measure wire sizes**
- **determine the SWG number or diameter of wires by using the conversion table.**

Necessity of measuring the wire sizes

To execute a wiring job proper planning is necessary. After considering the requirements of the house owner, the wireman prepares a layout plan of the wiring and an estimate of the cost of the wiring materials and labour. A proper estimate involves determination of current in different loads, correct selection of the type of cable, size of the cable and the required quantity. Any error will result in defective wiring, fire accidents and bring unhappiness to both the house owner and the wireman.

While selecting the cable sizes, the wireman has to take into consideration the proposed connected load, future changes in load, the length of the cable run and the permissible voltage drop in the cable.

A sound knowledge about the area of the cross-section of the core, the diameter of the single strand of the conductor and the number of conductors in each core of the stranded conductor is essential for a wireman to be successful in his carreer.

To measure the size of conductors, a wireman can use normally a standard wire gauge or an outside micrometer for more accurate results.

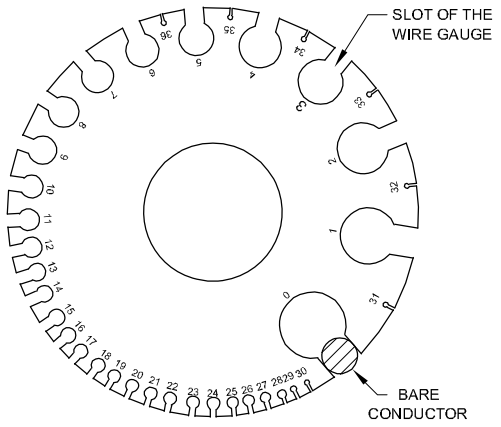
The size of wires are designed more carefully by the manufacturers. Though the Bureau of Indian Standards specifies the cables by the area of the cross-section in square millimetres, the manufacturers still produce the cable with the diameter of each wire and number of wires in the stranded cables. Sometimes the indicated size of cable by the manufacturer may not be correct and the wireman has to ascertain the size by measurement.

Standard wire gauge (SWG)

The size of the conductor is given by the standard wire gauge number. According to the standards each number has an assigned diameter in inch or mm. This is given in Table 1. The standard wire gauge, shown in Figure 1 could measure the wire size in SWG numbers from 0 to 36. It should be noted that the higher the number of wire gauge the smaller is the diameter of the wire.

For example, SWG No. 0 (zero) is equal to 0.324 inch or 8.23 mm in diameter whereas SWG No.36 is equal to 0.0076 inch or 0.19 mm in diameter.

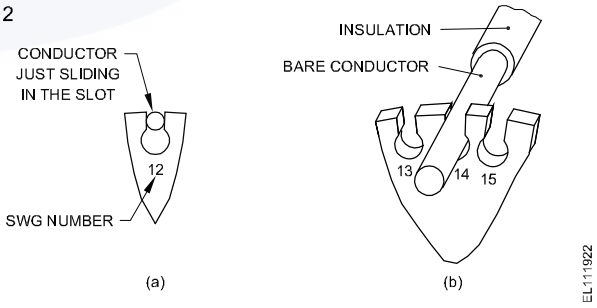
Fig 1



STANDARD WIRE GAUGE

While measuring the wire, the wire should be cleaned and then inserted into the slot of the wire gauge to determine the SWG number (Fig 2). The slot in which the wire just slides in is the correct slot and the SWG number could be read in the gauge directly. In most of the wire gauges to save the trouble of referring to the table, the wire diameter is inscribed on the reverse of the gauge.

Fig 2



The American wire gauge is different from the British standard wire gauge. In an American wire gauge (AWG) the diameter is represented in mils rather than inch or mm. One mil is one thousandth part of an inch. Please note there is no direct conversion from AWG to SWG.

TABLE 1 - **Conversion table SWG to mm/inch**

SWG No.	mm	inch
7/0	12.7	0.500
6/0	11.38	0.464
5/0	10.92	0.432
4/0	10.16	0.400
3/0	9.44	0.372
2/0	8.83	0.348
0	8.23	0.324
1	7.62	0.300
2	7.01	0.276
3	6.40	0.252
4	5.89	0.234
5	5.38	0.212
6	4.88	0.192
7	4.47	0.176
8	4.06	0.160
9	3.66	0.144
10	3.25	0.128
11	2.95	0.116
12	2.64	0.104
13	2.34	0.092
14	2.03	0.080
15	1.83	0.072
16	1.63	0.064
17	1.42	0.056
18	1.22	0.048
19	1.02	0.040
20	0.91	0.036
21	0.81	0.032
22	0.71	0.028

SWG No.	mm	inch
23	0.61	0.024
24	0.56	0.022
25	0.51	0.020
26	0.46	0.018
27	0.42	0.0164
28	0.38	0.0148
29	0.34	0.0136
30	0.31	0.0124
31	0.29	0.0116
32	0.27	0.0108
33	0.25	0.0100
34	0.23	0.0092
35	0.21	0.0084
36	0.19	0.0076
37	0.17	0.0068
38	0.15	0.0060
39	0.13	0.0052
40	0.12	0.0048
41	0.11	0.0044
42	0.10	0.0040
43	0.09	0.0036
44	0.08	0.0032
45	0.07	0.0028
46	0.06	0.0024
47	0.05	0.0020
48	0.04	0.0016
49	0.03	0.0012
50	0.02	0.0010

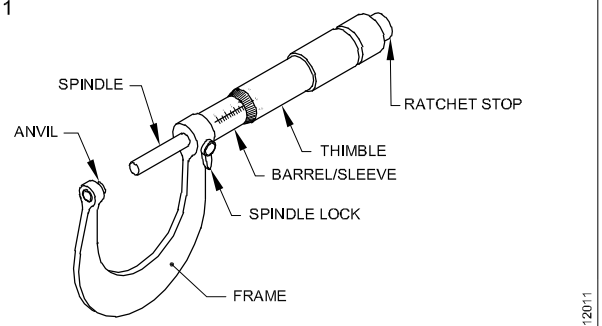
Outside micrometers

Objectives: At the end of this lesson you shall be able to
- **identify the parts of an outside micrometer and their functions**
- **state the principle of a micrometer**
- **determine the least count of an outside micrometer**
- **select the required range of a micrometer**
- **read micrometer measurements.**

A micrometer is a precision instrument used to measure a job, generally within an accuracy of 0.01 mm.

Micrometers used to take the outside measurements are known as outside micrometers. (Fig 1)

Fig 1



The parts of a micrometer are listed here

Frame

The frame is made of drop-forged steel or malleable cast iron. All other parts of the micrometer are attached to this.

Barrel/sleeve

The barrel or sleeve is fixed to the frame. The datum line and graduations are marked on this.

Thimble

The thimble is attached to the spindle and on the bevelled surface of the thimble, the graduation is marked.

Spindle

One end of the spindle is the measuring face. The other end is threaded and passes through a nut. The threaded mechanism allows for the forward and backward movement of the spindle.

Anvil

The anvil is one of the measuring faces which is fitted on the micrometer frame. It is made of alloy steel and finished to a perfectly flat surface.

Spindle lock-nut

The spindle lock-nut is used to lock the spindle at a desired position.

Ratchet stop

The ratchet stop ensures a uniform pressure between the measuring surfaces.

Principle of the micrometer

The micrometer works on the principle of screw and nut. The longitudinal movement of the spindle during one rotation is equal to the pitch of the screw. The movement of the spindle to the distance of the pitch or its fractions can be accurately measured on the barrel and thimble.

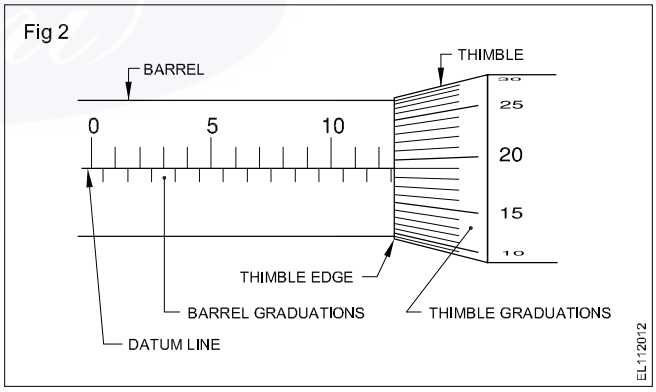
Graduations

In metric micrometers the pitch of the spindle thread is 0.5 mm.

Thereby, in one rotation of the thimble, the spindle advances by 0.5 mm.

In a 0-25 mm outside micrometer, on the barrel a 25 mm long datum line is marked. (Fig 2) This line is further graduated in millimetres and half millimetres (ie. 1 mm & 0.5 mm). The graduations are numbered as 0, 5, 10, 15, 20 & 25 mm on the barrel.

Fig 2



The circumference of the bevel edge of the thimble is graduated into 50 divisions and marked 0-5-10-15... 45-50 in a clockwise direction.

The distance moved by the spindle during one rotation of the thimble is 0.5 mm.

Movement of one division of the thimble
= 0.5 x 1/50 = 0.01 mm.

This value is called the least count of the micrometer.

The accuracy or least count of a metric outside micrometer is 0.01 mm.

Ranges of an outside micrometer

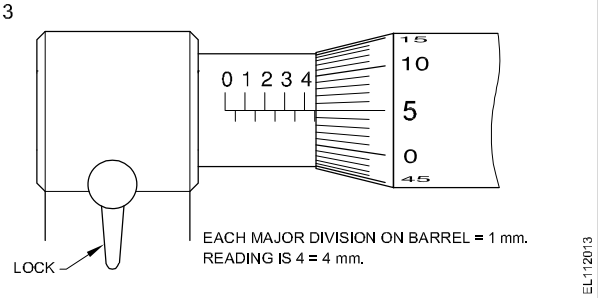
Outside micrometers are available in ranges of 0 to 25 mm, 25 to 50 mm, and so on. For wiremen, to read the size of the wire 0 to 25 mm is only suitable.

Reading micrometer measurements

How to read a measurement with an outside micrometer?

a) Read on the barrel scale, the number of whole millimetres that are completely visible from the bevel edge of the thimble. It reads 4 mm. (Fig 3)

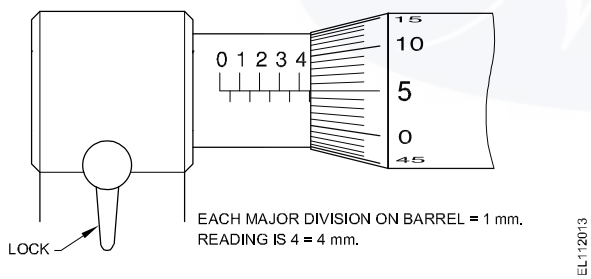
Fig 3



b) Add to this any half millimetre that is completely visible from the bevel edge of the thimble and away from the whole millimetre reading.

The figure reads one division (Fig 4) mm after the 4 mm mark. Hence 0.5 mm to be added to the previous reading.

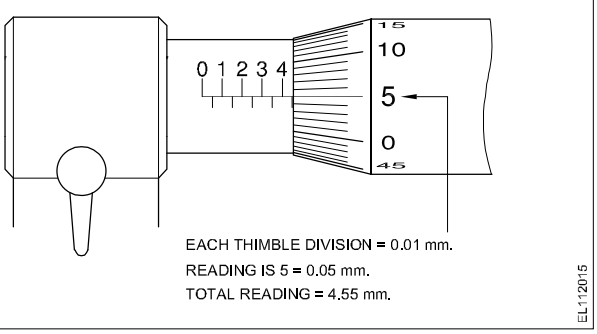
Fig 3



c) Add the thimble reading to the two earlier readings.

The figure shows the 5th division of the thimble is coinciding with the datum line of the barrel. Therefore, the reading of the thimble is 5 x 0.01 mm = 0.05 mm. (Fig 5)
The total reading of the micrometer.

Fig 5



a 4.00 mm
b 0.50 mm
c 0.05 mm.

Total reading = 4.55 mm (Fig 5)

Some examples of metric micrometer readings and their solution.

1) Refer to Fig 6 a

Barrel-whole mm	12.00 mm
half mm	0.50 mm
Thimble division	0.19 mm
Total	12.69 mm

2) Refer to Fig 6 b
Error is + 0.02.

	22.00 mm
	0.50 mm
	0.49 mm
	22.99 mm
Error (subtract)	0.02
Total	22.97 mm

Precautions to be followed while using a micrometer

Before using the micrometer for measurement, it is necessary to ascertain that there is no error in the micrometer. To find the error, close the jaws of the measuring surfaces using the ratchet. Read the micrometer. If the thimble zero is coincident with the datum line of the barrel, error is zero. If it reads higher value, the error is +ve; if it reads lesser value the difference between zero and the read value is -ve error.

If there is minus error it should be added to the total reading and if there is plus error the value should be subtracted from the total reading.

The faces of the anvil and spindle must be free from dust, dirt and grease.

While reading the micrometer, the spindle must be locked with the reading.

Do not drop or handle the micrometer roughly.

Crimping and crimping tool

Objectives: At the end of this lesson you shall be able to
- **describe the functions of the different parts of a crimping tool**
- **identify the various types of crimping sockets**
- **state the advantages of crimped termination**
- **state the precautions necessary for the crimping tool application.**

The ends of cables can be prepared for termination with lugs by the soldering process or by mechanical means - compression or crimp fitting.

In crimp compression fitting, a ring-tongued terminal (lug) is to be compressed to the bared end of an insulated multi-strand cable. The process is called crimping and the tool used is called crimping pliers or crimping tool.

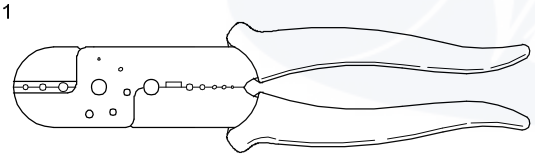
Compression type connectors apply and maintain pressure by compressing the connector around the conductor.

The principal purpose of the pressure is to establish and maintain suitable low contact resistance between the contact surfaces of the conductor. Improper crimping will create increased contact resistance and will cause overheating while carrying electrical load.

Crimping tools

The crimping pliers illustrated in Fig 1 is of a type which crimps from 0.5 to 6 mm cables.

Fig 1

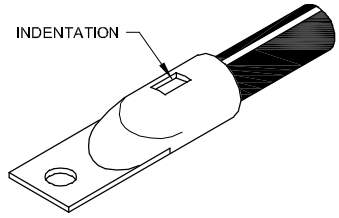


HAND CRIMPING PLIERS

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The tool is operated by squeezing the handles. The jaws move together, grip and then crimp the fitting. Using the crimping tool that matches the specific crimp lug will give the correct crimping force for a properly executed crimp. Properly executed crimp will indent the top of the lug and the indentation will hold the conductor securely as shown in Fig 2.

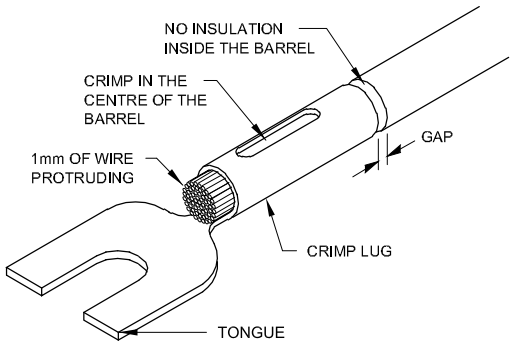
Fig 2



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If the terminal has too deep a crimp, the strength of the joint is reduced. With too shallow a crimp, the electrical contact has a high resistance. Selection of the correct crimping tool is essential. A properly crimped terminal is shown in Fig 3.

Fig 3



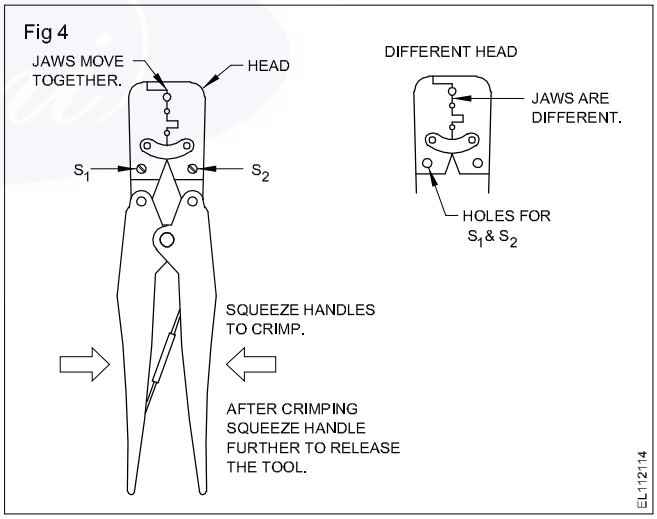
A PROPERLY CRIMPED TERMINAL

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Terminal lug crimping pliers are available in lengths ranging from 180 to 300 mm. Crimping tools are available in sets. For higher capacity cables crimping tools are operated by hydraulic force.

Fig 4 shows another type of crimping tool which crimps from 26 to 10 SWG.

Fig 4



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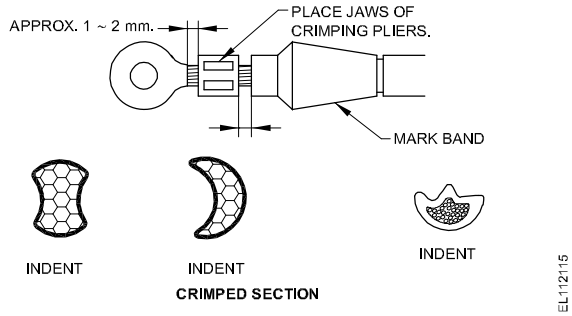
The head and jaws, may be removed, by unscrewing the screws S_1 and S_2. A head with different shaped jaws may then be secured to the tool. The shape of the jaws determines the shape of the crimp (indent). Some crimp sections are shown in Fig 5.

Safety

When using this type of crimping tool care must be taken not to trap the finger, as the operating cycle of the tool is non-reversible i.e. once the handles are squeezed together the jaws can only be released by applying further pressure to the handles as shown in Fig 4.

Terminal types

Fig 5



It is important to consider both the mechanical and electrical requirements when selecting a lug connector.

The factors are:

– the type of tongue, i.e. rectangular, ring, spade, etc.
– the mechanical size, i.e. tongue size and thickness, hole size etc. for the cable selected
– the electrical considerations such as the current carrying capacity, that may also determine some of the mechanical dimensions.

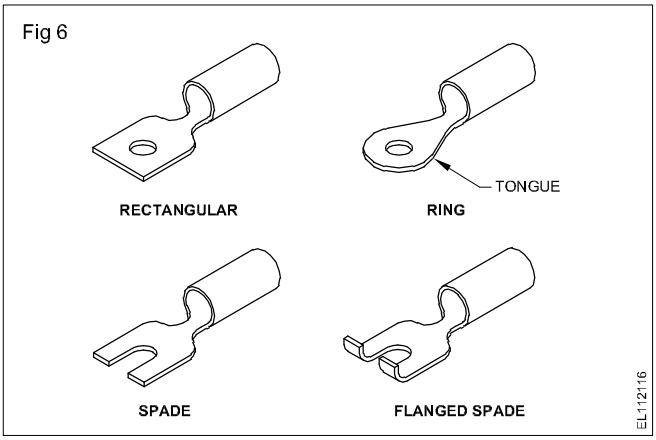
The electrical and mechanical requirements for the lug and the base material of the lug are decided by the cable material, and the place of connection will determine the minimum tongue size and the barrel size. The most commonly used base materials are copper and brass. Nickel, aluminium and steel are also used, but less frequently.

Fig 6 shows some lug connectors normally used in practice terminals. They are ring, rectangular, spade, flanged spade etc. Ring and rectangular terminals are not intended for frequent removal to disconnect the terminal whereas in spade and flanged spade lugs (terminals) the screw need not be removed to disconnect.

Precautions for crimping tool application

Do not handle the job/tool roughly e.g. drop, hammer, etc. which may harm the tool.

Fig 6



Do not alter the crimping tool, e.g. alter the shape of the die etc.

Do not let metal chips adhere to the working position of the tool, particularly on the lower surface of replaceable die on the crimping part.

If a pin, spring, etc. is found damaged in the crimping tool, repair it immediately.

Apply oxide inhibiting grease to the aluminium conductor end just before crimping.

Advantages of crimping terminations

1 A properly made crimp is better in electrical conductivity and mechanical strength.
2 Less costly.
3 When the same size cables are to be terminated through lug connectors, the crimping process is faster than soldering.
4 The crimping operation surely needs good skill but soldering operation needs advanced skills.
5 Heat generated in the conductor sometimes melts the solder and the connection is open circuited. But crimped connection will not open that easily.

Current carrying capacity of copper & aluminium cables - voltage grading

Objectives: At the end of this lesson you shall be able to
- **select cables according to their current carrying capacity based upon the type of circuit protection**
- **state the size and number of strands available in copper and aluminium cables and their current carrying capacity**
- **apply the rating factor and determine the current capacity of cables with respect to temperature**
- **differentiate between solid and stranded conductors.**

Selection of cables

The current carrying capacity of a particular area of cross-section cable depends upon the following factors.

- Type of conductors (metal)
- Type of insulation
- Cable run in conduit or in open surface
- Single or three phase circuit
- Type of protection - coarse or close excess current protection
- Ambient temperature
- Number of cables in bunches
- Length of circuit (permissible voltage drop) - this will be discussed at a later stage.

Depending upon the above factors the current rating of cables may vary to a great extent.

Information in this lesson will enable the wireman to select the correct cable under normal working conditions.

Current rating of cables based on type of protection

Cables insulated with PVC, may sustain serious damage when subjected, even for relatively short periods, to higher temperature than the temperature permissible for continuous operation.

Therefore, current ratings of cables insulated with PVC are determined not only by the maximum conductor temperature admissible for continuous rating but also by the temperature likely to be attained under conditions of excess current.

Hence, the current rating of cables are given under two headings:

- cables provided with coarse excess current protection
- cables provided with close excess current protection.

Coarse excess current protection

In this type of protection, circuit protection will not operate within four hours at 1.5 times the designed load current of the circuit which it protects.

The devices affording coarse excess current protection include:

- fuses which are having a fusing factor exceeding 1.5 times the marked rating
- carriers and bases used in rewirable type electrical fuses.

Close excess current protection

In this type of protection the circuit protection will operate within four hours at 1.5 times the designed load current of the circuit which it protects.

Devices include:

- fuses fitted with fuse links having fusing factor not exceeding 1.5 times the marked rating (H R C & cartridge etc.)
- miniature and moulded case circuit breakers
- circuit breakers set to operate at an overload not exceeding 1.5 times the designed load current of the circuit.

Electrical inspectors, who are assigned by the Government to test installation and give permission for effecting supply, now recommend close excess current protection devices like MCB and HRC fuses to be included in the circuit for safety to the user and to reduce fire accidents.

Rating factor with respect to protection

For circuits with coarse excess current protection (rewirable fuse unit) current rating of cables is given in Table 1. Though the cables can carry a higher value of current than the current notified in the Table 1, for circuits having coarse excess current protection, the permissible current in cables is obtained by multiplying the normal current capacity by a rating factor of 0.81, whereas for circuits protected by close current protection the normal current capacity is multiplied by a rating factor of 1.23.

The following example will clarify the above information.

Normal current carrying capacity of 1.5 sq mm copper cable = 16 amps (normal rating)

Current capacity of the same cable when protected by coarse excess current protection (Rating factor 0.81)

= Normal capacity x Rating factor
= 16 x 0.81 = 13 amps.

Close excess current protection (Rating factor 1.23)

= Normal capacity x Rating factor
= 16 x 1.23 = 19.7 = 20 amps.

Current capacity for close excess current protection could be obtained by the following formula also.

$$= \frac{\text{Coarse excess current protection rating}}{\text{Rating factor of coarse protection}} \times \text{Ralting factor of close excess current protection}$$

TABLE 1

Current rating for single core PVC insulated sheathed copper and aluminium conductor cables of size 1 to 50 sq. mm at ambient temperature of 40°c (Refer to IS 694 Part I -1964). (Cables provided with coarse excess current protection.)

Nominal cross-sectional area	Number and diameter of wires	Bunched and enclosed in conduit or trunking			
		2 cables single phase AC or DC		3 or 4 cables 3-phase AC	
mm^2	Number of strands/ dia, in mm	Copper Amps.	Aluminium Amps.	Copper Amps.	Aluminium Amps.
1	1/1.12	11	--	9	--
1.5	1/1.40	13	8	11	7
2.5	1/1.80	18	11	16	10
4	1/2.24	24	15	20	13
6	1/2.80	31	19	25	16
10	1/1.40	42	26	35	22
16	7/1.70	57	36	48	30
25	7/2.24	71	45	60	38
35	7/2.50	91	55	77	47
50	19/1.80	120	69	100	59

Rating factor for ambient temperature

Further the current rating of cables is greatly affected by the ambient temperature. As such if the ambient temperature is other than 40°C the current rating shown in the above table should be multiplied by the rating factor given in Table 2.

TABLE 2

Ambient Temp. °C Rating factor for cables	25	30	35	40	45	50	55	60	65
1 Having coarse excess current protection	1.09	1.06	1.03	1.00	0.97	0.94	0.82	0.67	0.46
2 Having close excess current protection	1.22	1.15	1.08	1.00	0.91	0.82	0.70	0.57	0.40
3 Flexible cords	--	1.09	1.04	1.00	0.95	0.77	0.54	--	–

Example 1

Find the current rating of 2.5 sq mm, aluminium cable at 50°C. The circuit is single phase AC, protected by rewirable fuses and the cable is run in conduit.

Solution

The protection is coarse excess current protection. Hence referring to Table 1 the current rating of 2.5 sq mm aluminium cable at 40°C is = 11 amps.

Rating factor at 50°C referring to Table 2 = 0.94.

The current rating of 2.5 sq.mm aluminium cable protected by coarse excess current protection run in conduit and at ambient temperature of 50°C = 11 x 0.94 = 10 amps.

Example 2

Find the current rating of 4 sq mm copper cable at 60°C, when used in a 3-phase circuit and the circuit is protected by H R C fuses.

Solution

The protection is close excess current protection.

Referring to Table 1, the current rating of 4 sq. mm copper cable for coarse excess current protection (rewirable fuse) at 40°C, when used in 3 phase circuit is = 20 amps

Current rating for closed excess current protection at 40°C when used in 3-phase circuit = (20 x 1.23)/0.81
= 30.37 amps.

The rating factor at 60°C is (Referring to Table 2) = 0.57.

Hence, the current rating of 4 sq. mm copper cable in a circuit protected by close excess current protection at an ambient temperature of 60°C is = 30.37 x 0.57
= 17.31 amps
= say 17 amps.

Current rating of flexible cables is given in Table 3.

Advantages of stranded conductors over solid conductors

As stranded conductors are more flexible, chances of break of conductors and crack of insulation at the bend is less. They can be easily handled and laid.

Connections and joints of stranded conductors are stronger and have longer life.

TABLE 3

Current ratings for copper conductor flexible cords, insulated with PVC according to BIS No.694

Nominal cross-sectional area of conductor mm^2	Number and diameter of wires Number/mm	Current rating DC, single phase or 3-phase AC (Amperes)
0.50	16/0.20	4
0.75	24/0.20	7
1.00	32/0.20	11
1.50	48/0.20	14
2.50	80/0.20	19
4.00	128/0.20	26

Comparison between solid and stranded conductors

Solid conductor	Stranded conductor
1 Rigid.	1 Flexible.
2 Less mechanical strength.	2 More mechanical strength
3 Available in square,round and flat shapes.	3 Available in round shape having small diameters.
4 Used for bus-bars and in the winding of large capacity transformers.	4 Used for cables and wires.

In stranded conductors the insulation has a better grip on the wire.

Solid conductors between supports of overhead lines may break due to vibration. This breakage is less in stranded conductors.

The space between the strands permits flow of oil in U G cables enabling better insulation properties and cooling.

For a given area of cross- section stranded cables carry more current than solid conductors.

Classification of voltage grading

Voltage is classified as

1 Low voltage (L.V): Normally not exceeding 250V (i.e.) from 0 to 250 volts

2 Medium voltage (M.V): Exceeding 250V but not exceeding 650V from 250 to 650 volts

3 High voltage (H.V): Exceeding 650V but not exceeding 33000V.(650-33000 volts)

4 Extra high voltage: All voltages above 33000V comes under this category

TABLE1

Various types of electrical cables

Type of code	Voltage grade	Range of cross section in (mm^2)	Application	B.I.S. applicable
A.Writing cable				
1 PVC insulated	250/440,650/ 1100	1.5 to 50	Domestic/industrial wiring in conduits. Domestic/industrial wiring in batten.	694 part II
a)non-sheathed single core				
b) PVC sheathed				
i) single core	-do-	-do-	-do-	
ii) flat twin-core	-do-	1.5 to 16	Domestic wiring for power plug.	
iii) flat twin-core ECC and 3-core	250/440	1.5 to 50	Domestic/industrial wiring on batten.	
iv) circular 2,3 or 4 core	650/1100V	1.5 to 300	Sub-main/industrial.	
c)non-sheathed single core and twisted twin flexible copper	250/400 650/1100	4 to 5	Temporary wiring interconnections, household applicances.	694 part I 694 part I&II
d)PVC sheathed circular twin, 3 and 4 core flexible copper	-do-	-do-		
e)Single extrusion	-do-	1.5 to 50	Domestic wiring on batten	694 part I,II
2 Polythene insulated and PVC sheathed with aluminium conductor				
a) single core flat & circular twin core	250/440	1.5 to 50	Domestic wiring on batten	1596
b) flat twin with ECC & circular	-do-	1.5 to 10	-do-	1596
3 Lead alloy sheathed		Aluminium Copper		
i) single core		1.5 to 50 1.5 to 50		
ii) 2,3 and 4-core circular	250/440	70 to 625 64.5 to 645		
iii) twin & 3 core flat (ECC)	650/1100 250/440	1.5 to 16 1.5 to 16	Industrial wiring in damp corrosive atmosphere.	434 part I,II
4 TRS sheathed				
i) single core				
ii) 2,3 and 4-core circular	-do-	1.5 to 50 0.5 to 50	Wiring residential on batten,industrial wiring	434 part I,II
iii) Twin & 3 core flat (ECC)	-do-	1.5 to 625 64.5 to 645	Residential batten	-do-
e) TRS sheathed flexible		1.5 to 16 1.5 to 16		
f) Fire resisting asbestos sheathed	250/440 650/1100		Welding cables in fire hazards.	-do-
g) Poly Phropene sheathed flexible	-do- -do-		Training cable for lifts and other mobile equipments	-do-

Type of code	Voltage grade	Range of cross section in (mm^2)	Application	B.I.S. applicable
5 Weather-proof cables	250/440	1.50 to 50		
a)VIR insulated cotton, braided and treated with weather resistance compound	650/1100			
b)PVC insulated PVC sheathed	-do-	-do-	Service connection and other outdoor application.	434 part I,II 3035 part I
c)Polythene insulated, taped braided and compounded	-do-	-do-		3035 part II
6 Power cables heavy duty 1.1kV grade PVC insulated PVC sheathed cable				
a)Unarmoured/armoured				
i) Single core	650/1100	1.5 to 1000	Armoured cable in singlecore not available. Unarmoured power cables are used only in protected places. Use of copper is banned for such applications	1554 Part I/76
ii) Twin core	650/1100	1.5 to 500		
iii) Three-core	-do-	1.5 to 400		
iv) Three and a half core	-do-	16 to 400		
v) Four core	-do-	1.5 to 50		
7 Paper insulated, lead, covered, single core, unarmoured.	1.1kV	6 to 625 6 to 625	Dry places, heavy duty, hazardous applications underground.	692-73
	-do-	-do- -do-		
a) Twin-core, armoured	-do-	-do- -do-		
b) Three and three and half, armoured.	-do-	-do- -do-	Dry places for cotton braided, otherwise metal sheathed.	693-1965
8 Varnished cambric insulated	-do-			

N.B. 1 Where material of core is not mentioned, it is aluminium.
2 ECC - Earth continuity conductor.

Electrical soldering practice - types of solders, flux and methods

Objectives: At the end of this lesson you will be able to
- **explain the necessity of soldering in electrical work and its process**
- **state the types of solders, their melting points and their uses**
- **state the purpose of the flux, types of fluxes and their uses**
- **state the different methods adopted for soldering.**

What is soldering?: Soldering is the process of joining two metal plates or conductors without melting them, with an alloy called solder whose melting point is lower than that of the metals to be soldered. The molten solder is added to the two surfaces to be joined so that they are linked by a thin film of the solder which has penetrated into the surfaces.

Necessity of soldering: Wire and cable joints should have the same electrical conductivity and mechanical strength as that of the parent conductor. This cannot be achieved by a mere mechanical joint. As such cable joints are soldered to have good mechanical strength, electrical conductivity and also to avoid corrosion.

The following are the general proportions of tin and lead used in the solders.

Designation	Compo-sition	Working temp.	Uses
Tinman's solder	Tin-50% Lead-50%	200^{0}C.or 392^{0}F.	Fine soldering
Electrician's solder	Tin-60% Lead-40%	185^{0}C. or 365^{0}F.	Tinning and soldering electrical joints etc.
Fine solder	Tin-90% Lead-10%	219^{0}C.or 426^{0}F.	Tinning
Plumber's solder	Tin-35%	237^{0}C. or Lead-65%	Heavy duty soldering. 459^{0}F.

Solder used for copper: The metal alloy used as a bonding agent in soldering is called a solder. The solders used for soft soldering consist of an alloy (mixture) of mostly tin and lead.

Factors influencing the choice of a solder

The factors that influence the choice of a solder are:

– place of use
– melting point
– solidification range
– strength
– hardness
– sealability
– price.

Flux: Flux is a substance used to dissolve oxides on the surface of conductors and to protect against de-oxidisation during the soldering process.

General properties of flux

The purpose of the flux is to

– dissolve oxides, sulphides etc. thereby making the soldering surface free of oxides and dirt
– prevent re-oxidation during the soldering operation thereby making the solder adhere to the surface to be soldered.
– facilitate the flow of the solder through surface tension so as to make the solder flow into the surface to be soldered.

The state of the flux can be solid or liquid.

The activity of the flux can be weak or strong, and is classified with regard to the corrosive properties, as slightly corrosive or highly corrosive.

The type of solder often determines the flux to be used for soldering.

The following table lists the fluxes used for soldering.

TABLE

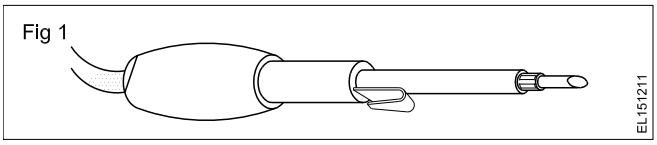
Suitable flux	Metals/job - used for	Type of solder
1 Zinc chloride (acidic)	Cast iron, wrought iron, mild steel,cast steel, brass, bronze, copper etc. for soldering at low temperature	Tinman's solder Fine solder
2 Hydrochloric acid 10% diluted with water 90%	Zinc Galvanised iron	Coarse solder
3 Sal ammonia rosin (Not fully acid-free)	Copper, brass, tin plate, gun-metal: for clean and finer soldering work.	Coarse solder
4 Rosin	Joining electrical conductors	Electrician's solder
5 Tallow - (turpentine, acid free)	For joining electrical conductors, for soldering.	Electrician's fine solder

Fluxes shown under 1, 2 and 3 are not recommended for electrical purposes as they are highly corrosive, hygroscopic (absorb moisture), and the residues are electricity conductive.

Soldering Methods

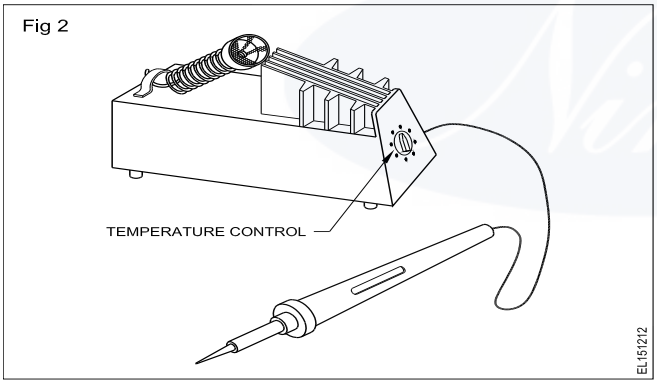
Soldering with a soldering iron: The most common method of soldering is with a soldering iron as shown in Fig 1. This is widely used for most kinds of soft soldering work.

This tool is simple and inexpensive. Soldering irons are



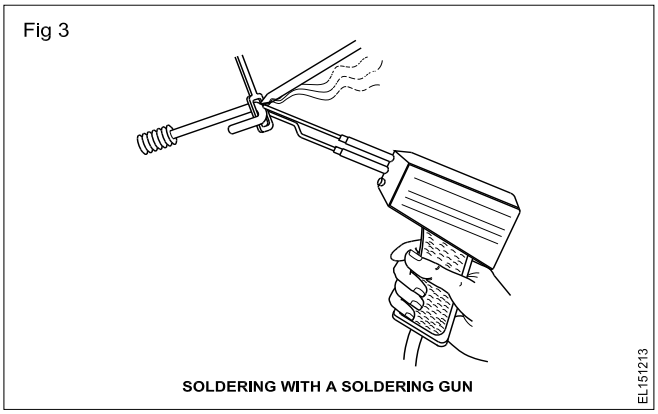
available in a wide range of sizes and models. Heating is generally by electrical means, though non-electrical irons are also used.

For soldering miniature components on printed circuit boards, a temperature-controlled soldering iron is used as shown in Fig 2. The electrical supply given to the soldering iron is of low voltage, and is completely isolated from the main supply. Low voltage does not endanger the life of the user and will also not spoil the sensitive electronic components. Controlled temperature makes the job easy for the user.



Soldering with a soldering gun: This method, shown in Fig 3, is used for individual soldering, e.g. for servicing and repair work.

The principle of this method is that an electric current flows through a wire coil heating it. The temperature is difficult to

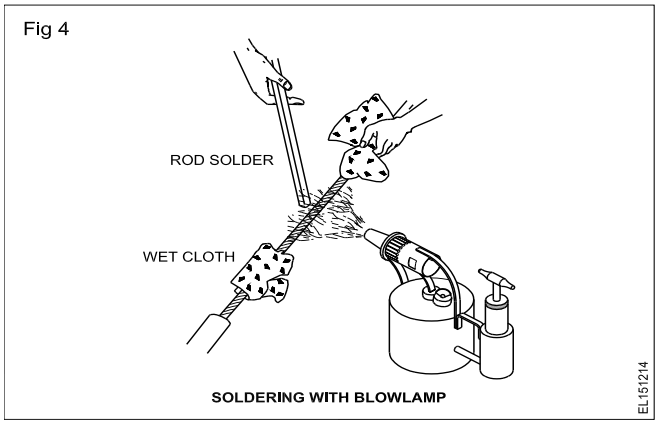


check, and overheating can easily occur. This is the disadvantage.

Soldering with a flame: Soldering with a flame is used when the heat capacity of a soldering iron is insufficient.

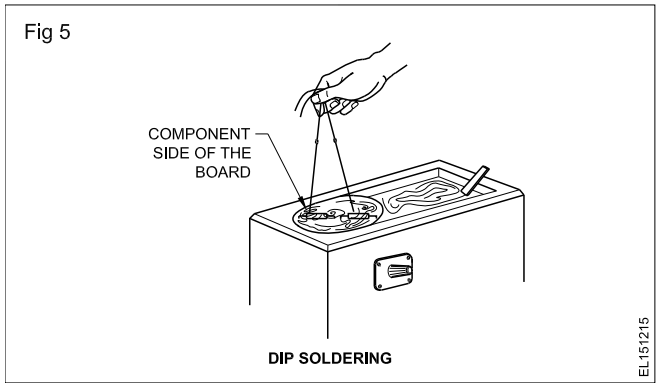
This method, shown in Fig 4, permits rapid heating and is used primarily for larger jobs, such as piping and cable work, vehicle body repairs and some applications in the building trade.

This method requires skilful management of the flame.



Dip soldering: This method, shown in Fig 5, is used for quantity production and for tinning work similar to component soldering on Printed Circuit Boards (P.C.B.). Components to be soldered or tinned are dipped into a bath of molten solder, which is heated electrically. The solder is kept in motion by an agitator in order to obtain an even temperature and to keep the surface free from oxides. If no agitator is provided, the surface must be protected or skimmed at regular intervals to remove the oxides.

The temperature can be controlled very accurately.

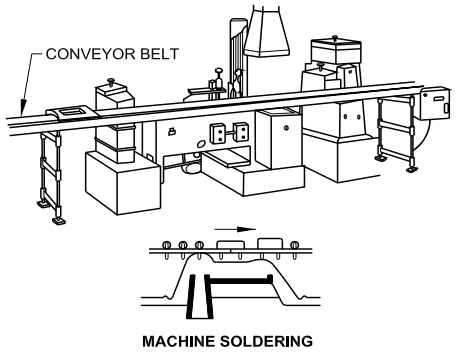


Machine soldering: This method, shown in Fig 6, is used for quantity production, and is based on the principle that molten solder or a mixture of oil and molten solder is set in rapid motion, thus breaking up the oxide film. The solder comes into direct contact with the component ends to be soldered.

Soldering machines of different designs are used for wave soldering, cascade soldering and jet soldering.

Equipment for machine soldering is expensive and the cost of production is high.

Fig 6



MACHINE SOLDERING

EL151216

Accurate temperature control can be arranged.

Apart from these, any one of the following methods can also be used for soldering.

- Resistance soldering
- Induction soldering
- Oven soldering
- Soldering in vegetable oil
- = Soldering by hot gas

Techniques of soldering

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

- **explain the procedure of soldering/wetting with i) soldering iron and ii) pot and ladle**
- **state the precautions to be followed while soldering**
- **state the method of reconditioning the solder which is subjected to repeated heating**

Soldering with electric soldering iron: In this method, the joining surface is first cleaned and then the flux is applied over the surface. The joint is then heated, and the solder is kept over the surface to be soldered, and heat is applied by keeping the soldering iron tip over it. The solder melts and spreads on the surface evenly.

The electric soldering iron: The heating element in the iron is heated by an electric current passing through it.

The bit is heated by the heating element.

The face of the bit is the part of the iron, used to make contact with the surfaces to be soldered.

Soldering irons of the following voltages and input power (wattage) are available (I.S.950-1980).

Ratings

Voltage	6	12	24	50	110	230 or 240
Wattage	25	25	25	25	25,75, 250	5,10,25,75, 125,250,500

Select an iron with adequate power to suit the size of the work.

The bit: Most bits are made of copper because it is a good conductor of heat. The face of the bit may be either:

- un-plated or
- iron-plated.

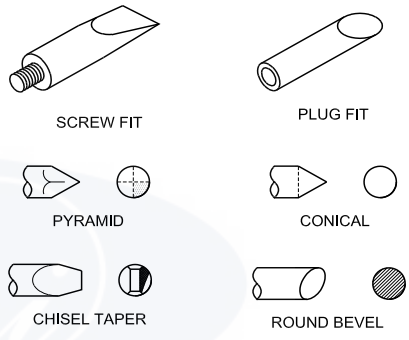
Iron-plated faces do not wear out as rapidly as un-plated faces.

Most irons are so constructed that the bit can be changed.

Different shapes of bits are available as shown in Fig 1.

Selecting the bit (Fig 2)**:** Select the bit to give a compromise between:

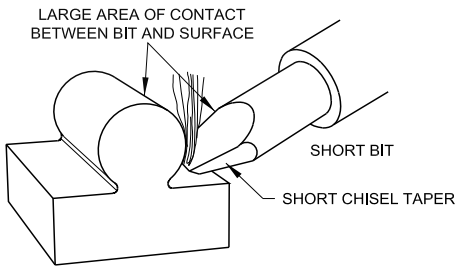
Fig 1



SHAPES OF SOLDERING BITS

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Fig 2



SELECT CORRECT SOLDERING BIT FOR THE JOB

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- the best approach to the work
- the shortest bit and bit taper
- the ideal contact with the surfaces.

Care of the bit (Fig 3)**:** Un-plated bits become pitted quickly and get covered in oxide. If the iron is in constant use, this will occur within a few hours.

Fig 3



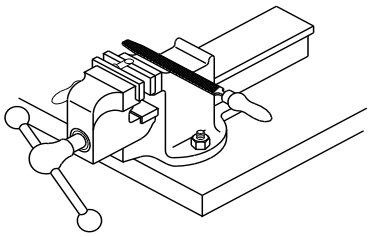
SOLDERING BITS

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To make a good soldered joint, the bit must be maintained clean, smooth and correctly shaped.

Dressing the bit (Fig 4)**:** To dress an un-plated bit follow the procedure stated below.

Fig 4



FILING THE SOLDERING BIT

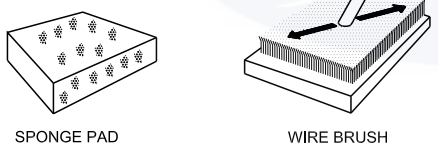
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- Switch off, unplug the iron and allow it to cool.
- Remove the bit from the iron, if possible.
- Mount the bit in a vice.
- File to shape.

Do not file the bit in an electronic assembly area. Copper dust from the bit may settle in the equipment and cause a short circuit. Iron-plated bits must not be filed. Renew when worn out.

Cleaning the bit: (Fig 5) The bit should be cleaned frequently. To clean the bit, rub the face of the un-plated bits on a wire brush or special sponge pad when the iron is hot.

Fig 5



CLEANING THE SOLDERING BIT

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Iron-plated bits must not be cleaned on a wire brush. Rub on a sponge pad.

Wetting (soldering): To make a good joint, the solder must flow evenly over and between the surfaces to be soldered. Wetting is a term used to describe the extent to which this occurs.

Good wetting results can be obtained if:

- the surfaces are clean
- sufficient flux of the correct type is used
- the surfaces are hot enough
- the surfaces have been tinned.

Techniques of soldering

Soldering involves the following main operations.

- Tinning the soldering iron
- Cleaning the parts to be soldered
- Applying the solder

Tinning the soldering iron: To make the solder adhere to the tip of the soldering iron, the surface of the tip must be coated with the solder, and this operation is known as tinning.

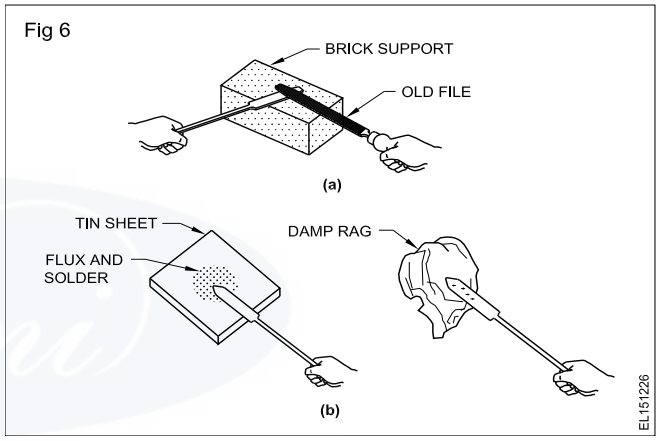
First the tip is cleaned with a cloth and heated either directly or indirectly. The tip is then filed to remove the scales, and is wiped again with a cloth.

The right temperature for tinning could be judged by the change of colour of the tip when heated. If the surface of the copper tip tarnishes immediately, the temperature is high and needs to be cooled slightly by withdrawing the source of heat temporarily. A correctly heated tip tarnishes slowly.

After the soldering iron tip attains the correct temperature, place a small quantity of solder and the flux on a tin plate and rub the bit on the mixture. The solder should stick to the surface of the tip evenly. Wipe out the superfluous solder with a clean damp cloth.

The whole process of tinning is shown in Figures 6a and 6b.

Fig 6



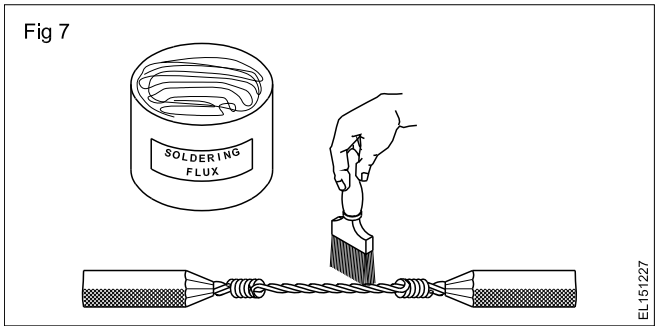
EL151226

The surface should present a bright silvery appearance when properly tinned.

Cleaning the surface to be soldered: The parts to be soldered should be well cleaned for perfect soldering. The scales, dirt, oil and grease should be completely removed either by wiping or by rubbing with a sandpaper. Immediately after cleaning, the flux should be applied on the surface to avoid oxidization.

Applying the flux: The rosin which is recommended as a flux may be sprinkled over the surface to be soldered or may be applied with a brush as shown in the Fig 7.

Fig 7



EL151227

Applying the solder: The quantity of the solder to be applied depends upon the size of the job. For small jobs like printed circuit boards soldering or soldering joints in wires of diameter 2 mm or lower, an electric soldering iron is used whereas for soldering joints of large sized cables, pot and ladle are used.

Soldering precautions: Remove the iron as soon as the solder has flowed over the surfaces.

Excessive heating may damage:

- the wire and its insulation
- the component being soldered
- the adjoining components.

Safety

Soldering irons can be dangerous if not maintained or used proprerly. Follow the directions given below.

Inspect the iron regularly for physical damage, especially the power cord. Replace it, if found damaged.

Keep the iron in a stand when not in use. This prevents burns and fires and protects the iron from damage.

Do not subject the iron to rough treatment.

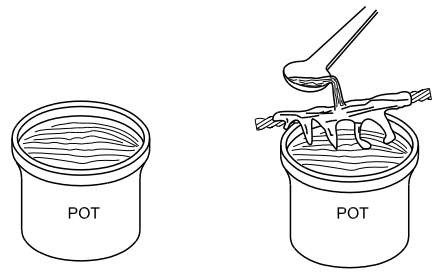
Keep the iron away from all parts of the body and from its own power cord.

A proper earth connection must be made to all mains-connected irons. If you suspect that an iron is not earthed, do not use the iron.

Never flick excess solder off the bit. The hot solder may cause burns to someone or fall into a part of the work, and cause a short circuit.

Soldering with pot and ladle: (Fig 8) For larger sized jobs like underground cable jointing, a melting pot and ladle are used. The solder is kept in the pot and heated either by a blowlamp or by charcoal. Initially the surface to be soldered is cleaned and a coat of flux is given.

Fig 8



POT AND LADLE METHOD OF SOLDERING

EL151228

Then the surface to be soldered is heated by pouring molten solder over it in quick succession. The dripping solder is collected in a clean tray. After several pourings, the surface attains the same temperature as that of the molten solder. The flux is again applied and the solder is slowly poured on the surface as it forms an even layer. Superfluous solder collected in the tray is re-melted in the pot.

Safety

Ensure that the conductor is dry and clean before applying the molten solder, and that it is not allowed to enter the insulation.

Never drop anything, including the metal to be soldered into the bath. Splashes of hot molten solder can cause serious injury. Always wear protective clothing when working with solder baths, like gloves, apron, boots etc. and emsure that no unprotected part of the body touches the pot.

When pouring solder over a joint, keep the ladle low as far as possible to prevent splashing of the molten solder over the sides of the pot.

During the solidification period, the parts of the joint must not be disturbed under any circumstances. If they are disturbed, the strength, conductivity and appearance of the joint will be endangered. The result will be what is often called COLD SOLDER and the joint will be defective.

Cooling must not be accelerated. If cooling is accelerated, the solder will assume a crystalline form. This lowers the mechanical strength.

Do not allow the molten solder to fall on to the gas pipe or the electric cables nearby.

Beware of the naked flames to avoid a fire risk.

Reconditioning of solder which is subjected to re-peated melting

In practice, when the solder is subjected to repeated melting during the soldering process, the tin content in the solder is considerably reduced due to:

– the slug formation of tin on the molten solder
– oxidization of tin due to its low boiling point.

As such the solder, which is subjected to repeated heating, will have a low percentage of tin as compared with the solder taken from the stores. To recondition the solder and to bring up the tin percentage, tin is added to the solder at the end of each use. The quantity to be added depends upon the length of time the solder is kept in the molten state.

Soldering aluminium cables

Objectives: At the end of this lesson you will be able to
- **state the type of solder and flux used for soldering aluminium cables**
- **explain the recommended procedure of soldering aluminium cables**
- **state the precautions to be followed while soldering aluminium cables.**

Soldering of aluminium cables: Soldering aluminium conductors is more difficult than soldering copper conductors owing to the highly tenacious, refractory and stable nature of the oxide film which forms immediately on any aluminium exposed to air.

This oxide film does not allow the solder to wet the surface to be soldered, and also prevents the solder from entering the interior surface by capillary action. Hence special solders and fluxes are used for aluminium soldering.

Solder: A special soft solder having a small percentage of zinc is used for joining aluminium conductors. (Soft solders are alloys which have a melting point below 300^{0}C.) IS 5479-1985 gives details of the chemical composition of soft solders and their grades used for soldering aluminium conductors. Details are given in Table 1.

The object of this small zinc content which is a common feature of aluminium solders is to fecilitate the alloying of the solder with an aluminium surface. A typical composition of solder with 51% lead, 31% tin, 9 % zinc and 9% cadmium with the brand name `ALCA P' solder is available in the market for soldering aluminium conductors. In addition a special solder by name Ker-al-lite is also available for soldering aluminium conductors.

Flux: In soldering aluminium conductors, organic fluxes of reaction type, free from chlorides and suitable for soft soldering are used.

The composition of the organic fluxes decomposes at approximately 250^{0}C to effect the removal of the oxide film and also to assist in the spreading of the molten solder to enable tinning the deoxidised surface immediately.

The major disadvantage of organic flux is that it tends to char at a temp. above 360^{0}C. The charring, thus caused, renders the flux ineffective and gives rise to the danger of creating voids in the joint due to charred flux residues. For this reason, it is essential that the temp. of this solder during the operation is maintained well within 360^{0}C. The commercial name of fluxes used for joining aluminium conductors are Kynal Flux and Eyre No.7.

Procedure of soldering aluminium

The procedure of soldering aluminium cables to standard copper lugs employing Kynal's flux and Ker-al-lite special solder is explained below.

Strip the cable in preparation for jointing in the usual manner.

Spread out the strands so as to effect a general loosening and slight displacement of the wires, and clean the surface preferably with a wire brush.

Apply a small quantity of flux by brushing well into the fanned-out ends of the conductor and baste (moisten) the fluxed conductor with a full ladle of molten solder.

Apply more flux and baste again with the molten solder. Continue to make repeated alternate applications of flux and solder until the wires exhibit a brightly tinned surface free from dull spots.

After the final basting, wipe off the surplus metal from the strands with a clean and dry piece of cloth.

Flux the lug inner surface and fill it with the molten solder.

Insert the tinned end of the cable inside the lug and hold both the cable and the lug firmly without shaking.

Allow the lug to cool and baste the surface quickly with the molten solder to remove the excess solder.

Wipe the lug surface with a clean cloth.

Apply a coating of graphite conducting grease on the lug before using.

Precautions to be followed while soldering aluminium

All surfaces must be scrupulously clean.

When a joint is being made between stranded conductors, the strands must be `stepped' to increase the surface area.

The surface must be fluxed before the heat is applied.

Safety

During the jointing operation copious fumes are given off when the flux is heated. These fumes contain small quantities of fluorine, and it is, therefore, advisable not to inhale them.

As smoking during the jointing operation results in the inhaling of toxic fumes, smoking during soldering should be avoided.

TABLE 1

Grade	% of alloying elements			Melting temp. n in ^{0}C	Flux type	Applications
	Zinc	Lead	Tin			
SnPb53Zn	1.75–2.25	52–54	45.71–45.21	170–215	Organic	Conductors of electrical cables
SnPb58Zn	1.75–2.25	57–59	40.66–40.6	175–220		-do-

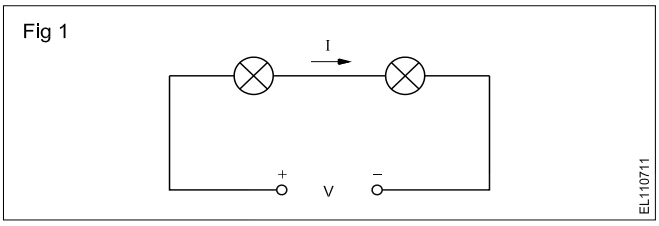
DC series circuit

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

- **state a series connection**
- **calculate current in a series circuit**
- **calculate total resistance in a series circuit**
- **calculate voltage across elements in a series circuit**
- **voltage sources in series**
- **state the uses of series connection.**

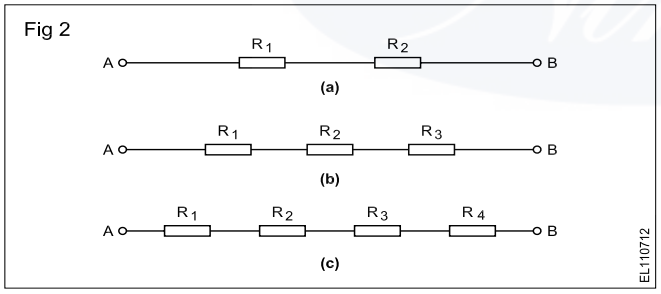
The series circuit: It is possible to connect two incandescent lamps in the way shown in Fig 1. This connection is called a series connection, in which the same current flows in the two lamps.

Fig 1



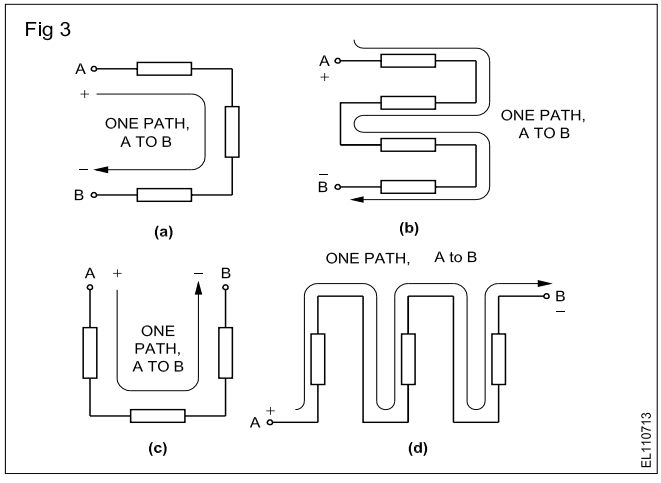
The lamps are replaced by resistors in the Fig 2. Fig 2a shows two resistors connected in series between point A and point B. Fig 2b shows three in series, and Fig 2c shows four in series. Of course, there can be any number of resistors in a series connection. Such connection provides only one path for the current to flow.

Fig 2



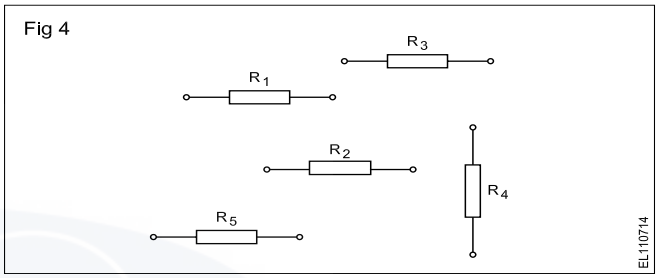
In an actual circuit diagram, a series connection may not always be as easy to identify as those in the figure. For example, Fig 3 shows series resistors drawn in other ways.

Fig 3



Question 1: An assembly of 5 resistors is shown in the figure. Draw the connection on the diagram to connect R_1,R_2,R_3,R_4 and R_5 in series with the same order. (Use your exercise notebook to copy the arrangement, and for drawing the connections and get it approved by your instructor)

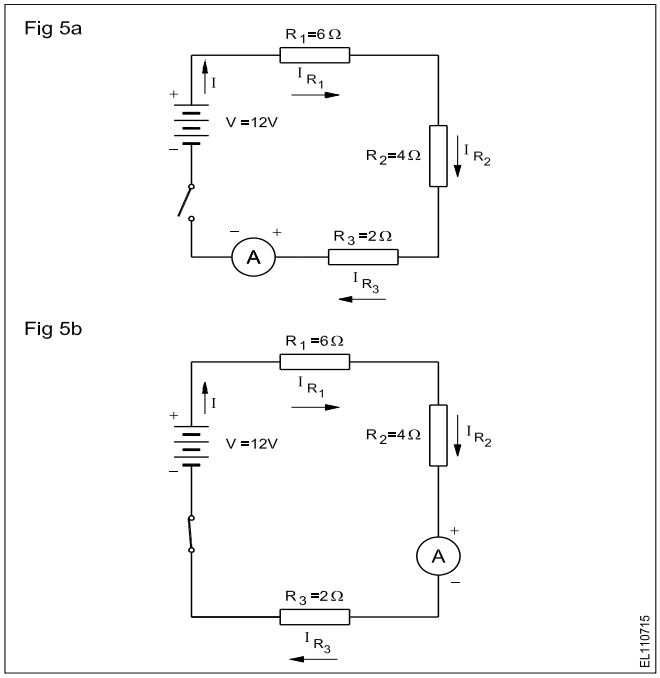
Fig 4



Current in series circuits: Current in a series circuit can be measured by inserting a meter in series. Will there be any difference in the reading of the meter in Figs 5a and 5b? No, the only difference between the two circuits is the position where the meter is inserted. Since there is only one path for the current, the same current flows through the circuit.

Fig 5a

Fig 5b



The current relationship in a series circuit is:

$$I = I_{R1} = I_{R2} = I_{R3}.$$

Total resistance in series circuit: You know how to calculate the current in a circuit. By Ohms law, if resistance and voltage are known, R_1 offers some opposition to the current flow. As the same current should flow through R_2 in series it has to overcome the opposition offered by R_2.

The total resistance in a series circuit is equal to the sum of the individual resistances around the series circuit. This statement can be written as

$$R = R_1 + R_2 + R_3 + ...$$

where R is the total resistance.

When a circuit has more than one resistor of the same value in series, the total resistance is

$$R = r \times N$$

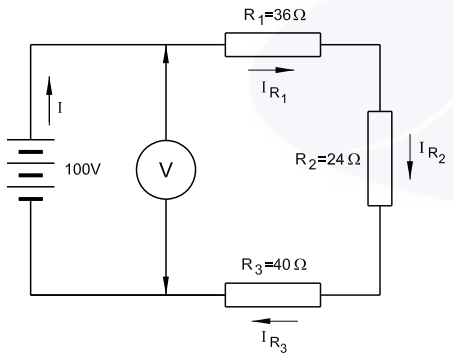
where r is the value of each resistor and N is the number of resistors in the series.

Voltage in series circuits: The source voltage divides up across the load resistors. It always divides up so that the sum of the individual load voltages equals the source voltage. That is,

$$V = V_{R1} + V_{R2} + V_{R3} + ...$$

The total voltage of a series circuit must be measured across the voltage source, as shown in Fig 6.

Fig 6



MEASURING THE TOTAL VOLTAGE OF SERIES CIRCUIT

EL110716

Voltages across the series resistors are also easily measured. The correct connections for measuring series voltages are illustrated in Fig 7 a,b and c.

When Ohm's law is applied to the circuit as a whole, for an applied voltage V, the total resistance is R.

$$I = \frac{V}{R}$$

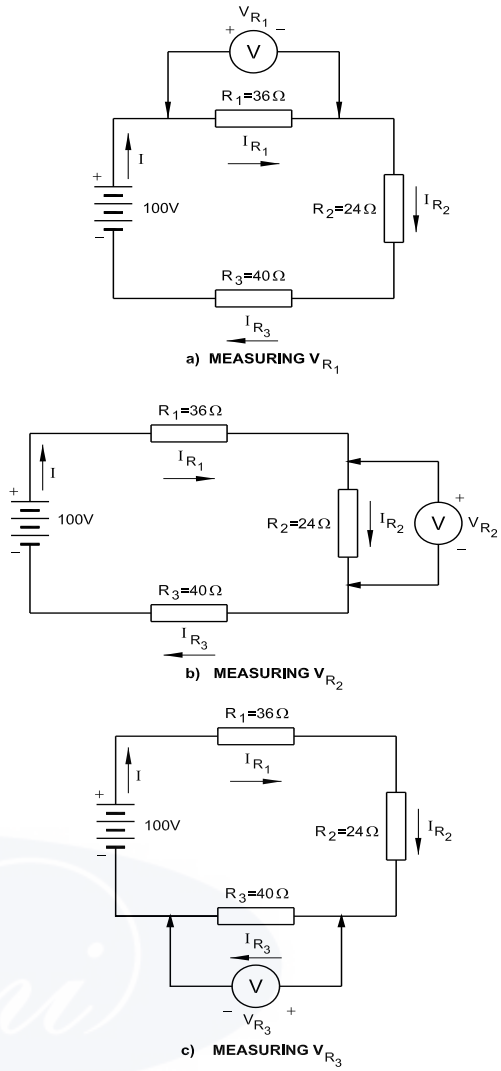
Application of Ohm's Law: Applying Ohm's law to the series circuit the relation, between various currents could be stated as below:

$$I = I_{R1} = I_{R2} = I_{R3}$$

this could be stated as

$$\frac{V}{R} = \frac{V_{R1}}{R_1} = \frac{V_{R2}}{R_2} = \frac{V_{R3}}{R_3}$$

Fig 7



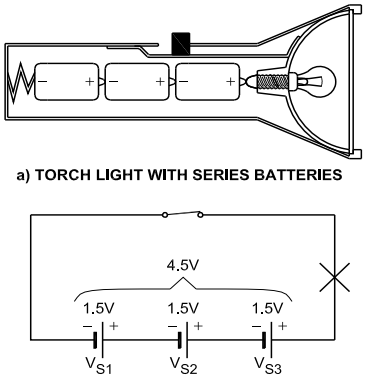
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You can use any of the above formulae to calculate current in the series circuit. We know the total supply voltage.

$$V = (V_{R1} + V_{R2} + V_{R3})$$
$$IR = (IR_1 + IR_2 + IR_3)$$
$$R = (R_1 + R_2 + R_3)$$

Voltage sources in series: When cells are placed in a torch light, they are connected in series to produce a larger voltage as shown in Figs 8a and 8b.

Fig 8



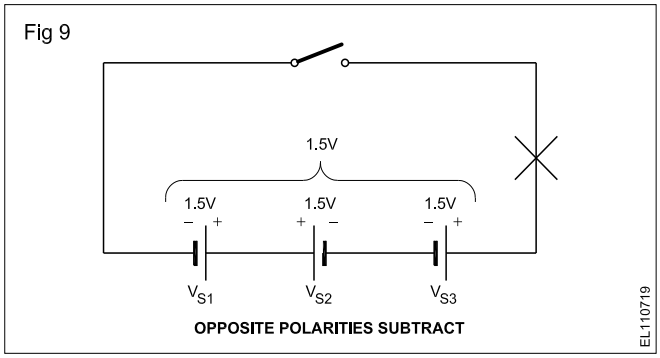
a) TORCH LIGHT WITH SERIES BATTERIES

b) SCHEMATIC OF TORCH LIGHT CIRCUIT

EL110718

Series voltage sources are added when their polarities are in the same direction, and subtracted when their polarities are in the opposite direction. For example, if one of the cells in a torch light is turned around as indicated in the schematic of Fig 9 its voltage reduces as follows.

Fig 9



V_{Total} = VS_1 – VS_2 + VS_3

= 1. 5V – 1. 5V + 1. 5V

= 1. 5V

Use of a series connection

- Cells in torch light, car batteries, etc.
- Cluster of minilamps used for decoration purposes
- Fuses
- Overload coil
- Multiplier of a voltmeter

DC Parallel circuit

Objectives: At the end of this lesson you shall be able to
- **state the relation between resistance and conductance**
- **state the unit of conductance**
- **state the parallel circuit for given conditions**
- **state the formulae that reflect the characteristics of a parallel circuit**
- **solve simple problems on parallel circuits**
- **list applications of a parallel circuit.**

Review of Ohm's Law: To begin with,let us look again at Ohm's Law. It represents the relationship between three important terms:

Term	Symbol	Unit	Abbrn.
PD(Voltage)	V	Volt	V
Resistance	R	Ohm	W
Current	I	Ampere	A

Ohm's Law expressed as a formula: V= R x I.

Expressed in words it is:

the potential difference (PD) across a resistor is equal to the product of the resistance of the resistor and the current through it.

Exercise 1: A torch battery with an emf of 4.5V and negligible resistance supplies a lamp with a current of 0.2A.

What is the resistance of the lamp?

Answer in your exercise book. Compare your answer with the solution given at the end of the information section

Electrical conductance: Conductance is opposite of resistance.

We can rearrange Ohm's Law,

V = RI and obtain

$$I = \frac{V}{R}$$

$$\text{or current} = \frac{\text{Potential difference}}{\text{resistance}}$$

Such a formula would involve long division and as multiplication is often preferred, the formula can be written

as $I = \frac{1}{R} \times V$

or, denoting G as the reciprocal of resistance I = GV.

The quantity G (= 1/R) is called the electrical conductance. It is measured in units of Siemens so that a resistance of one ohm is equivalent to a conductance of one Siemens. If R = 4W then

$$G = \frac{1}{4} S = 0.25 \text{ S}.$$

The higher the resistance of a circuit, the greater the opposition to the flow of electrical current. Hence a high resistance takes a low current.

A large conductance presents, on the other hand, low opposition to the flow of electrical current. Hence a high conductance takes a high current.

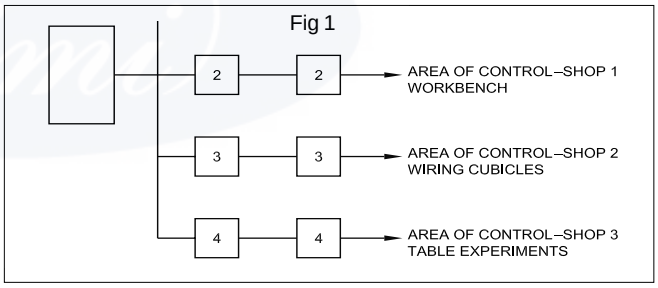
Good conductor - large conductance - small resistance

- $$G = \frac{1}{R}.$$

Exercise 2: What is the conductance of a lamp that has a resistance of R = 22.5W?

The node/ junction: An electrical current is in many ways analogous to the flow of water, in that it can divide into branches or paths.

Fig 1



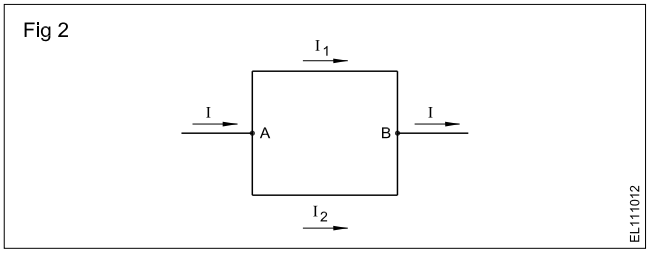
In Fig 1, for example, a quantity of water W flows from the left every second. The water divides into the two quantities W_1 and W_2 and then recombines again to W. W_1 and W_2 added together are equal to the quantity W. Written as a formula

$W_1 + W_2 = W.$

Similarly, the electrical current I in Fig 2 divides at the node or junction point A, into two component currents I_1 and I_2 which, when added together, are exactly equal to I. Written as a formula:

$I_1 + I_2 = I.$

Fig 2

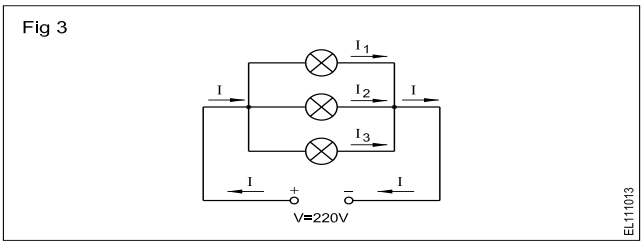


After recombining at node B the current I flows into the next part of the circuit.

In practice, a node is often a solder or screw terminal. It is represented in drawings as an enlarged dot. The current paths are drawn with a straight edge, normally either horizontally or vertically.

Exercise 3: Draw a circuit in which the current I divides at node A into three branch currents, I_1= 1A, I_2 = 2A, I_3 = 3A,

Fig 3



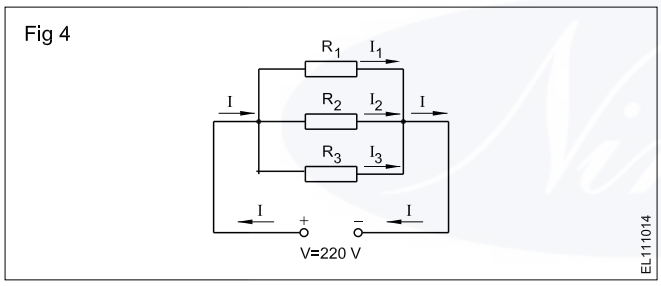
and which recombine at a node B. What is the current I?

The =parallel circuit: The diagram (Fig 3) shows a circuit where the current flows in three parallel branches.

Three incandescent lamps are connected in parallel.

Now the total current is equal to the sum of the three parallel component currents, that is $I = I_1 + I_2 + I_3$.

Fig 4



For the purpose of this example, the three incandescent lamps will be represented by three resistors. Hence the diagram (Fig 4) is the equivalent circuit hown in Fig 3 of the parallel circuit.

In this problem the three incandescent lamps are rated at 100W, 60W, and 40W. The ratings of the lamps, measured in watts, are not necessary for solving this problem, but you will gain an idea of the currents which flow in these lamps and in the cables connected to them.

Exercise 4: The total current from the supply is I = 0.91A. If I_1 = 0.455A, and I_2 = 0.273A, what is I_3?

The parallel circuit : total conductance and individual conductance: In Fig 5, the current: at node A divides into three parallel paths. The potential difference between the two nodes A and B is V and this is the same for every current path between A and B.

The equation $I = I_1 + I_2 + I_3$ can, therefore, also be written (see diagram) as

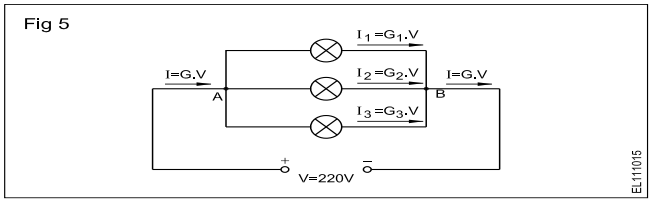
$$GV = G_1V + G_2V + G_3V$$
$$= (G_1 + G_2 + G_3)V.$$

Dividing both sides of the equation by V, we find that

$$G = G_1 + G_2 + G_3$$

or expressed in other words:

Fig 5



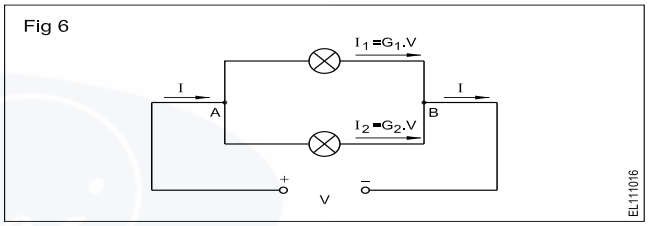
the total conductance G of the parallel paths is equal to the sum of the conductance of individual paths.

Several wires in parallel give the same conductances as one thick wire with the same total cross-sectional area. Therefore, a thick wire has a higher conductance than a thin wire.

Exercise 5: If you compare electrical current to the flow of water through a pipe, with what can you compare the conductance?

- With the pipe cross-section
- With the length of the pipe
- With the gradient of the pipe

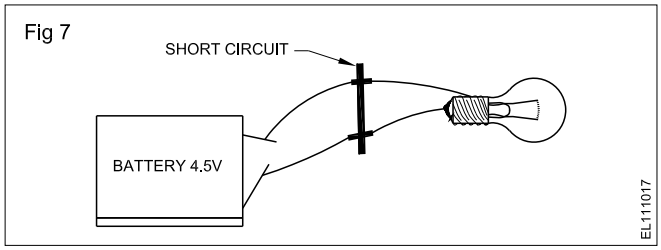
Fig 6



The parallel circuit: relationship between current and conductance : If,in a two-branch parallel circuit, G_2 is twice (or three times, or four times etc.) as large as G_1, then I_2 is twice (or three times, or four times, etc.) as large as I_1 (see Fig 6)

$I_1 : I_2 = G_1 : G_2$

Fig 7



In a parallel circuit the currents are proportional to the conductances of their individual paths.
You may consider this as follows:

- the larger the conductance, the larger the current so that when several conductors are connected in parallel more current flows through the lower resistance path.

Exercise 6: If you place a thick wire (a short circuit) across the non-insulated leads to a lamp Fig 7, a parallel path for the current is formed. The conductance of the parallel path is probably about 1000 times larger than that of the lamp. How do the currents in the conductors behave?

Intermediate test 1 :

The questions given below are on the subject covered in the preceeding sections. Re-read the text in case any difficulty is experienced in answering.

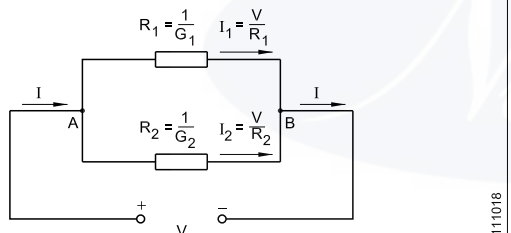
1 What is the relationship between electrical conductance and electrical resistance?
2 In the following statements only two are correct. Which are they?
In parallel circuits
(a) individual conductances are added together to give the total conductance
(b) individual resistances are added together to give the total resistance
(c) individual currents are added together to give the total current.
3 In an electrical circuit, what is a node?

Parallel circuit: relationship between current and resistanc: If, in the constant potential difference across the parallel circuit, the resistance R_2 is twice (or three times, four times, etc.) as well as R_1, then the current I_2 will be one half (or one third, or one quarter, etc.) of that of I_1.

In a parallel circuit the currents are inversely proportional to the resistance of their individual paths.

$$I_1 : I_2 = R_2 : R_1$$

Fig 8



If in the above equation you make the product of the two outer elements equal to the product of the two inner elements, you obtain the equation

$$I_1 R_1 = I_2 R_2 = V.$$

Therefore, $\frac{I_2}{I_1} = \frac{R_1}{R_2}$

These quantities are shown in the Fig 8 .

Exercise 7: A 100W lamp and a 60W lamp are connected in parallel. The currents are 0.455A and 0.273A respectively. The resistance of the 100W lamp (with the larger current) is 484 ohms. What is the resistance of the 60W lamp?

Parallel circuit: addition of reciprocal resistance: You learned that the conductance

$$G = \frac{1}{R}$$

This is called the reciprocal resistance. Each individuall conductance is equal to its reciprocal resistance.

$$G_1 = \frac{1}{R_1}, \; G_2 = \frac{1}{R_2}, \; G_3 = \frac{1}{R_3}$$

We now write the rule of addition of conductances

$$\text{i.e., } G = G_1 + G_2 + G_3$$

in the form

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Expressed in words: in a parallel circuit by adding the reciprocal values of the individual resistances, the total reciprocal resistance value is obtained.

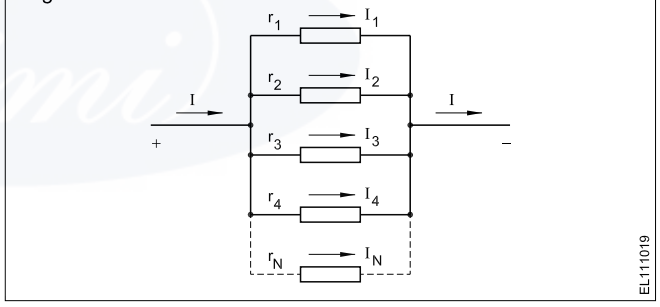
Exercise 8: Prove for the case when R_1 = 1ohm, R_2 = 2 ohms, R_3 = 3 ohms that when the resistances are connected in parallel their total resistance is smaller than the smallest single resistance, which in our example will be smaller than 1 ohm.

Special case: Equal Resistances in parallel

Total resistance, R of equal resistors in parallel (Fig 9) is equal to the resistance of one resistor, r divided by the number of resistors, N.

$$R = \frac{r}{N}$$

Fig 9



Exercise 9: Ten lamps are connected in parallel. The resistance of each lamp is 817 ohms. The current taken by the lamps when connected to 220V is 0.273A. What is the total resistance and current ?

Parallel circuit: the nodal rule: These laws governing the branching of electrical currents were laid down by the German physicist, Gustav Robert Kirchhoff in 1847.

The nodal low states that the sum of the currents flowing towards a node equals the sum of the currents flowing away from the node.

Expressed as a formula :

$$\Sigma I_{to} = \Sigma I_{away}$$

Therefore in the Fig 10

$$I_1 + I_2 = I_3 + I_4 + I_5.$$

(Σ is the Greek capital letter Sigma. It is the sign for 'sum of'.)

Fig 10

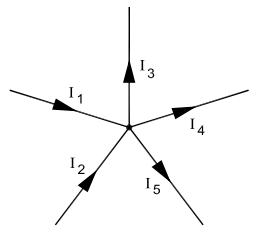
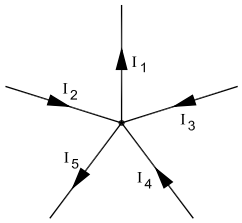


Fig 11



Exercise 10: Write the appropriate equation for the diagram illustrated in Fig 11.

Applications of parallel circuits: An electric system in which one section can fail and other sections continue to operate has parallel circuits. As previously mentioned, the electric system used in homes consists of many parallel circuits.

A domestic electric system uses parallel circuits for lights, heater, motor, radio, etc. Each of these devices operates independently of the others.

Individual television circuits are quite complex. However, the complex circuits are connected in parallel to the main power source. That is why the audio section of television receivers can still work when the video (picture) is inoperative.

Key to exercises

1 $V = R \times I$ is Ohm's Law and this gives

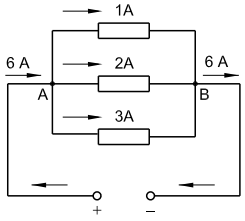
$$R = \frac{V}{I}$$

$$Hence\ R = \frac{4.5}{0.2}\Omega$$

$$= \frac{45}{2}\Omega$$

Therefore $R = 22.5\Omega$.

Fig 12



2 $$G = \frac{1}{R} = \frac{1}{22.5}\ S = 0.044\ S.$$

The conductance G of the lamp is 0.044S.

3 (If you have drawn the nodes as enlarged dots then you have been particularly careful. (Fig 12)

4 $I = I_1 + I_2 + I_3$ can be transformed to

$$I_3 = I - I_1 - I_2$$

$$I_3 = 0.91 - 0.455 - 0.273A = 0.182A$$

5 (a) with the pipe cross section.

6 The current through the short-circuit is 1000 times as large as the current through the lamp.

7 $I_1 : I_2 = R_2 : R_1$

$$R_2 = \frac{I_1 R_1}{I_2}$$

$$= \frac{0.455}{0.273} \times 484\ \Omega = 806.66\ \Omega$$

8 From $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

it follows that $\frac{1}{R} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3}$

$$= \frac{6+3+2}{6} = \frac{11}{6}$$

so that $R = \frac{6}{11} = 0.545\ \Omega$

9 Resistance of each lamp $= r = 817\Omega$

Numbers of parallel branches $= N = 10$

Total resistance $R = \frac{r}{N} = \frac{817}{10} = 81.7\Omega$

Total current $I = I_1 + I_2 + \ldots$

$I = 10 \times I_1$

$= 10 \times 0.273$

$= 2.73\ A.$

10 $I_1 - I_2 - I_3 - I_4 + I_5 = 0$

Answers to Intermediate Test 1

1 $G = \frac{1}{R}$ or $R = \frac{1}{G}$ (Lesson2)

Conductance is the reciprocal of resistance (or the inverse of resistance).
These answers are also correct.
When the conductance is large the resistance is small.
When the resistance is large the conductance is small.

2 (a) and (c) are correct.

The resistance of parallel connected resistors should not be added to obtain the total resistance (one adds the reciprocals of the resistance, i.e. the conductances, to obtain the total conductance).

3 A node is a junction point of electrical conductors or node is a point where two or more conductors are connected together.

Measurement of energy in single phase circuits

Objectives: At the end of this lesson you shall be able to
- **describe the construction and working principle of single phase energy meters**
- **state and explain creeping error in energy meter.**

Necessity of energy meter: The electrical energy supplied by the Electricity board should be billed, based on the actual amount of energy consumed. We need a device to measure the energy supplied to a consumer. Electrical energy is measured in kilowatt hours in practice. The meter used for this is an energy meter.

In AC, an induction type of energy meter is universally used for measurement of energy in domestic and industrial circuits.

Principle of a single phase induction type energy meter: The operation of this meter depends on the induction principle. Two alternating magnetic fields produced by two coils induce current in a disc and produce a torque to rotate it (disc). One coil (potential coil) carries current proportional to the voltage of the supply and the other (current coil) carries the load current. (Fig 1) Torque is proportional to the power as in wattmeter. The watt-hour meter must take both power and time into consideration. The instantaneous speed is proportional to the power passing through it. The total number of revolutions in a given time is proportional to the total energy that passes through the meter during that period of time.

Fig 1

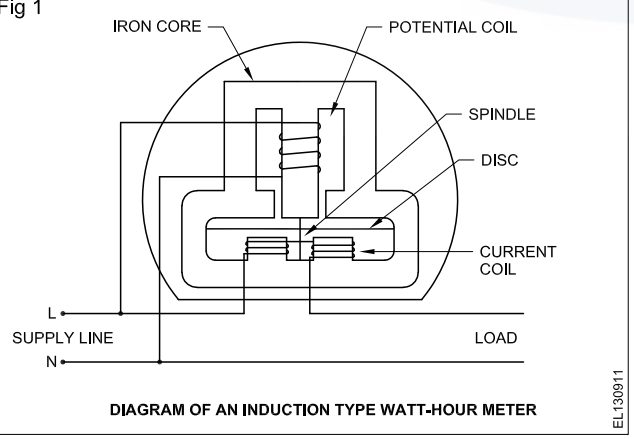


DIAGRAM OF AN INDUCTION TYPE WATT-HOUR METER

Parts and functions of an energy meter: The parts of the induction type single phase energy meter are as shown in Fig 1.

Iron core: It is specially shaped to direct the magnetic flux in the desired path. It directs the magnetic lines of force, reduces leakage flux and also reduces magnetic reluctance.

Potential coil (voltage coil): The potential coil is connected across the load and is wound with many turns of fine wire. It induces eddy current in the aluminium disc.

Current coil: The current coils, connected in series with load, are wound with a few turns of thick wire, since they must carry the full load current.

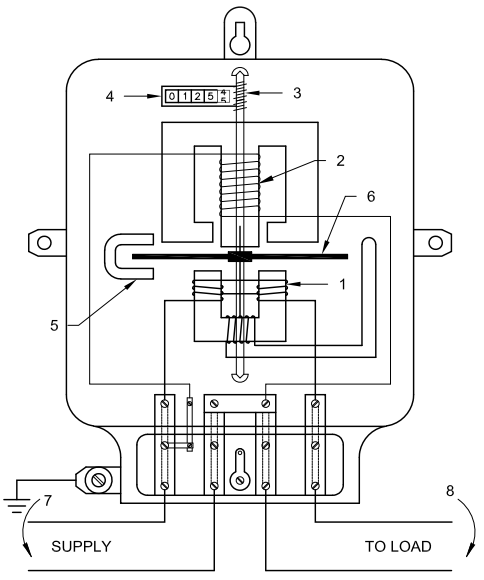
Disc: The disc is the rotating element in the meter, and is mounted on a vertical spindle which has a worm gear at one end. The disc is made of aluminium and is positioned in the air gap between the potential and current coil magnets.

Spindle: The spindle ends have hardened steel pivots. The pivot is supported by a jewel bearing. There is a worm gear at one end of the spindle. As the gear turns the dials, they indicate the amount of energy passing through the meter.

Permanent magnet/brake magnet: The permanent magnet restrains the aluminium disc from racing at a high speed. It produces an opposing torque that acts against the turning torque of the aluminium disc.

Functioning of energy meters: The rotation of the aluminium disc in Fig 2 is accomplished by an electromagnet, which consists of a potential coil and current coils. The potential coil is connected across the load. It induces an eddy current in the aluminium disc. The eddy current produces a magnetic field which reacts with the magnetic field produced by the current coils to produce a driving torque on the disc.

Fig 2



1. CURRENT COIL
2. VOLTAGE COIL
3. WORM GEAR
4. REGISTERING MECHANISM
5. PERMANENT MAGNET
6. ALUMINIUM DISC
7. SUPPLY TERMINALS
8. LOAD TERMINALS

INDUCTION TYPE ENERGY METER

The speed of rotation of the aluminium disc is proportional to the product of the amperes (in the current coils) and the volts (across the potential coil). The total electrical energy that is consumed by the load is proportional to the number of revolutions made by the disc during a given period of time.

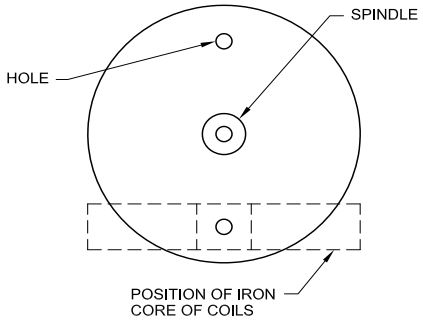
A small copper ring(shading ring) or coil (shading coil) is placed in the air gap under the potential coil, to produce a forward torque, large enough to counteract any friction produced by the rotating aluminium disc.

This counter torque is produced when the aluminium disc rotates in the magnetic field established by the permanent magnet. The eddy currents, in turn, produce a magnetic field that reacts with the field of the permanent magnet, causing a restraining action that is proportional to the speed of the disc. The faster the disc rotates, the greater the induced eddy currents, and greater the restraining action. This restraining action is necessary to make the speed of rotation proportional to the current taken by the load and also to stop the disc from further rotation due to inertia when the supply is disconnected.

Creeping error and adjustment: In some meters the disc rotates continuously even when there is no current flow through the current coil i.e. when only the pressure coil is energised. This is called creeping. The major cause for creeping is over-compensation for friction. The other causes for creeping are excessive voltage across the pressure coil, vibrations and stray magnetic fields.

In order to prevent creeping, two diametrically opposite holes are drilled in the disc (Fig 3). The disc will come to rest with one of the holes under the edge of a pole of the potential coil magnet, the rotation being thus limited to a maximum of half a revolution.

Fig 3



Multimeter

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

- **state multimeters - different types - functions of the main parts, controls-schematic diagrams showing internal connections for different modes of operation**
- **explain the method of measuring direct/alternating voltages with a multimeter**
- **explain the method of measuring direct current with a multimeter**
- **explain the method of measuring resistance by a multimeter**
- **explain the precautions to be observed while measuring voltage,current and resistance in the circuit**
- **state the applications of a multiplier**
- **state the types of multimeter**
- **explain the working of digital multimeter**
- **compare analog and digital multimeter.**

Multimeter: A multimeter is an instrument in which the function of an ammeter, voltmeter and ohmmeter are all incorporated for measurement of current, voltage and resistance. Some manufacturers call this as VOM meter as this meter is used as a volt, ohm and milliammeter. The multimeter uses the basic d'Arsonval (P.M.M.C) movement for all these measurements. This meter has facilities through various switches to change the internal circuit to convert the meter into a voltmeter, ammeter or ohmmeter. There are several types of multimeters available in the market, manufactured by various manufacturers. Each model differs from the others by the extra facilities available. It is a versatile tool for all electricians. With proper usage and care, it could give service for many years.

Types of multimeters: There are two types of multimeters available in the market. They are:

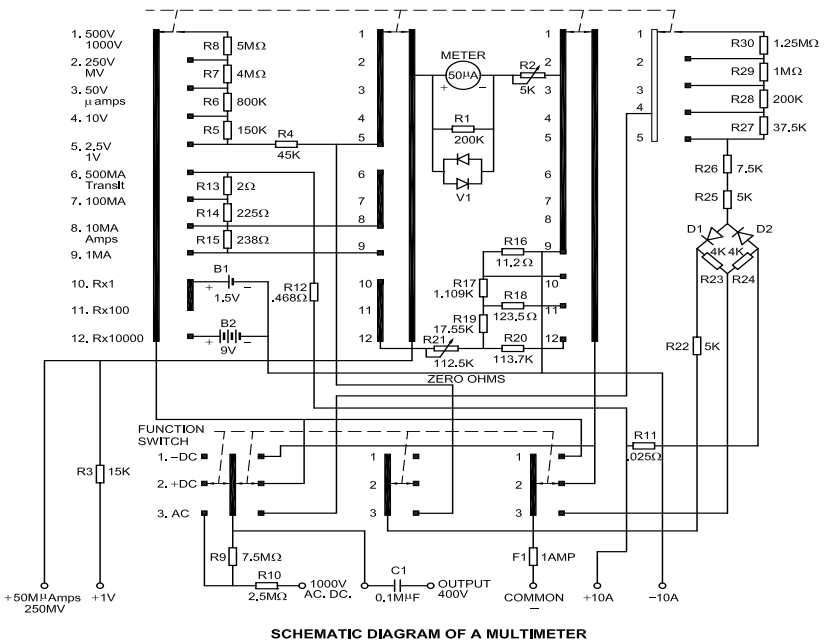
– ordinary multimeter having passive components in the internal circuitry
– electronic multimeter having active and passive components in the internal circuitry.

Though the ordinary multimeters are of an analog type, the electronic multimeters can be either analog or digital type. Most of the ordinary multimeters will have a sensitivity of 20 K ohms per volt whereas electronic multimeters have internal resistance to the tune of 5 to 10 megohms, irrespective of the selected ranges. The explanation given here is for an ordinary multimeter only.

Fig 1 shows the schematic diagram of a commercial multimeter. This meter is a combination of a multi-range DC voltmeter, AC voltmeter, DC milliammeter, an ohmmeter and an output meter. The indicating meter in this multimeter uses the d'Arsonval movement which has a resistance of 2000 ohms, having full scale deflection current of 50 micro-amperes.

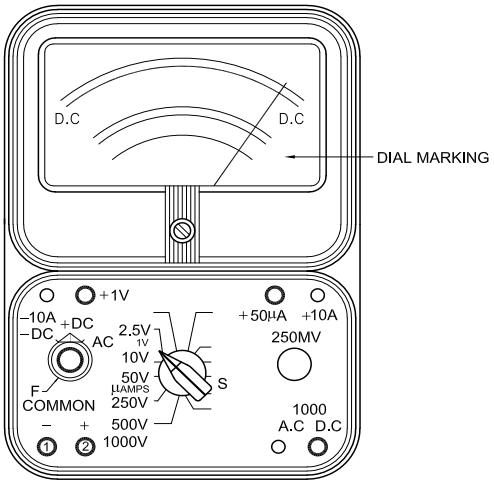
This instrument is provided with a function switch 'F' to select the type of supply, whether AC or DC Further the same switch can be used to select the polarity of the meter in DC mode without changing the leads as indicated by position +DC or –DC in Fig 2.

Fig 1



SCHEMATIC DIAGRAM OF A MULTIMETER

Fig 2

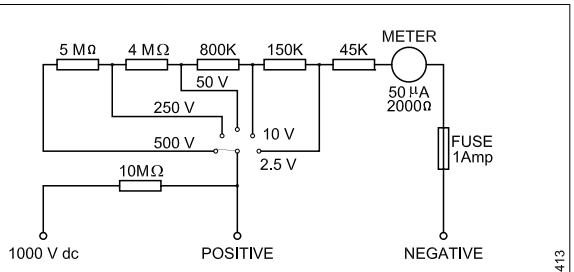


A single range switch S at the centre selects the range of AC or DC voltages, DC current (no facility to measure alternating current in this meter) and resistance.

The range switch, along with the function switch, connects the required circuit elements to convert the meter for the required measurement of electrical quantities as described below.

Multimeter as a DC voltmeter: The circuit shown in Fig 3 is for DC voltmeter section when common input terminals are used for voltage. The voltage range can be selected with the help of the range switch. The circuit in Fig 3 shows the value of the multiplier resistance for various ranges at DC voltage mode. This instrument has a sensitivity of 20K ohms/volt in the DC mode which is fairly high. Hence suitable for electronic measurements also. A separate jack is provided for measuring voltage 1000V. Apart from using separate jacks, the range switch should be set to 500V position for measuring 1000V.

Fig 3



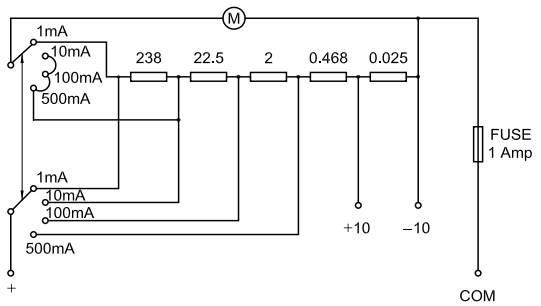
SCHEMATIC DIAGRAM OF MULTIMETER AS DC VOLTMETER

Multimeter as a DC ammeter: Fig 4 shows the circuit configuration of this multimeter for measuring DC milliampere or ampere. For measuring DC current up to 500mA common jacks are used whereas the jacks marked +10 and - 10A should be used for 0-10A range.

Multimeter as an ohmmeter: For the ohmmeter function, the range switch should be set as shown in Fig 5 and the function switch should be in DC mode. The details of the ohmmeter section of this multimeter are shown in Fig 6.

Fig 6a shows the ohmmeter section for a scale multiplication of x1 range, 6b for x100 and 6c for x10000 ohms ranges.

Fig 4



SCHEMATIC DIAGRAM OF THE MULTIMETER IN DC CIRREMT MODE

Fig 5

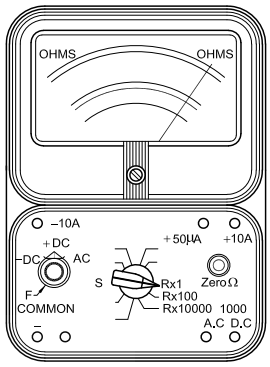
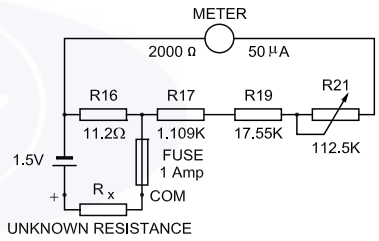
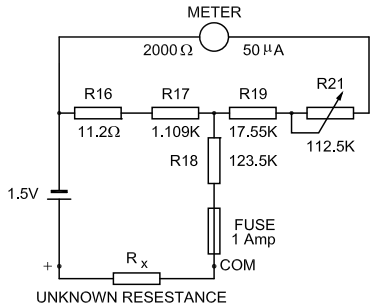


Fig 6(a)



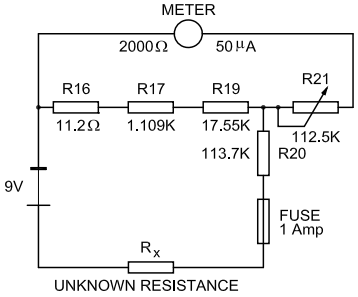
RESISTANCE MODE Rx1 RANGE

Fig 6(b)



RESISTANCE MODE Rx100 RANGE

Fig 6(c)



RESISTANCE MODE Rx 10k RANGE
SCHEMATIC DIAGRAM OF THE MULTIMETER IN OHMMETER MODE

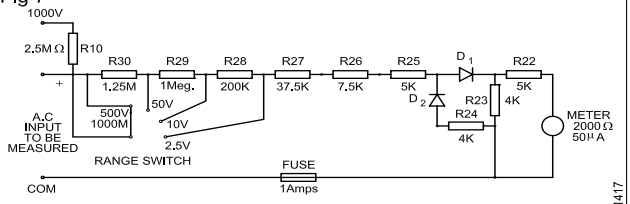
Though resistance ranges x 1 and x 100 uses a single cell, the R x 10000 range uses an additional battery of 9V.

Note that the meter supply polarities to the unknown resistance is reversed in the multimeter. This hint will be useful when testing diodes and transistors.

Multimeter as a AC voltmeter: For the AC voltage measurement the function switch should be in AC position and the range switch should be set to the suitable range.

Fig 7 shows the circuit arrangement for measuring AC voltages. As shown in figure 7, D1 is used to convert AC input to DC for meter movement. Due to the use of a rectifier, the sensitivity in an AC voltmeter mode for this multimeter is only 5000 ohms/volts..

Fig 7



SCHEMATIC DIAGRAM OF THE MULTIMETER IN AC VOLTMETER MODE

The method of using a multimeter for measuring various quantities is as follows.

Methods of measuring DC voltages: Refer to Fig 2, set the function switch (F) in the DC position and set the range switch (S) as per the voltage to be measured, plug in the black lead to the jack(1) marked `Common', the red lead to the +ve jack(2). Connect the test prods to the voltage source to be measured.

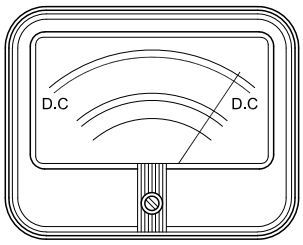
When measuring DC voltage, care must be taken to prevent damage to the instrument by applying a higher voltage than the voltage indicated in the range setting. For this, while measuring voltages, it is always better to select the highest range first and then reduce to the lower range to have either a full scale deflection or a reading which is above mid- scale.

For example, if the percentage error is 3% for the full scale deflection, at the middle of the scale the error goes to 6% and for 1/4 scale the deflection error shoots up to 12%. Hence it is advisable to get the reading somewhere between the centre of the scale and the full scale.

If higher voltages are measured in low range settings, the meter will get damaged.

On the other hand if low voltages are measured in higher range settings, the deflection will be less and the percentage error will be more. Hence, a proper range is to be selected to have a deflection more than half of the dial. Refer to Fig 8.

Fig 8

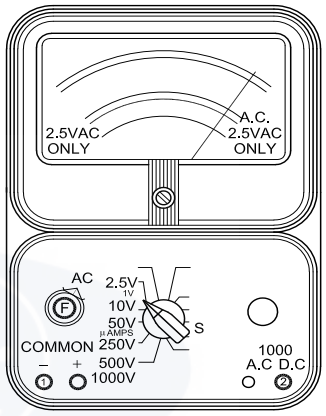


Method of measuring AC voltages: The function switch should be set at AC position, and the range switch to a proper voltage position. Plug the black test lead in the COMMON jack and the red lead in the +ve jack. Then connect the test leads across the voltage source. For 0-2.5V range, read the value directly on the scale marked 2.5V AC only.

Refer to Fig 9 for 10V, 50V and 250V ranges, read the red scale marked AC and use the red figure below the scale. For the 500V range read the red scale marked AC having 0-50 scale and multiply the reading by 10.

Method of measuring direct current: Always connect the instrument in series with the load. Set the function switch in DC position and the range switch on the desired

Fig 9

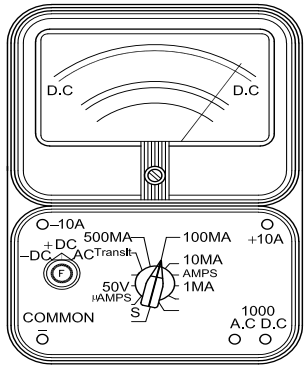


range of current or preferably at a higher range. The black lead is to be connected to the `COMMON JACK' and the Red lead to the +ve jack. The current in milliamps should be read on the black scale. Refer to Fig 10.

In all direct current measurements, be certain that the power to the circuit being tested has been turned `OFF' before disconnecting or connecting the test leads. For 10 amps current measurement, use jacks marked +10 and -10 only.

When using the instrument in 10A range never remove the test lead from its panel jack while the current is flowing through the circuit. This causes damage to the banana plugs and jacks.

Fig 10



Method of measuring resistance: When resistance is to be measured, set the function switch 'R' to + DC position and set the range switch 'S' to the resistance position of the desired range as shown in Fig 5. Plug the black lead in the common jack and the red test lead in the jack. Short the lead and check the zero position of the pointer. If the pointer is not in zero position, adjust the zero ohms adjustment knob until the pointer sets on the zero position. If the pointer does not come to the zero position of the ohmmeter, the battery should be replaced.

Before measuring resistance in any circuit, be sure the power is off in the circuit being tested. Discharge any electrolytic capacitor in the circuit before measuring the resistance.

Method of use:

Use R x 1 for resistance values from 0 to 200 ohms.

Use R x 100 for resistance values from 200 to 20,000 ohms.

Use R x 10,000 for resistance values for above 20,000 ohms.

The topmost scale on the dial is intended for resistance measurement.

Application of a multimeter: A multimeter is used for testing and fault finding in electrical/electronic circuits, electrical appliances and machines. An understanding of its proper use helps in achieving better results.

It is a handy instrument electricians use for:

- checking continuity of circuits, appliances and devices
- measuring/checking the supply presence at the source
- checking the components for their condition by resistance measurement for voltage drop across it in on line measurement
- measuring the current drawn by the circuit to infer its condition
- measuring resistance of the electrical appliances and devices for knowing their condition.

Other applications of the multimeter are for testing capacitors, diodes and transistors to know their condition. Some meters have provision also for temperature measurement with suitable sensing prods.

Types of multimeters

Analogue types:

- Selector switch type
- Multi-plug type

Digital types:

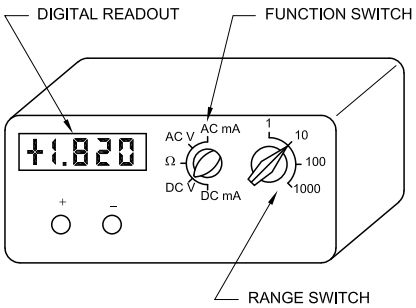
- Selector switch type
- Auto-ranging type
- LCD display

Analogue type multimeters: They have a meter movement mechanism, a calibrated scale and a pointer. Reading is obtained by looking at the position of the pointer on the scale.

The multimeter explained earlier is an analoque type.

Digital multimeter: In a digital multimeter, the meter movement is replaced by a digital readout. (Fig 11) This readout is similar to that used in electronic calculators. The internal circuitry of the digital multimeter is made up of digital, integrated circuits. Like the analog-type multimeter, the digital multimeter has a front panel switching arrangement. The quantity measured is displayed in the form of a four digit number, with a properly placed decimal point. When DC quantities are measured, the polarity is identified by means of a + or – sign displayed to the left of the number.

Fig 11



Comparison of analogue and digital multimeters

Analoque type	Digital type
1 Instrument has moving exercised. Position of use fixed.	There are no moving pointer. Care should be parts. Used in any position.
2 Reading error due to parallax is possible.	No reading error as they have numerical display.
3 Actual value of indication obtained by computation.	No need to compute. Direct indication of value.
4 Manual zero setting for resistance measurement is required.	Automatic zero setting for resistance measurement.
5 Auto-range setting not possible.	Auto-ranging instruments are available.
6 It can track short term variations and trends in measured quantity.	Not possible - slow response.
7 Indication of measured quantity by the pointer over the graduated scale.	Digital numerical read-out.
8 Loads the measuring of circuit.	Practically no loading.

DMM functions: The basic functions found on most DMMs are the same as those on analogue multimeters. That is:

- Ohms
- DC voltage and current
- AC voltage and current.

Some DMMs provide special functions such as transistor or diode tests, power measurement, and decibel measurement for audio amplifier tests.

DMM displays: DMMs are available with either LCD (liquid-crystal display) or LED (light-emitting diode) read-outs. The LCD is the most commonly used read-out in battery-powered instruments because it requires only very small amount of current. A typical battery-powered DMM with an LCD read-out operates on a 9 V battery that will last from a few hundred hours to 2000 hours and more. The disadvantages of LCD read-outs are that (a) they are difficult or impossible to see in poor light conditions, and (b) they are relatively slow to respond to measurement changes. LEDs, on the other hand, can be seen in the dark, and respond quickly to changes in measured values. LED displays require much more current than LCDs, and, therefore, battery life is shortened when they are used in portable equipment.

Both LCD and LED-DMM displays are in a seven-segment format as shown in Fig 12.

Fig 12



SEVEN SEGMENT DISPLAY

EL13141C

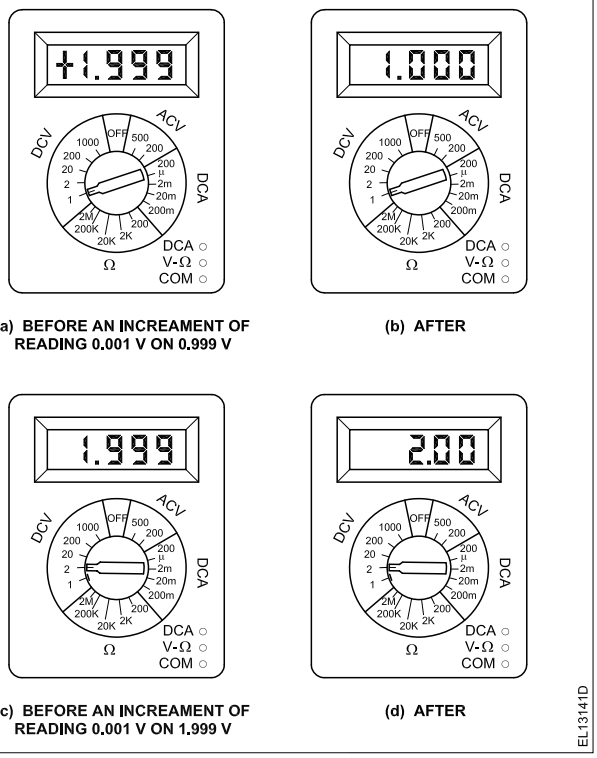
Many meters have 3 digits in their display. We will use this case for illustration. A 3 digit multimeter has three digit positions that can indicate from 0 through 9, and one digit position that can indicate only a value of 1. This latter digit, called the half-digit, is always the most significant digit in the display.

For example, suppose a DMM is reading 0.999 volt, as shown in Fig13a. If the voltage increases by 0.001 V to 1V, the display correctly shows 1.000 V, as shown in Fig 13b. The 1 is the half-digit. Thus, with 3 digits, a variation of 0.001 V, can be observed.

A 3 digit DMM illustrates how the number of digits in use changes.

Now, suppose the voltage increases to 1.999 V, this value is indicated on the meter as shown in Fig 13c. If the voltage increases by 0.001V to 2V, the half-digit cannot display the `2', so the display shows 2.00. The half-digit is blanked and only three digits are active, as indicated in Fig 13d. DMMs with displays of 4 through 8 digits are also available.

Fig 13



(a) BEFORE AN INCREAMENT OF READING 0.001 V ON 0.999 V

(b) AFTER

(c) BEFORE AN INCREAMENT OF READING 0.001 V ON 1.999 V

(d) AFTER

EL13141D

Multimeter - Safety precautions: Using a multimeter safely is an important technical skill. When measuring electricity, you are dealing with an invisible and often a lethal force. Voltage levels above 30V can kill. The following safety precautions should always be followed.

- Never use the ohmmeter section on a live circuit.
- Never connect the ammeter section in parallel with voltage source.
- Never overload the ammeter or voltmeter sections by attempting to measure currents or voltages far in excess of the range switch setting.
- Check the meter test leads for frayed or broken insulation before working with them.
- Avoid touching the bare metal clips or tips of the test probes.
- Whenever possible, remove the voltage before connecting the meter test leads into the circuit.
- When connecting the meter test leads to live circuits, work with one hand hanging at your side to lessen the danger of accidental shock.
- To lessen the danger of accidental shock, disconnect the meter test leads immediately after the test is completed.

Conduit wiring - batten wiring and earthing

Objectives: At the end of this lesson you shall be able to
- **distinguish between the different types of conduits used in wiring**
- **state the gauge, diameter and length of the metallic and non-metallic conduits available in the market**
- **compare metal and PVC conduit wiring**
- **state the different types of accessories used in non- metallic conduits wiring**
- **select a suitable size of conduit for a specific number and size of cables.**

In general, a conduit is defined as a tube or channel. Tubular conduit is the most commonly used material in electrical installations. When cables are drawn through the conduit and terminated at the outlet or switch points, the system of wiring is called conduit wiring.

Types of conduits

There are four types of conduits used for wiring.
- Rigid steel conduit
- Rigid non-metallic conduit
- Flexible steel conduit
- Flexible non-metallic conduit

Rigid steel conduit:

This can be further divided into:
- heavy gauge screwed conduit and
- light gauge conduit.

Heavy gauge screwed conduit: This can be either solid-drawn or seam - welded. A solid-drawn conduit is expensive, and hence, its use is restricted to gas-tight, explosive-proof installations. Seam - welded conduit is the one commonly used in modern domestic, commercial and industrial wiring.

Light gauge conduit: This is constructed from a length of flat, thin sheet steel which is manufactured to form a tube. The seam, which is often left open, does not provide a weatherproof installation. Hence, the use of a light gauge conduit is restricted to indoor-conduit wiring to have protection for inlaid cables. This conduit itself should not be used as earth continuity conductor; separate earthing conductors are, therefore, necessary.

Size of metal conduits: Commercially metal conduits are available in lengths of 3.00 metres and in diameters from 16 mm to 65 mm.

Normally the conduit pipe size refers to the outer diameter, whereas for G.I. pipes, the sizes are referred to in terms of the internal diameter.

All metallic conduits get corroded in damp and chemical environment. Hence conduits are to be protected against corrosion by galvanising them, when used for outdoor work or where dampness is present. For dry environments black enamelling on the conduit would be sufficient.

TABLE 1

Nominal size of conduit in mm		Wall thickness of heavy gauge conduit in mm	Wall thickness of light gauge conduit in mm
Metal	16	1.6	1
	19	1.8	1.0
	25	1.8	1.2
	32	1.8	1.2
	38	2.0	---
	50	2.24	---
	64	2.5	---
Non- metal 16 to 64		2 or more than 2	Less than 1.5

Non-metallic conduits: These are made of fibres, asbestos, polyvinyl chloride (PVC), high density polyethylene (HDP) or polyvinyl (PV). Of the above, PVC conduits are popular owing to their high resistance to moisture and chemical atmosphere, high dielectric strength, low weight and low cost. These conduits may be buried in lime, concrete or plaster without harmful effects.

However, light gauge (lower than 1.5 mm wall thickness) PVC pipes are not as strong as metal conduits against mechanical impact. Special PVC pipes called heavy gauge, high impact types are available in the market which can withstand heavy mechanical impact as the wall thickness of the pipes is more than 2 mm.(Refer Table 1)

There are some PVC conduits called heavy gauge, high temperature type which are of special base material made to withstand temperatures up to 85°C. These PVC conduits are available in 4 m length.

Flexible conduits: Apart from rigid conduits, flexible conduits are also used for protecting cable-ends connected to a vibrating machine. In the case of metal flexible conduits, steel strips are spirally wound to form a tube. However, these flexible conduits cannot be relied on as the sole means of earthing due to the manufacturing method as well as material. Hence earthing conductors should run either externally or internally to the flexible conduit to form the earth connection.

Variation in conduit-wiring system: There are two types of conduit-wiring systems as stated below, for either metal of non-metallic types.

- Surface conduit-wiring system done on wall surfaces.
- Concealed (recessed) conduit-wiring system done inside the concrete, plaster or wall.

Selection of the type of conduit: Metallic or PVC conduits are equally popular in electrical installations. Selection of the type of conduit depends upon the following criteria.

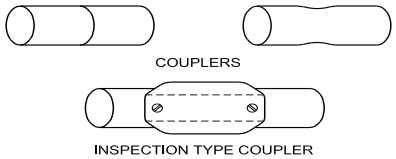
- Location-outdoor or indoor
- Atmosphere-dry or damp or explosive or corrosive
- Working temperature
- Physical damage due to mechanical impact
- Weight of conduit-runs
- Cost

A comparison between metal and PVC conduit wirings given in Table 2 will help in choosing the right type of conduit for a specific installation.

Non-metallic conduit accessories: Non-metallic conduit fittings and accessories shall be fabricated or moulded to the required shape. They shall be so designed and constructed that they can be fitted with the corresponding conduit sizes without any adjustment, and ensure ready limited mechanical protection to the cables. These fittings and accessories are used for conduit extension and tappings or to assist the pulling conductors.

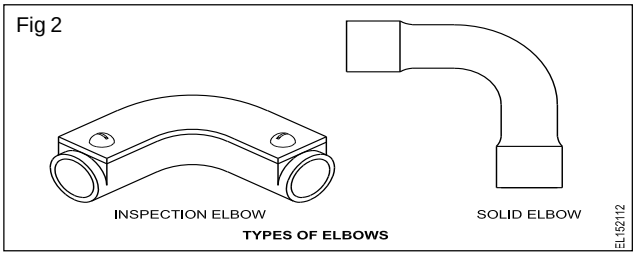
Inspection type, non-metallic fittings and accessories are permitted to be used only with surface-mounting type wiring. Inspection fittings shall be so constructed that the screws used for fixing the cover do not deform the conduits or damage the insulation of the cables enclosed.

Fig 1



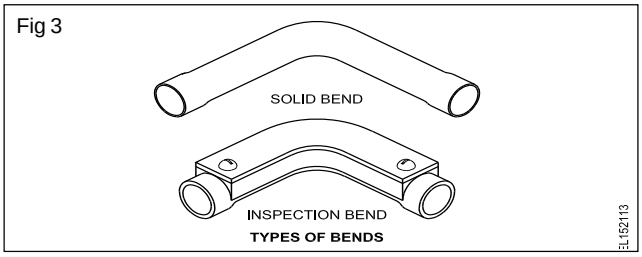
PVC fittings and accessories couplers (Fig 1): Normally push-type couplers are used and the conduit shall be pushed right through to the interior of the fittings. Inspection type couplers are used in straight conduit-runs to assist in the inspection of the straight cables.

Fig 2



Elbow (Fig 2): The axis of any elbow shall be a quadrant of a circle plus a straight portion of each end. Elbows are used at sharp ends of nearby walls or roofs and walls.

Fig 3



Bends (Fig 3): A bend gives a diversion of 90°C in the turn of a conduit, and a normal bend shall be a large sweep. Inspection-type bends are used to assist in the inspection at the corners and for drawing cables.

Tees (Fig 4): Tees are used to take diversion from the main line either to drop to switch points or to the light points. It may be either an ordinary type or an inspection type. Inspection-type tees are used to assist in the inspection in case there is a need.

Fig 4

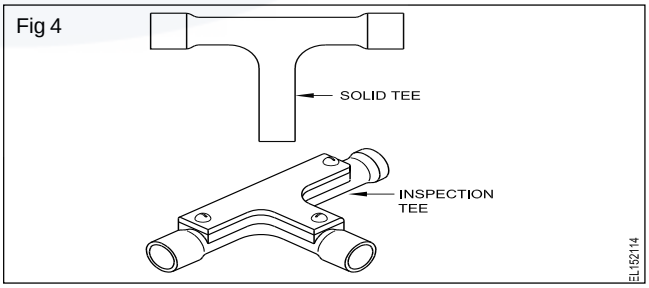


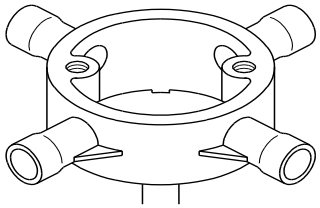
TABLE 2

Metal conduit	PVC conduit
1 Provides good physical protection to cables.	Comparatively poor.
2 Weighs more for a given length.	Lighter.
3 Needs skill and time for installation.	Needs less skill and time.
4 Risk of electric shock due to leakage.	No risk as PVC is an insulator.
5 Good earth continuity available through the	Not possible.Separate earth wire is required.pipe itself.
6 Can be used in gas-tight and explosive-proof installation.	Not suitable.
7 Not resistant to corrosion, needs protective coating.	Resistant to corrosion.
8 Large ambient temperature range.	Suitable for limited temperature range. At temperatures above 60°C, the conduit starts melting. At very low temperatures the conduit cracks.
9 Fire-resistant.	Not fire-resistant.
10 More costly.	Less costly.

Boxes

Circular boxes (Fig 5): Small, circular boxes shall be provided with two machine screws of a diameter not less than 2.8 mm for fixing the covers. Large, circular boxes have four machine screws of a diameter not less than 4 mm for fixing a cover. They are available in single-way, two-way, three-way and four-way as well as back outlet types which can be used as per necessity in the wiring.

Fig 5

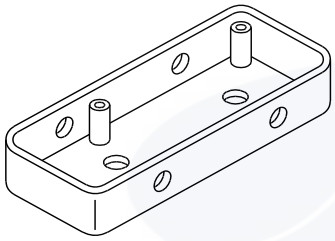


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Rectangular boxes (Fig 6): These boxes shall be provided with two machine screws of a diameter not less than 2.8 mm for fixing the cover. They can be used as a junction box or a switchboard, for fixing flush-type switches.

Apart from the above types, various other types are used as junction boxes. (Fig 7)

Fig 6

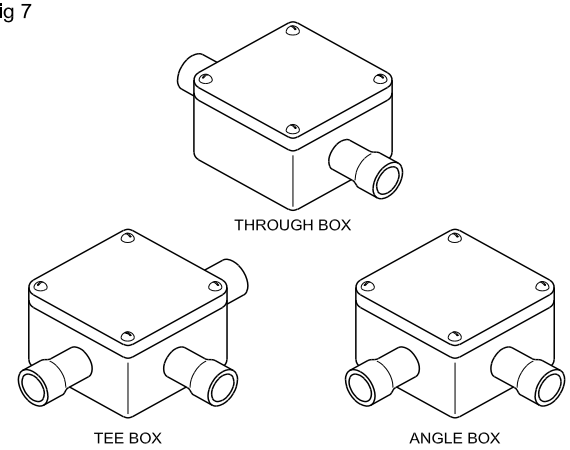


RECTANGULAR BOX

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Selection of conduit size: Non-metallic conduit pipes, used in wiring, should have a minimum size of 16 mm in diameter. Where a large number of conductors are to be drawn, the size of the diameter depends on the size of the conductor and the number of conductors.

Fig 7



TYPES OF BOXES (JUNCTION BOXES)

EL152117

Table 3 gives details of numbers and the size of conductors that can be drawn in each size of a non-metallic conduit.

Example: For selection of a PVC conduit :

When 2.5 sq mm 250V grade, single core cables of six numbers are to be drawn in a single run we can use 25 mm non-metallic conduit. (Table 3) When 6 sq mm. 250V single core 6 cables are to be drawn in a single pipe, we can use 32 mm PVC pipe. (Table 3)

TABLE 3

Size of conduit and permissible number of cables of 250 V grade

Size of cable		Size of conduit(mm)					
Nominal cross-	Number and diameter	16	19	25	32	38	51
		(Number of cables, max. in straight run)					
1.0	1/1.12 Cu	5	7	13	20	-	-
1.5	1/1.40 Al/Cu	4	6	10	14	-	-
2.5	1/1.80 Al/Cu	3	5	10	14	-	-
4	1/2.24 Al/Cu 7/0.85 Cu	2	3	6	10	14	-
6	1/2.80 Al/Cu 7/1.06 Cu	-	2	5	8	11	-
10	1/3.55 Al 7/1.40 Cu	-	-	4	7	9	-
16	7/1.70 Al/Cu	-	-	2	4	5	12
25	/2.24 Al/Cu	-	-	-	2	2	6
35	7/2.50 Al/Cu	-	-	-	-	2	5
50	7/3.00 Al 19/1.80 Al/Cu	-	-	-	-	2	3

Cu - For copper conductors only.

Al - For aluminium conductors only.

Conduit wiring - Bending Method - Cable drawing Procedure - Relevant Rules and Regulations

Objectives: At the end of this lesson you shall be able to
- **explain the bending procedure of non-metallic (PVC) conduit pipes**
- **state the method of drawing cables**
- **state the N.E. code and B.I.S. regulations pertaining to the installation of non-metallic conduit-pipe wiring systems. (Reference B.I.S. 732-1963)**

While doing the conduit wiring, it becomes essential that the length has to be increased or decreased. Further the conduit is to be bent according to the required situation.

Cutting PVC conduit: PVC conduit is easily cut using a hacksaw. Any roughness of cut and burrs should be removed with the aid of a knife blade, or sometimes, by using a reamer.

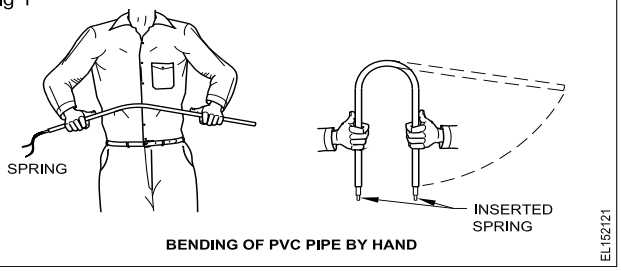
Joining conduit with fittings: The most common jointing procedure uses a PVC solvent adhesive. The adhesive should be applied to the receiving portion of the conduit fitting, and the conduit twisted into it to ensure a total coverage. Generally, the joint is solid enough for use after two minutes although complete adhesion takes several hours. In order to ensure a sound joint, the tube and fittings must be clean and free from dust and oil.

Where expansion is likely and adjustments become necessary, a mastic adhesive should be used. This is a flexible adhesive which makes a weatherproof joint, ideal for surface installations and in conditions of wide temperature variation. It is also advisable to use the mastic adhesive where there are straight runs on the surface exceeding 8 metres in length.

Conduit fittings should be best avoided, as far as possible, on outdoor systems

Cold bending PVC conduit pipes: PVC conduits, not exceeding 25 mm diameter, can be bent cold by using a correct diameter spring. The bend is then made by using either the hands or across the knee as shown in Fig 1. In order to achieve the angle required, the original bend should be made at twice the angle required and the tube allowed to return to the correct angle.

Fig 1



BENDING OF PVC PIPE BY HAND

Bending larger sizes of PVC: In cold weather it may become necessary to warm the conduit slightly at the point where the bend is required. One of the simplest ways to do this is to rub the conduit with the hand or a cloth. The PVC will retain the heat created long enough for the bend to be made. In order that the bend is maintained at the correct angle, the conduit should be saddled as quickly as possible.

Bending larger sizes of PVC: When bending larger size conduits, the conduit must be heated until it is pliable. This is best achieved by inserting it into a large steel pipe of around 100 mm diameter placed over a gas burner. The heat is applied along the whole length of the pipe, and therefore, it provides a more constant temperature to the conduit.

Rules and regulations regarding conduit wiring system with rigid non-metallic conduits as per NE code

Conduit wiring system with rigid non-metallic conduits: Rigid non-metallic conduits are used for surface-recessed and concealed conduit wiring.

Type and size: The conduit may be either threaded type or plain type and shall be used with the corresponding accessories.

Bunching of cables: Conductors of AC and DC supply shall be bunched in separate conduits. For lighting and small power outlet circuits, phase segregation in a separate circuit is recommended. The number of insulated cables that may be drawn into the conduits shall be as per Table 3.

Conduit joints: Conduits shall be joined by means of screwed or plain couplers depending on whether the conduits are screwed or plain. Where there are long runs of straight conduits, inspection-type couplers shall be provided at intervals.

Fixing of conduits: Spacing between saddles or supports is recommended to be 60 cm for rigid non-metallic conduits.

Bends in conduit: Wherever necessary, bends or diversion may be achieved by bending the conduits or by employing normal bends, inspection bends, inspection boxes, elbows or similar fittings.

Fittings: Conduit fittings shall be avoided, as far as possible on outdoor systems.

Outlets: All the outlets for fittings, switches, etc. shall be boxes of substantial construction. In order to minimise condensation or sweating inside the conduit, all outlets of conduit systems shall be properly drained and ventilated, but in such a manner as to prevent the entry of insects, etc. as far as possible.

Recessed-conduit wiring system: This system shall comply with all the requirements for surface, rigid steel conduit system.

Heat may be used to soften the conduit for bending and forming the joints in the case of plain conduits. As the material softens when heated, positioning of conduit in close proximity to hot surfaces should be avoided. Caution should be exercised in the use of this conduit in locations where the ambient temperature is 50^0C or above.

Rigid PVC conduits are not suitable for use where the normal working temperature of the conduits and fittings may exceed 55^0C. Certain types of rigid PVC conduits and their associated fittings are unsuitable for use where the ambient temperature is likely to fall below 5^0C.

Non-metallic conduit systems shall be used only where it is ensured that they are:

- suitable for extremes of ambient temperature to which they are likely to be subjected to in service
- resistant to moisture and chemical atmosphere
- resistant to low temperature and sunlight effects.

For use underground, the material shall be acceptably resistant to moisture and corrosive agents.

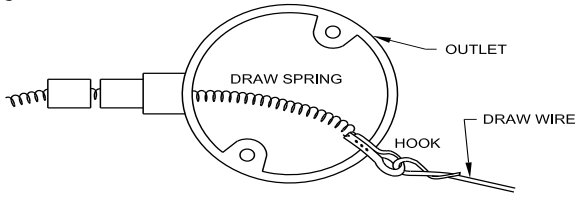
Rules and regulations for non-metallic flexible conduits: Where flexible non-metallic conduits are unavoidable, they shall be secured at intervals not exceeding 1.5 m and within 300 mm on each side of every outlet box or fitting. However, this provision is not applicable where flexible conduit is fixed and for lengths of not over 900 mm at terminals where flexibility is necessary.

Points to be followed while drawing cables through a conduit: Cables should not be drawn into a conduit system until the conduit system is complete. When drawing in cables, they must first be run off the reels or drums, or the reels must be allowed to revolve; if the cables are allowed to spiral off the reels they will become twisted, and this would cause damage to the insulation. If a large number of cables is to be drawn into a conduit system at the same time, the cable reels should be arranged on a stand or support so as to permit them to revolve freely.

In new buildings, cables should not be drawn in until the conduit is dry and free from moisture. If in doubt, a draw tape with a swab at the end should be drawn through the conduit so as to remove any moisture that may have accumulated.

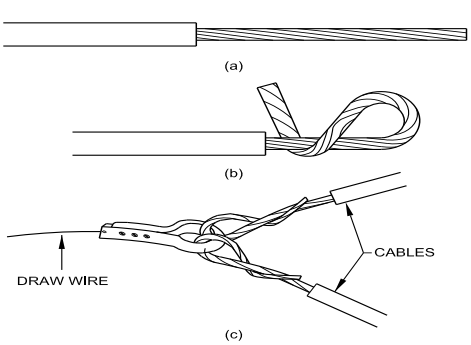
It is usual to commence drawing in cables from a mid-point in the conduit system so as to minimise the length of cable which has to be drawn. A steel tape or spring should be used from one draw-in point to another. The tape or spring should not be used for drawing in cables as it may get damaged; a steel tape or spring should only be used to pull through a draw a wire as shown in Fig 2. The ends of the cables must be bared for a distance of approximately 75 mm, and threaded through a loop in the draw wire as shown in the Fig 3.

Fig 2



METHOD OF DRAWING THE CABLE IN THE CONDUIT

Fig 3



METHOD OF FASTENING THE CABLES WITH DRAW SPRING

When drawing in a number of cables they must be fed in very carefully at the delivery end whilst someone pulls them at the receiving end. Care should be taken to feed into the conduit in such a manner as to prevent any cable crossing. Always leave some slack cable in all the draw-in boxes and make sure that cables are fed into the conduit so as not to finish up with.

This operation needs care and there must be synchornization between the person who is feeding the cable and the person who is pulling it. If in sight of each other this can be achieved by some pre-arranged signal or if within speaking distance by word of command given by the person feeding the cables. If the two persons are not within earshot, then the process is somewhat more difficult. A good plan is for the individual feeding the cables to give pre-arranged signals by tapping the conduit. If the cables are not drawn in carefully in this manner, they will almost certainly become crossed and this might result in the cables becoming jammed inside the conduit which would prevent one or more cables from being drawn out of the conduit should this become necessary at a later date.

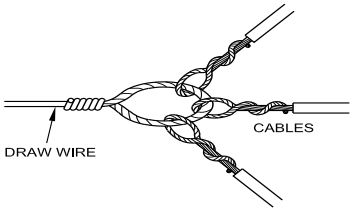
Methods of drawing cables through conduit: Pass the draw-tape or spring through the conduit between the outlets as shown in Fig 2.

Fasten a draw-wire securely to the draw-tape or spring as shown in Fig 2.

Feed the draw-wire into the conduit, withdrawing the draw-tape or spring. Ensure that the draw-wire is long enough and strong enough for the job.

Fasten the cables to the draw-wire. Atleast 75 mm (3") of the insulation should be stripped away and secured as illustrated in Figs 3 and 4. Fasten each cable separately.

Fig 4



Batten wiring - NE code and B.I.S. recommendations

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

- **state the NE code/BIS recommendations with respect to selection of cables, cable runs and accessories in batten wiring installation**
- **describe the types of clips (size, material, shape)**
- **state the B.I.S. regulation regarding spacing of clips.**

Batten wiring: Tough rubber-sheathed (T.R.S.) or PVC-sheathed cables are suitable to run on teak wood battens.

Varnishing of teak wood batten: Prior to erection, these shall be painted with one coat of varnish or an approved paint for the colour to match with the surroundings.

Method of securing the battens: These battens shall be secured to the walls and ceilings by flat-head wood screws to wood plugs at an interval not exceeding 75cm. The flat-head wood screws shall be countersunk within the wood batten and smoothed down with a file.

Suitability of tough rubber-sheathed cable: Wiring with tough rubber-sheathed cables is suitable for low voltage installation, and shall not be used in places exposed to sun and rain, nor in damp places. It may, however, be installed in the above places, provided the wires are sheathed in special protective covering to withstand dampness and other atmospheric factors.

Suitability of PVC-sheathed cable: Wiring with PVC-sheathed cables is suitable for medium voltage installation, and may be installed directly under exposed conditions of sun and rain or damp places. This system of wiring is also suitable in situations where acids and alkalies are likely to be present.

Protection of tough rubber-sheathed or PVC-sheathed wiring from mechanical damage: In cases where there are chances of any damage to the wiring, such wiring shall be covered with sheet metal protective covering, the base of which is made flush with the plaster or brickwork as required or the wiring shall be drawn through a conduit pipe.

Such protective covering shall in all cases be fitted on all down-drops within 1.5m from the floor.

Painting: If so required, the tough rubber-sheathed wiring shall, after erection, be painted with one coat of an oil-free paint or distemper of suitable colour over a coat of oil-free primer, and the PVC-sheathed wiring shall be painted with a synthetic enamel paint of a quick drying type.

Bends in wiring: The wiring shall not in any circumstances be bent so as to form a right angle but shall be rounded off at the corners to a radius not less than six times the overall diameter of the cable.

Passing through walls: Where conductors pass through walls, one of the following methods shall be employed. Care shall be taken to see to it that wires pass freely through the protective pipe or box, and that the wires pass through in a straight line without any twist or cross on either end of such holes.

Where a wall tube passes outside a building and is exposed to the weather as a result, the outer end shall be well mounted and turned downwards, and properly bushed on the open end.

Passing through floors: All cables taken through the floors shall be enclosed in an insulated, heavy gauge steel conduit extending 1.5m above the floor and flush with the ceiling below. The ends of all conduits or pipes shall be neatly bushed with porcelain or PVC or wood brushings.

Buried cables: The tough rubber-sheathed cables shall not be buried directly in plaster. Where it is specified, they may be taken in teak wood channeling or a cement chase or conduit pipe buried in the wall.

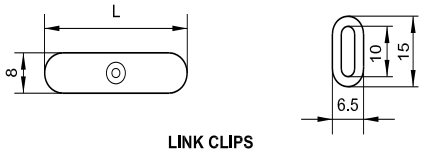
Stripping of outer covering: While cutting and stripping the outer covering of the cables, care shall be taken so that the sharp edge of the cutting instrument does not touch the rubber or PVC-sheathed insulation of the conductors. The protective outer covering of the cables shall be stripped off near the connecting terminals, and the protective covering shall be maintained as close to the end of the connecting terminals as possible and practicable. Care shall be taken to avoid hammering on the link clips with any metal instruments, after the cables are laid. Where junction-boxes are provided, they shall be made moisture-proof with a plastic compound.

Link clips: Link clips are used for firmly clipping the cables in position.

Link clips are of two types:

– Link clip which has separate linking eye. (Fig 1)
– Joint link clip which has combined linking eye.(Fig 2)

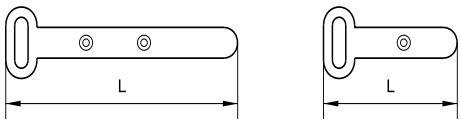
Fig 1



LINK CLIPS

EL151711

Fig 2



JOINT LINK CLIPS

EL151712

They are available in the following sizes.

25mm, 32mm, 40mm, 50mm, 63mm, 80mm, out of which up to 40mm clips have one hole, while above that they have two holes for fixing.

Joint link clips: Fig 2 shows the joint link clips. These are available in the sizes - 16 mm, 25 mm, 32 mm, 40 mm, 50 mm, 63 mm, 80 mm with a thickness of 0.32 mm and have one hole up to 40 mm, while above that they have two holes for fixing. Link clips are made of tin or brass or brass-coated tin or aluminium.

Packing: According to B.I.S. rules, link clips are packed in cardboard boxes at the rate of 100 link clips per box. If the linking eyes are a separate part, 5% excess of linking eyes are to be provided.

Fixing the link clips: Link clips shall be so arranged that one single clip shall not hold more than two twin-core TRS - or PVC-sheathed cables up to 1.5 sq. mm. Above this, a single clip shall hold a single twin-core cable. The clips shall be fixed on the varnished wood battens with any rust-resisting pins and screws and spaced at intervals of 10 cm in the case of horizontal runs, and 15 cm in the case of vertical runs. For the wiring and runs of mains exposed to heat and rain, clips specially made for outdoor use from a durable metal, resistant to weather and atmosphere corrosion, shall be used.

Method of increasing the width of the batten: In the case of additional circuits to be wired in the existing installation, the increased number of cables could be laid on new battens laid in parallel to the existing ones.

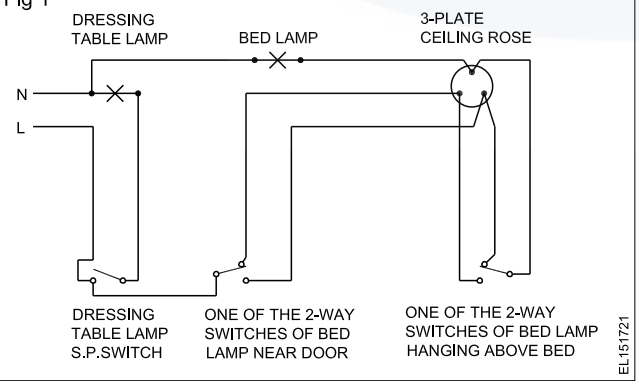
Typical lighting circuits

Objectives: At the end of this lesson you shall be able to
- **draw schematic diagrams for typical wiring circuits using special accessories.**

House wiring requirements may be as simple as one lamp controlled by one switch or may be a special requirement of controlling one lamp from two or more number of places. For example, such circuits are used for staircases, bedrooms and the corridor lighting system. The basic principle involved in such circuits, and the requirement of additional special accessories are discussed below.

Circuit No.1 - Bedroom lighting: A bedroom may require one lamp at the dressing table controlled by a switch, and one lamp just above the bed which may require dual control

Fig 1



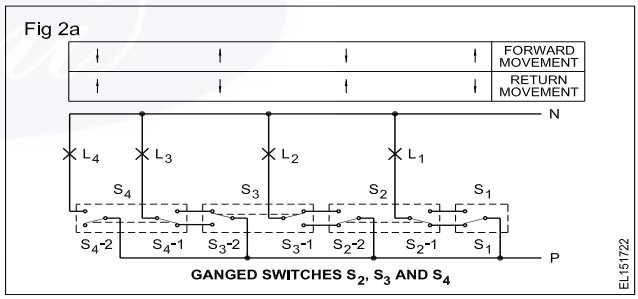
by two 2-way switches, one provided near the entrance (door) and the other provided above the bed in the form of a pendant switch hanging from a 3-plate ceiling rose. Fig 1 shows such an arrangement.

Circuit No.2 - Corridor lighting circuit: Let us consider a long corridor having 4 lamps, L1, L2, L3and L4 which are to be controlled such that as a person moves in the corridor, in either direction, he switches ON one light after the other while the lamp lighted earlier is switched off. Such an arrangement is shown in Fig 2a. Switches S2,S3 and S4 are ganged two-way switches operated by cross-bars.

According to another requirement for corridor lighting circuits, the entire set of lamps in the corridor is controlled from 4 different places in such a way that all lamps together can be switched `ON' or switched `OFF' by any one of the control switches from four different places as shown in Fig 2b.

Circuit No.3 - Series/parallel circuits: Connection of single and two way switches or special switches called

Fig 2a



GANGED SWITCHES S_2, S_3 AND S_4

Fig 2b

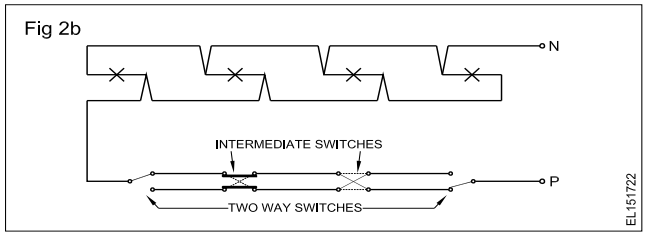
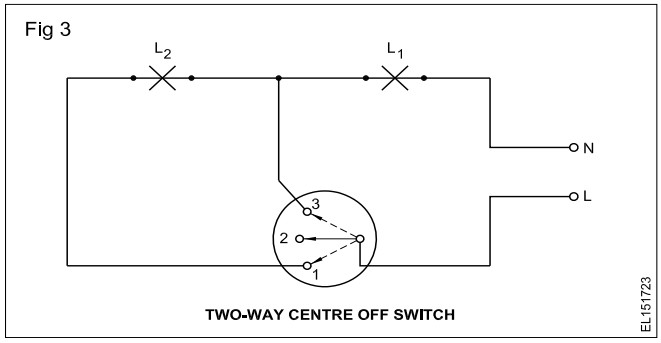


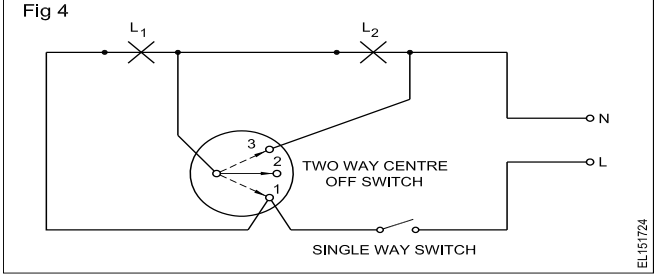
Fig 3



TWO-WAY CENTRE OFF SWITCH

two-way centre OFF switches may be used to provide bright or dim lights in the same circuit through a series or parallel connections. Such lamps are commonly found in corridors and bedrooms of hostels, hospitals, railway compartments etc.

Fig 4

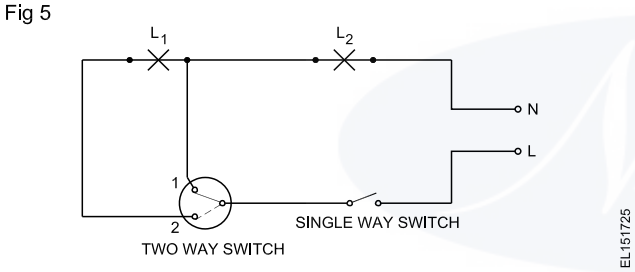


With two-way centre off switch to control one lamp bright and two lamps dim

Fig 3 shows two lamps controlled by a two-way centre off (ON/OFF and ON) switch. When the switch position is on the terminal No.3, the lamp L1 burns bright and when the switch is in position No.1, the lamps L1 and L2 are connected in series so as to give dim light. Switch position 2 indicates `OFF' position.

With one 2-way centre off switch and one 1-way switch to control two lamps independently bright or dim

Fig 5



According to the circuit shown in Fig 4, when the two-way switch is on, terminal 3, L2 is short circuited and the lamp L1 burns bright. Alternatively when the two-way switch is on terminal 1, the lamp L1 is short-circuited while the lamp L2 burns bright and when the two-way switch is on terminal 2 , both the lamps give dim light because they are in series.

With one 2-way switch and one 1-way switch to control two lamps in such a way that one lamp is bright or two lamps are dim.

Fig 5 shows such a circuit. When the single way switch is in `ON' position and the two-way switch is in position 1, then the lamp L2 burns bright and lamp L1 is off. When the two-way switch is in position 2 both the lamps are in series and burn dim.

Circuit No.4 - Master switch controls: A master switch derives its name from its function and any switch, such as a one-way or two-way switch, depending on the circuit requirement, can be used for this function. A master switch can be used as `master off', `master on' or a `variable master' control.

A master `OFF' switch is incorporated in a circuit to keep the lamps in the `OFF' position irrespective of the position of the individual switches. Further this switch prevents one from switching `ON' the lamps. Single way switches incorporated as shown in Figs 4 and 5 are examples of such controls.

Fig 6

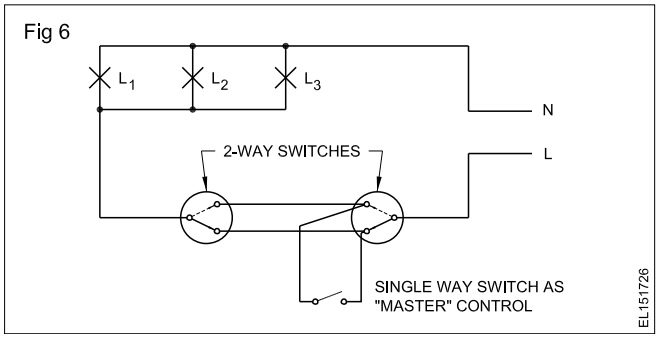
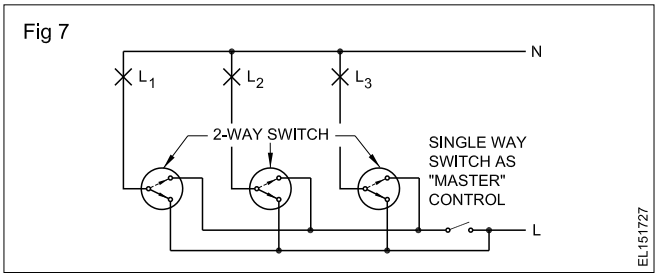
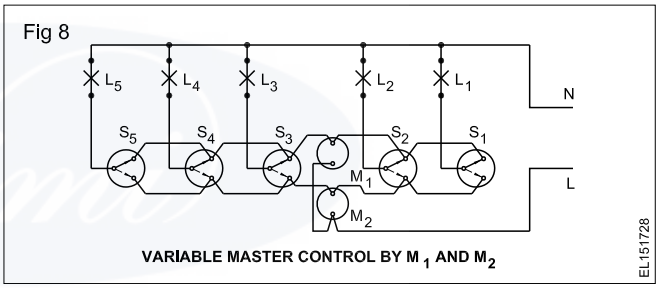


Fig 7



A master `ON' switch is incorporated in a circuit to keep the lamps in an `ON' position irrespective of the position of the individual switches. Further this switch prevents one from switching `OFF' the lamps.

Fig 8



Figs 6 and 7 show the application of a master `ON' switch, with variations in connection.

Variable master control: When master `ON' and `OFF' controls are incorporated together, the control is called variable master control. As shown in Fig 8, the lamps L1 to L5 are controlled independently by switches S1 to S5 respectively whereas two single-way switches M1 and M2 act as variable master controls. A careful study of the circuit will reveal the following conditions.

M_1OFF M_2OFF - All lamps off irrespective of their position.

M_1or M_2ON - All lamps can be individually controlled for `ON' or `OFF'.

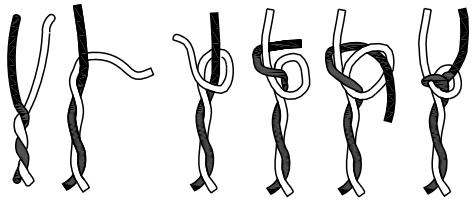
M1and M2ON - All lamps will be ON irrespective of their position.

Apart from the above there are a number of special switches available in the market to have various combinations of connections. One such switch is the manual switch. You are advised to investigate the number of terminals in such switches and the mode of connection in those switches with the help of a multimeter or Megger.

Cord grip and underwriter's knot: When a lamp or a lamp with its shade is hung from the ceiling, the flexible cable connected to the lamp-holder is subjected to mechanical stress due to the weight of the lampshade and the lamp.

If the stress is not removed, the cable connection may come out of the terminals and result in shock hazards. To relieve the strain from the terminals of the pendent, lamp

Fig 9



UNDERWRITER'S KNOT

EL151729

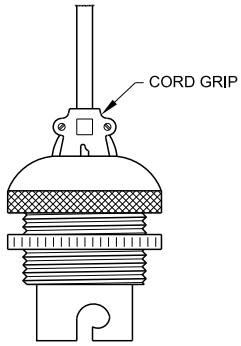
holders and ceiling roses, a cord grip or underwriter's knot is used. A cord grip or underwriter's knot is also used in pull-switches and other portable appliance connectors.

Underwriter's knot: A knot is made on twin-twisted or twin-core flexible cable inside the accessories cap cover.

The standard procedure of making this type of knot (underwriter's knot) is as shown in Fig 9.

Cord grip: In some of the electrical accessories like lamp-holders, appliance connectors, plug pin tops etc. a cord grip arrangement is provided. It is an effective means of relieving the terminals from strain due to pulling or twisting of the cord. A cord grip used in a lamp-holder is shown in Fig 10.

Fig 10



LAMP-HOLDER WITH CORD GRIP

EL151172A

Earthing domestic installation

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

- **explain the necessity of earthing of electrical devices in an installation**
- **determine the size of the earth conductor to be used in domestic installations and their protection as per B.I.S. 3043-1966**
- **explain the method of measuring the resistance of E.C.C.**
- **state the B.I.S. recommendations for earthing of domestic fittings and appliances.**

Necessity of earthing: It is essential that all electrical fittings and appliances in the house should be connected to the general mass of earth to protect the user from getting electrical shocks due to leakage or earth faults in the electrical supply.

Earth system resistance: This is the sum of the resistance of the general mass of earth and the resistance of the earth continuity conductor. (E.C.C.)

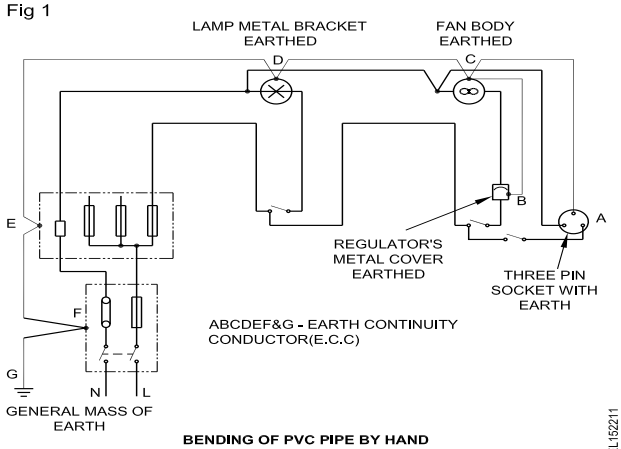
If the resistance of the general mass of earth is high it can be brought to a low value by:

- pouring water in the earth pit and keeping the pit always in a wet condition
- treating the earth pit with salt water
- increasing the length of the earth pipe below the ground
- making additional earth points and connecting them in parallel.

The resistance of the earth continuity conductor can also be lowered by using a larger area of cross-section conductor or by replacing the existing conductor with a higher conductivity metal wire of the same cross-section.

Protection by lower earth resistance: In accordance with the recommendations of B.I.S. 3043-1966, the earthing arrangement of the consumer's installation shall be such that on the occurance of a fault of negligible impedance from a phase or non-earthed conductor to adjacent exposed metal, a current corresponding to not less than three and a half times the rating of the fuse or one and a half times the setting of the overload leakage earth circuit breaker will flow (except where voltage operated earth leakage circuit breakers are used) and make the faulty circuit dead.

Fig 1



BENDING OF PVC PIPE BY HAND

EL152211

To facilitate easy flow of faulty current through the earth and thereby to blow the fuse or to activate circuit breakers, the sum of the resistance of the general mass of earth and that of the earth continuity conductor (E.C.C.) should be of such low value that the faulty current is atleast 3 times or more than the fuse rating to blow the fuses.

Let us say that the general mass of earth has a resistance (impedance) of 30 ohms and the earth continuity conductor (Route B,C,D,E and F) has a resistance of 20 ohms.(Fig 1) In case the phase wire touches the metal body of the regulator, the faulty current in a 230V supply system will be

$$= \frac{\text{Supply volts}}{\text{Earth Resistance + ECC Resistance}}$$

$$= \frac{230}{30+20} = \frac{230}{50} = 4.6 \text{ amps.}$$

If the circuit fuse is of 5 amps, this faulty current of 4.6 amps will not blow the fuse. As such, if anybody touches the regulator or fan or lamp-bracket or any other appliance connected to the 3 pin socket, he will get a shock.

Effect of high earth resistance: In the above circuit with an earth fault, the fuse may not blow at all if

- for the existing earth system resistance (50 ohms) the fuse of the circuit is 5 amps or more
- for the same fuse (5 amps) rating, the resistance of the earth system is more than, say 46 ohms.

Effect of an ineffective fuse in a faulty circuit could be stated thus.

- The earthed metal parts of switches / fans / regulators / appliances may become live and endanger the life of the user.
- Due to a higher faulty current passing through the cables, the cables may get heated up and end up in fire hazards.
- The energy meter in the installation may register a higher consumption even though the power used is less and in some cases, may even burn out.

Hence the permitted resistance `Z' (impedance) of the earth system (resistance of earth + ECC) to blow the fuse as per B.I.S.3043-1966 recommendations will be

$$Z = \frac{\text{Phase to earth voltage of system}}{\text{Minimum fusing current of fuse x Factor of safety}}$$

In the example given below, for better safety 3 times the fusing current has been enhanced to 5 as the factor of safety and the lighting circuit current is assumed to be 5 amps.

$$Z = \frac{230}{5 \times 5} = 9.2 \text{ ohms.}$$

Hence B.I.S. recommends the minimum size to be used as an earth continuity conductor in an electrical installation to be as follows.

Size of earth continuity conductor: The size of the earth continuity conductor should be co-related to the size of the current-carrying conductor in the particular circuit. That is, the size of the earth continuity conductor should not be less than half of the largest current-carrying conductor in the particular circuit, provided the minimum size of the earth continuity conductor is not less than 1.5 mm^2 for copper and 2.5 mm^2 for aluminium, which need not be greater than 70 mm^2 for copper and 120 mm^2 for aluminium as per B.I.S. 3043-1966.

As regards the size of galvanised iron and steel earth continuity conductors, they may be equal to the size of the current-carrying conductor of the circuit in which they are used.

The size of the earth continuity conductors to be used along with the aluminium current-carrying conductors should be calculated on the basis of the equivalent size of the copper current-carrying conductor.

In short we can tabulate the above information as shown in Table 1.

However, as a thumb rule and for easy reference, Table 2

TABLE 1

Sl. No.	Size of the circuit conductor in mm^2	Size of the earth continuity conductor		
		Copper in mm^2	Aluminium in mm^2	Steel/GI in mm^2
1	Copper of 1.5	1.5	2.5	1.5
2	Copper of 2.5	1.5	2.5	1.5
3	Copper of 10	5	5	10

is given, in which the selection of the size of the earth continuity conductor is based on the current passing through the circuit.

Method of measuring the resistance of E.C.C.: Normally

TABLE 2

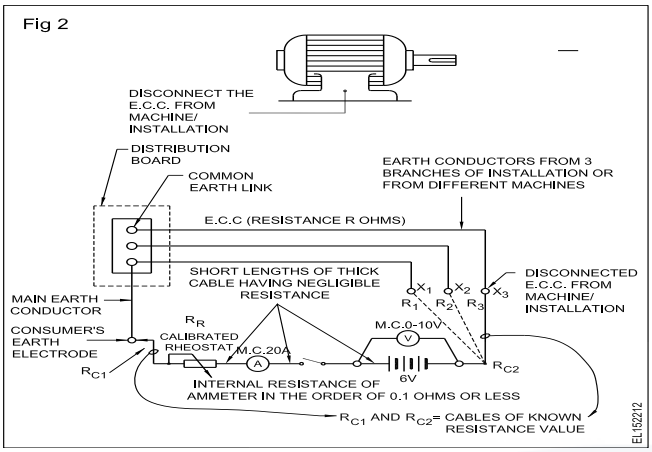
Maximum circuit current (Amperes)	Copper earth conductor size in SWG
15	No. 14
20	No. 12
30 - 60	No. 10
100	No. 8

the resistance of the earth continuity conductor used in a domestic installation is recommended to be less than one ohm. While using the above table, the length of E.C. C. used according to various points in an installation should be taken into consideration such that the resistance of E.C.C. is not higher than one ohm. In case the resistance is more than one ohm, it is advisable to use the next larger size of the same conductor material or to use a conductor of the same size but having better conductivity.

The method of measuring the resistance of an earth continuity conductor (ECC) is given below.

Fig 2 shows the details of connection to be made for the measurement of the resistance of E.C.C.

First switch `off' the power supply to the installation/ machine, and disconnect the earth continuity conductor from the earth point of the apparatus/equipment/installation/machines. Connect the secondary battery 6V to the end of the earth continuity conductor X3 as shown in Fig 2, and connect the other side of the battery through a switch, low internal resistance ammeter and a calibrated rheostat with the help of cables having a known resistance. Instead of 6V battery supply for test voltage, a voltage lower than 40V 50 Hz AC or 40V DC supply could be used.



The current to be tested may be 1.5 times the main current of the installation/machine under test but need not exceed 25 amps.

The supply is to be switched `on' and the reading has to be recorded in Table 3, and then the resistance of the E.C.C. has to be calculated.

Normally the measured value of ECC should not exceed one ohm. If the measured value of resistance is infinity, it shows that the E.C.C. is open. If the value is more than one ohm, it indicates that the E.C.C. is having high resistance and needs replacement with a higher conductivity conductor of the same size or replacement with a larger diameter conductor of the same material.

Protection of earth wires (Earth continuity conductors) B.I.S. 3043-1926

Earth wires shall be protected against mechanical damage and possibility of corrosion, particularly at the point of connection to earth electrode or earth-continuity conductor.

The connection of the earth wire to the earth-electrode or earth continuity conductor shall be readily accessible, and soundly made by the use of soldered joints or substantial clamps of non-ferrous material.

All joints shall be made on tinned surfaces.

Earthing of domestic fittings and appliances (B.I.S. 3043-1966)

Earthing of domestic appliances arises in case they have only functional insulation. Appliances having reinforced or double insulation need not be earthed.

Plugs and sockets: All plugs and sockets shall be of three-pin type, one of the pins being connected to earth.

Lighting fittings: If the bracket type lamp-holders are of metallic construction, it is recommended that they should be earthed. All pedestal lamp fittings of metallic construction shall also be earthed.

Fans and regulators: Bodies of all table fans, pedestal fans, exhaust fans, etc. shall be earthed by the use of three-pin plugs. The covers of the regulators, if of metallic construction, shall be earthed by means of a separate earth wire.

Cooking ranges: Bodies of hot plates, kettles, toasters, heaters, ovens and water heaters shall all be earthed by the use of three- pin plugs.

Bathroom: The body of automotic electric water heaters shall be earthed by the use of a three-pin plug or by a separate earth wire, if fixed wiring has been done. All non-electrical metal works including the bath-tub, metal pipes, sinks and tanks shall be bonded together and earthed.

Radio sets: From the point of view of good reception it is recommended that radio sets should be earthed through an electrode different from that of the main earth system meant for other electrical appliances. However, if it is not possible to have a separate earth electrode, radio sets may be earthed through the main earth system.

Electric irons and room air-conditioners: Refrigerators, air-conditioners and coolers, electric radiators, electric irons, etc. shall all be earthed by the use of three-pin plugs.

TABLE 3

Sl.No	Voltmeter reading	Ammeter reading	Total resistance R_T in ohms	Resistance value of rheostat R_R in ohms	Resistance value of cable R_C in ohms $Rc = RC_1 + RC_2$	Resistance of $E_{cc} = R_T-(R_R+R_C)$

Test board and colour code of cables

Objectives: At the end of this lesson you shall be able to
- **explain the method of using a test board**
- **state the general colour codes used in cables.**

Test board: A test board is used for conducting the following tests.

- **Continuity test** (Load connected in series with a lamp) ***Ex:*** Testing fan winding, condition of choke and tube light starter etc.
- **Direct test** ***Ex*** Testing electrical appliances of 1000 watts or lower rating for proper functioning.

The schematic diagram of connection of a testing board is shown in Fig 1 with all the outlets and controls. Sockets P_1 and P_2 provide direct, single-phase supply whereas socket P_3 and terminal block T provide a single-phase supply in series with the lamp L_3.

Continuity test: While performing a continuity test, the appliance to be tested is connected to the socket P_3 or to the terminal T which are in series with the lamp L_3 and are controlled by switch S_3. Normally this test is conducted by the electrician to ascertain whether the appliance is open-circuited or short-circuited. A low wattage, appliance when connected, will make the lamp L_3 to burn dim, and a high wattage appliance will make the lamp to burn bright. According to the brightness of the lamp, the behaviour of the appliance, as well as the wattage of the appliance and the lamp and the condition of the appliance could be judged. `No light' indicates either open circuit or high resistance in the appliance. In the same way, a choke coil and a starter of a tube light can be checked. (The flickering of the lamp L_3 with the starter indicates that the starter is good.)

Thus the testing board also works as a continuity tester.

Direct testing: By connecting the appliance direct to the socket P_1 or P_2, the performance of the appliance can be verified after repair.

Fuses: If the indicator lamp L_1 does not burn, it indicates no supply. On the other hand, in normal conditions, the indicator lamp L_2 will not burn, and it burns only when the fuse F_2 is open.

Thus the test board is a cheap and handy test set which is easy to use by an electrician to carry out his routine checks in the course of his work.

Colour identification of cables: The colour of the cables indicates their function. Every electrician should be able to identify the colour code used in electrical work and follow it meticulously to avoid hazards. Table 1 gives the colour code and the alpha-numeric notation as recommended by N.E.Code.

For purposes of the N.E. code, the provisions of Table 1 shall apply for the general application of marking conductors in installation. The rules also apply for marking conductors in equipment/apparatus.

Fig 1

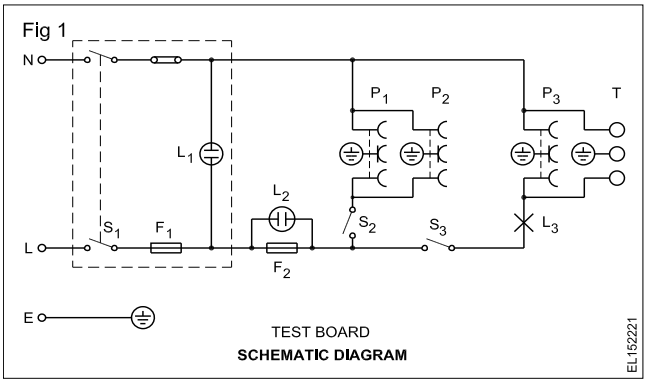


TABLE 1
Alpha-numeric notation and colours

Designation of conductors		Identification by	
		Alpha-numeric notation	Colour
Supply AC system	Phase 1	L1	Red
	Phase 2	L2	Yellow
	Phase 3	L3	Blue
	Neutral	N	Black
Apparatus AC system	Phase 1	U	Red
	Phase 2	V	Yellow
	Phase 3	W	Blue
	Neutral	N	Black
Supply DC system	Positive	L+	Red
	Negative	L-	Blue
	Mid-wire	M	Black
Supply AC system (Single phase)	Phase	L	Red
	Neutral	N	Black
Protective Earth conductor		PE	Green and yellow
Earth		E	No colour other than the colour of the bare conductor.

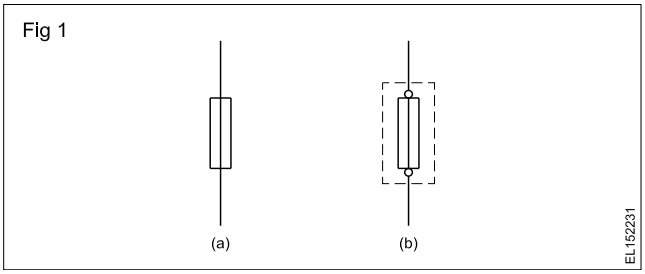
Fuses

Objectives: At the end of this lesson you shall be able to
- **explain the purpose of the fuse in a circuit**
- **classify the different types of fuses and their uses.**

Purpose of fuses: A fuse is a safety device used for the purpose of protecting a circuit against excess current. In the event of excessive current, the fuse element melts and opens up the circuit thereby protecting it from damage.

Symbols: These are the graphical symbols used to illustrate an electrical fuse in electro-technical diagrams.

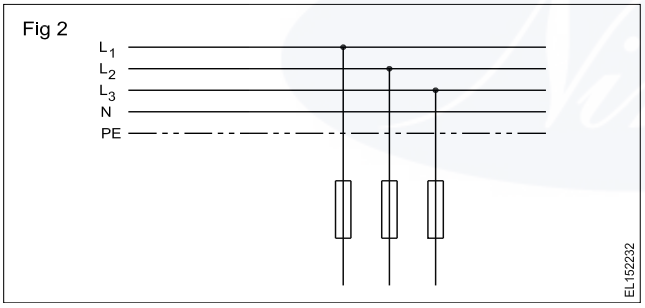
Fig 1



– General symbols of a fuse (Fig 1a)
– Fuse with terminals and protective housing (Fig 1b)

Placement of fuses: In electrical installations, the fuses are always connected into the live wires (L_1, L_2, and L_3 as shown in Fig 2) and never into the neutral N or the protective earth line PE.

Fig 2



Terminology

Fuse element: The part of the fuse which is designed to melt and open up a circuit.

Fuse-carrier: The removable portion for carrying the fuse element.

Fuse base: The fixed part of the fuse provided with terminals for connection to the circuit which is suitable for the reception of the fuse- carrier.

Current rating: Safe maximum current that can pass continuously without overheating.

Fusing current: The current at which the fuse element melts.

Cut-off factor: Time (period) taken by a fuse to interrupt the circuit in the event of a fault.

Fusing factor: Ratio between minimum fusing current and current rating.

$$\text{Fusing factor} = \frac{\text{Minimum fusing current}}{\text{Rated current}}$$

The fusing factor for a re-wirable fuse varies between 1.4 to 1.7 and may go up to 2.0, but for a HRC fuse it is 1.1

However, a fuse selected for over-current protection should not have a fusing factor of more than 1.4.

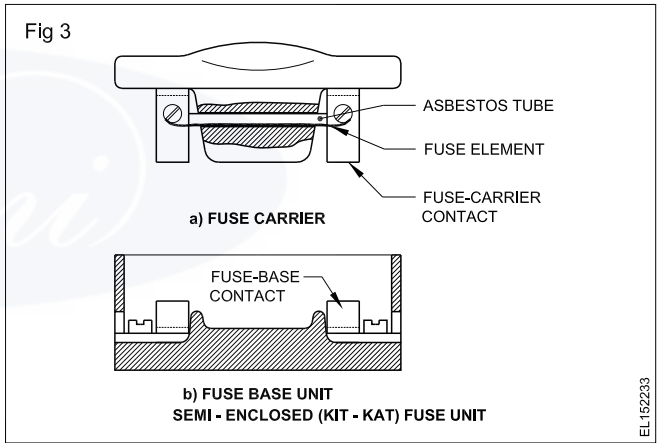
Types of fuses used in domestic wiring:

– Re-wirable type (up to 200A)
– Cartridge type (up to 1250A)

Rewirable type fuse (Fig 3): The fuse element in this type of fuse consists of a wire which may be replaced when necessary. These fuses are simple in construction and the initial cost as well as the renewal cost is very low.

The fuse elements used in this type are tinned copper wire, lead and tin alloy. Approximate sizes of fuse elements of

Fig 3



tinned copper wire or aluminium wire for use in semi-enclosed fuses are shown in Table 1.

The fuse element will melt after approximately 2 minutes when carrying a current equal to twice the current rating. However, the cut-off time factor varies in rewirable fuses due to:

- the construction of the carrier (design of fuse-carrier/ base)
- the manner in which the fuse wire has been fitted
- the length of time the fuse was in service
- ambient temperature
- the amount of current etc.

Small fuse wires in parallel in a carrier to carry a large current should be avoided, as far as possible. The actual rating becomes less than the sum of the ratings of the individual strands. A paralleling factor of 0.7 to 0.8 is used to multiply the sum of the rating of individual strands to get the actual current rating.

TABLE 1

Current rating for	Approximate fusing current Amp.	Tinned copper wire		Aluminium wire dia. in mm
		S.W.G.	Diameter in mm	
1.5	3	40	.12192	--
2.5	4	39	.13208	--
3.0	5	38	.1524	.195
4.0	6	37	.17272	--
5.0	8	35	.21336	--
5.5	9	34	.23368	--
6.0	10	33	.254	.307
7.0	11	32	.27432	--
8.0	12	31	.29464	--
8.5	13	30	.31496	--
9.5	15	--	----	.400
10.0	16	29	.34544	--
12.0	18	28	.37592	--
13.0	20	--	----	.475
13.5	25	--	----	.560
14.0	28	26	.4572	--
15.0	30	25	.508	.630
17.0	33	24	.5588	--
18.0	35	--	----	.710
20.0	38	23	.6096	--
21.0	40	--	----	--
22.0	45	--	----	.750
24.0	48	22	.7112	.850
25.0	50	--	----	.90
29.0	58	21	.8128	--
30.0	60	--	----	1.00
34.0	70	20	.9144	1.22
37.5	80	--	----	1.25
38.0	81	19	1.016	--
40.0	90	--	----	1.32
43.0	98	--	1.1176	--
43.5	100	--	----	1.40
45.0	106	18	1.2192	--
55.0	120	--	----	1.60
62.0	130	--	----	1.70
65.0	135	17	1.4224	--
66.0	140	--	----	1.80
69.0	150	--	----	1.85
73.0	166	16	1.6256	--
75.0	175	--	---	2.06
78.0	197	15	1.8288	--
80.0	200	--	----	2.24
102.0	230	14	2.032	--
130.0	295	13	2.3368	--

Example: 35 SWG - copper wire has a fuse rating of 5 amps, and 3 strands in parallel together will a have current rating equal to 5x3x0.8=12 amps when 0.8 is taken as the paralleling factor.

Disadvantages of rewirable type fuse:

- Deterioration of the fuse element by oxidation due to heating.
- Lack of discrimination.
- Effected by the fluctuation of the ambient temperature.
- Premature failure due to deterioration under normal load.
- Low speed operation (poor cut-off factor)
- External flash or arc on blowing.
- Poor rupturing capacity (under short-circuit condition).
- Wrong rating possible by human error.

Rewirable-type fuses up to 16A rated current should not be used in locations where short circuit level exceeds 2 KA, and those of higher ratings in locations where the S.C. level exceeds 4 KA. (I.S. 2086-963)

Cartridge fuses: Cartridge fuses are developed to overcome the disadvantages of the rewirable fuses. Due to high temperature, prolonged use and oxidation, rewirable fuses deteriorate and interrupt the supply even when carrying normal current. As cartridge fuse elements are enclosed in an air tight chamber, deterioration does not take place. Further the rating of a cartridge fuse could be accurately determined from its marking. However, the cost of replacement of cartridge fuses is more than that of rewirable fuses.

Cartridge fuses can be grouped as those with a:

- low rupturing capacity (Say rupturing capacity up to 50 KA.)
- high rupturing capacity. (Say rupturing capacity above 80 KA.)

Rupturing capacity is the ability of a fuse to open the faulty circuit without much arcing or damage to itself. For domestic installations, low rupturing capacity fuses are used whereas for high power factory installations, and for installations connected from high power sources, high rupturing capacity (HRC) fuses are used.

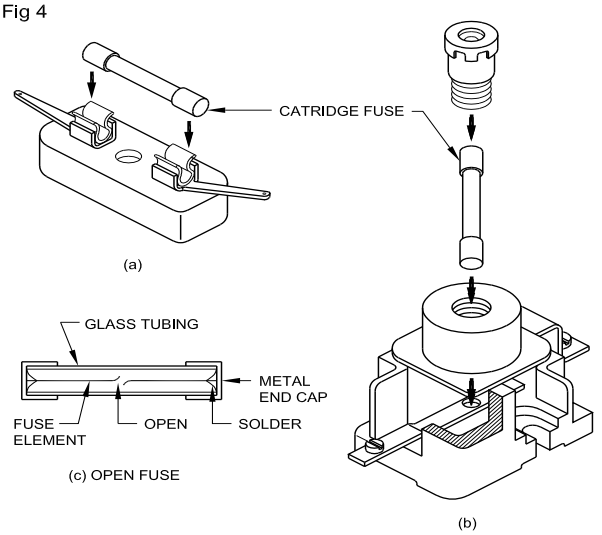
Low rupturing capacity cartridge fuses can be further divided into:

- Ferrule-contact cartridge fuses.(Fig 4)
- diazed screw-type cartridge fuses.(Fig 5)

Ferrule-contact cartridge fuses: This type, shown in Fig 4, is used for protecting electrical and electronic circuits. These are available in 25, 50, 100, 200, 250, 500 milliamperes, and also in 1,2,5,6,10,16 & 32 amperes capacity. Normally the current rating is written on one side of the cap, and while replacing, the same capacity fuse should be used. Its body is made of glass and the fuse wire is connected between two metallic caps.

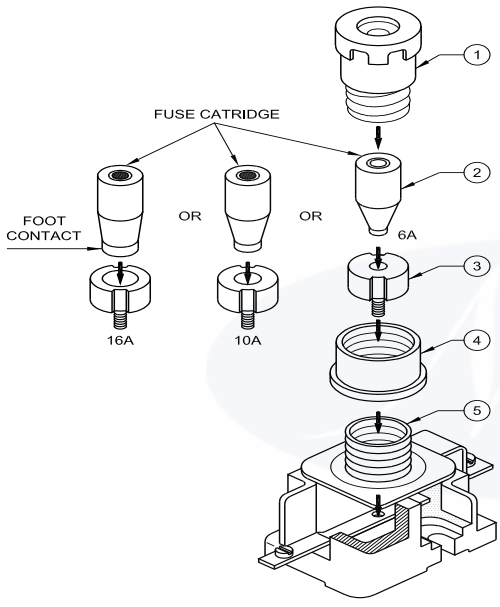
This fuse can be plugged into the fuse socket as shown in Fig 4a or it can be fitted into a fuse base with a screw, in a fuse- holder of the type shown in Fig 4b.

Fig 4



FERRULE - CONTACT CATRIDGE FUSE UNIT

Fig 5



DIAZED SCREW TYPE CATRIDGE FUSE UNIT

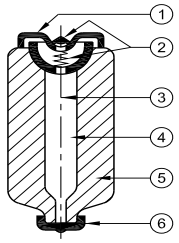
Diazed screw-type cartridge fuses: This is shown in Fig 5. It is also not of a rewirable type. This type of fuse is commonly used in domestic and industrical electrical installations in many countries. It consists of the following parts as shown in Fig 5.

- Screw cap or fuse cartridge-holder(1)
- Fuse cartridge(2)
- Fitting screw or contact screw(3)
- Protective plastic or ceramic ring(4)
- Fuse base or fuse socket(5)

Fuse cartridges are available for rated electric currents of: 2-4-6-10-16-20-25-35-50 and 63 amperes. To prevent the insertion of a fuse cartridge having a larger current rating than intended, the foot contacts of the fuse cartridges have different diameters for each rated current(the smaller the current the smaller the diameter of the foot contact). As there is also a separate fitting screw for each type of cartridge, it is not possible to insert, let's say, a 35 amp. fuse cartridge into the fitting screw of a 25 amp fuse cartridge.

Fig 6 shows the inside of one of the afore-mentioned fuse cartridges. It shows the ceramic body of the cartridge with its foot and head contacts. The two contacts are linked by a fuse wire which is embedded in sand. Each cartridge has a break indicator which will be ejected from the cartridge if the fuse wire is burnt out. The parts of this cartridge, shown in Fig 6, are:

Fig 6

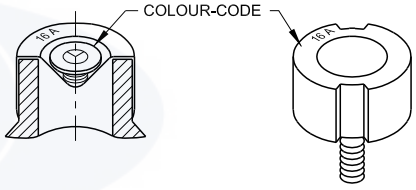


FUSE CATRIDGE

- head contact(1)
- break indicator(2)
- fuse wire(3)
- sand filling(4)
- ceramic fuse body(5)
- foot contact. (6)

For easy identification of the fuse cartridges and the corresponding fitting screws, they are marked with various colours at the places shown in Fig 7. For each current rating, a different colour is used.

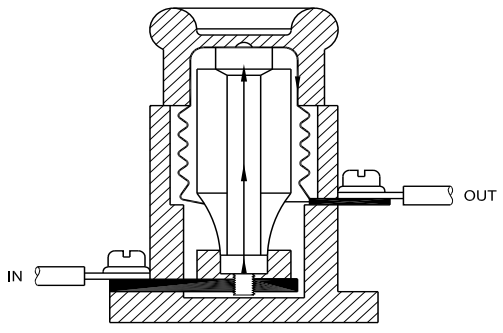
Fig 7



Pink	- 2 amperes	Blue	- 20 amperes
Brown	- 4 amperes	Yellow	- 25 amperes
Green	- 6 amperes	Black	- 35 amperes
Red	- 10 amperes	White	- 50 amperes
Grey	- 16 amperes	Copper	- 63 amperes

Fig 8 shows the flow of the electric current through the fuse base and the fuse. In order to prevent the accidental touching of a live line, the electrical supply must be connected to the terminal which is connected to the fixing screw at the bottom of the base.

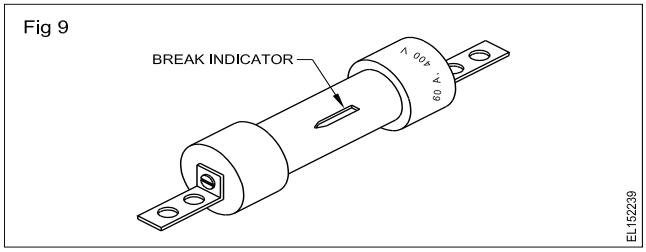
Fig 8



Diazed type fuses are available in two categories, a) quick-response type and b) delayed-action type. The quick-response type is used for heating circuits and normal loads whereas the delayed- action type is used for motor circuits and highly inductive circuits.

High rupturing capacity fuses (Fig 9): They are cylindrical in shape and are made of a ceramic body filled in with a chemically treated filling powder or silica to quench the arcing quickly without any fire hazard.

Fig 9



Normally a silver alloy is used as the fusing element and when it melts due to the excessive current, it combines with the surrounded sand/powder, and forms small globules without making an arc, spark or gas. HRC fuses can open a short-circuited circuit within 0.013 second. It has an indicator to show the fuse has blown. The rupturing capacity of the fuse could be calculated from the following formula.

$$\text{Rupturing capacity in MVA} = \frac{\text{Fault current in amperes} \times \text{Circuit voltage}}{10^6}$$

As HRC fuses are capable of opening circuits having very high faulty currents, these are preferred in high power circuits even though the replacement cost is high.

COMPARISON BETWEEN H.R.C. & REWIRABLE FUSES

	Rewirable	HRC fuse
Rupturing capacity	Not recommended for currents exceeding 200 A or for more than	Normal types cater to fault loads up to 600V or where
there	2500 KVA. For is a possibility of S.C. fault of more than 5 MVA.	certain applitions, fuses up to 50 MVA are obtainable.
Rupturing speed(Cut-off factor)	Rating and cut-off are not absolutely reliable.	Very rapid. Usually AC supply current is cut off within the first half cycle.
Discrimination	Poor.	Accurate.
Safety in operation	Risk of flash-over under heavy fault condition.	No external flame.
Deterioration	Oxidation and consequent scaling causes reduction in the cross-sectional area, thus increasing resistance, and leading to over-heating and premature rupturing.	No oxidation is the element is completely sealed.
Fusing factor	Copper wire upto 20A 1.7 over20A 2.0.	As low as 1.1.

Prepare electrical layout and wire up for a building

Objectives: At the end of this lesson you shall be able to
- **state the use of channel wiring system**
- **state the limitations of channel wiring system**
- **select the channel size according to size and number of cables from the chart**
- **state the rules regarding the installation of channels, floor/wall crossings and joints**
- **explain the method of fabricating neutral, bend, junction and double set in a metal channel system**
- **state the method of drawing cables and maintaining earth continuity in channel wiring system.**

Introduction : Channel (Casing and Capping) wiring is a system of wiring in which PVC/metallic channels with covers are used for drawing wires. This system of wiring is suitable for indoor surface wiring works. This system is adopted to give a good appearance and for extension of existing wiring installation. PVC insulated cables are generally used for wiring in casing and capping system. This is otherwise called 'wireways'.

The channel and top cover shall be of the same material either PVC or anodised aluminium. The casing is square or rectangular in shape. The capping shall be slide in type with double grooving in the case of PVC wire ways. Plain type capping are used for metallic wireways.

The only disadvantage in a channel wiring is that it is inflammable and risk of fire.

Channel (casing & capping) wireways should not be used.

In residential buildings or such buildings were there is a risk of tampering where ambient temperature exceeds 60°C or less than 5°C in areas exposed to sunlight.

Dimensions : The sizes of channel, the maximum number of wires which can be drawn in each size are given in the table 1 below.

The thickness of channel should be 1.2mm ± 0.1mm.

TABLE 1

Nominal cross sectional area of conductor in sq.mm	10/15mm x 10mm size channel	20mm x 10mm size channel	25mm x 10mm size channel	30mm x 10mm size channel	40mm x 20mm size channel	50mm x 20mm size channel
	No. of wires	No. of wires	No. of wires	No. of wires	No. of wires	No. of wires
1.5	3	5	6	8	12	18
2.5	2	4	5	6	9	15
4	2	3	4	5	8	12
6	-	2	3	4	6	9
10	-	1	2	3	5	8
16	-	-	1	2	4	6
25	-	-	-	1	3	5
35	-	-	-	-	2	4
50	-	-	-	-	1	3
70	-	-	-	-	1	2

Precautions

1 Neutral (Negative) cables should be carried in top channel and phase (Positive) in the bottom channel.

2 Crossing of cables between phase (Positive) and neutral (Negative) should be avoided.

3 Porcelain or PVC pipe should be used for crossing the cables through the walls.

Installation of PVC/Metal channel : The channel should be fixed to wall/ceiling with flat headed screws and rawl plugs. These screws shall be fixed at an interval of 60cm. On either side of joints this distance shall not exceed 15cm from the end point. Channel under steel joints shall be fixed with MS clips of not less than 1.2mm (18SWG) thickness and width not less than 19mm.

Floor/Wall crossings : When conductor pass through floors/wall the same should be carried in a steel conduit/ PVC conduits properly bushed at both ends. The conduits shall be carried 20cm above floor level and 2.5cm below ceiling level and properly terminated into the channel.

Joints in PVC/Metal channel : As far as possible wireways in straight runs should be single piece. All joints shall be scarfed or cut diagonally in longitudinal section. The section ends shall be filed smoothly but join without any gap is made. Care shall be taken to see that the joints in metal/PVC cover does not overlap those channel.

Joints shall also be done using standard accessories like elbows, tees, 3 ways/4 ways junction box etc of high grade PVC/Aluminium alloy. In PVC channel separate channel cover for joint, elbows, tees, cross etc are available. These can be fixed after fixing the channel to give a good appearance. The radius of curvature of the cables inside a bend should be more than 6 times its over all diameter.

In the case of PVC channel making joints is comparatively easy. Mark the joints by placing the two pieces in required angle. Identify the position to be cut and remove on each pieces. Cut through the lines and file the edges to get gapless joint.

Joint in metal channel : Joint in metal channel is made by the sections to required angles and then joining by rivetting, welding or with connecting with nuts and bolts.

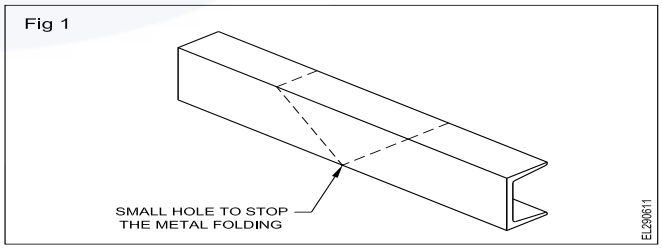
Fabricating a right-angled vertical bend

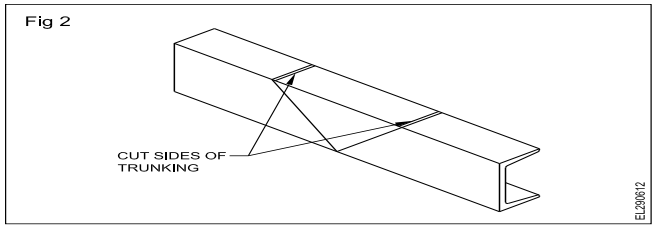
1 Mark out the position of bend of all sides as shown in Fig 1. the width 'Y' must be made equal to the diagonal length 'Y' to be cut.

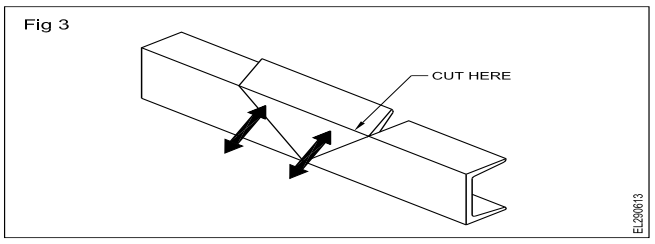
2 Drill small holes in corners at point of bend to stop metal folding. (Fig 1)

3 Place wood blocks inside trunking for support. Cut sides of trunking as shown in Fig 2.

4 Cut, file and break-off waste as shown in Fig 3.



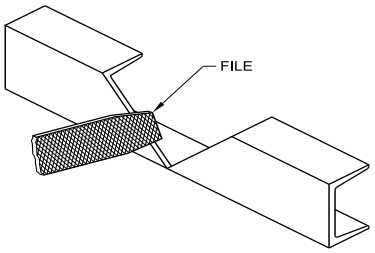




5 File all the edges smooth in order to bend to shape. (Fig 4)

6 Make fish plates out of scrap and drill for fixing holes. (Fig 5)

Fig 4

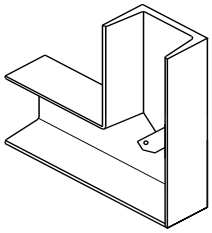


7 Mark out the trunking from fish plates and drill in the block.
8 Secure assembly with nuts and bolts or rivets. (Fig 6) Alternatively joints may be spot-welded.

Fig 5



Fig 6



Fabricating 90° bend

1 Mark out the position of bend as shown in Fig 7a & b.
2 Place wood blocks in trunking for support and make cuts with hacksaw.
3 Remove sections and file smoothly.
4 Bend shape and adjust the fit as required in Fig 8a, b & c.
5 Make fish plates from scrap and drill the holes (Fig 9b). Mark out trunking to take fish plates and drill holes.

Fig 7

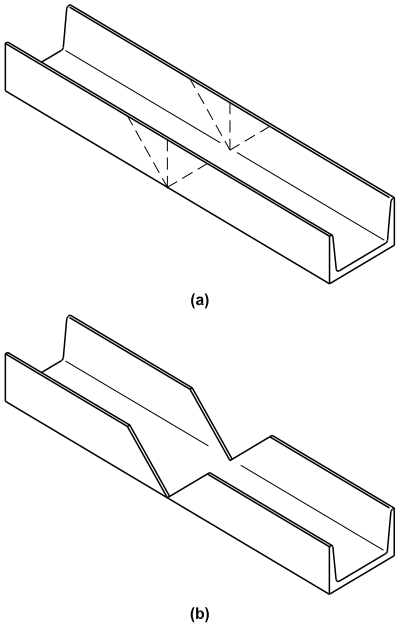
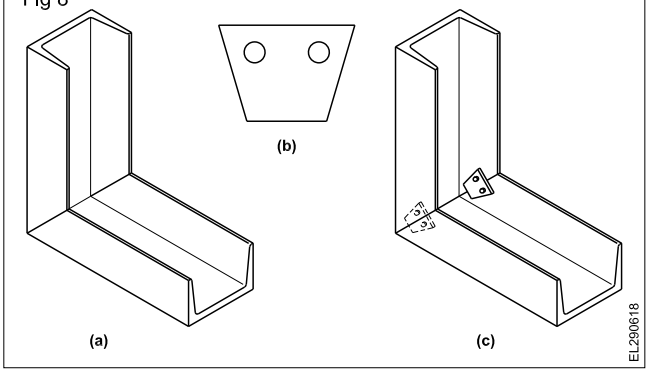


Fig 8

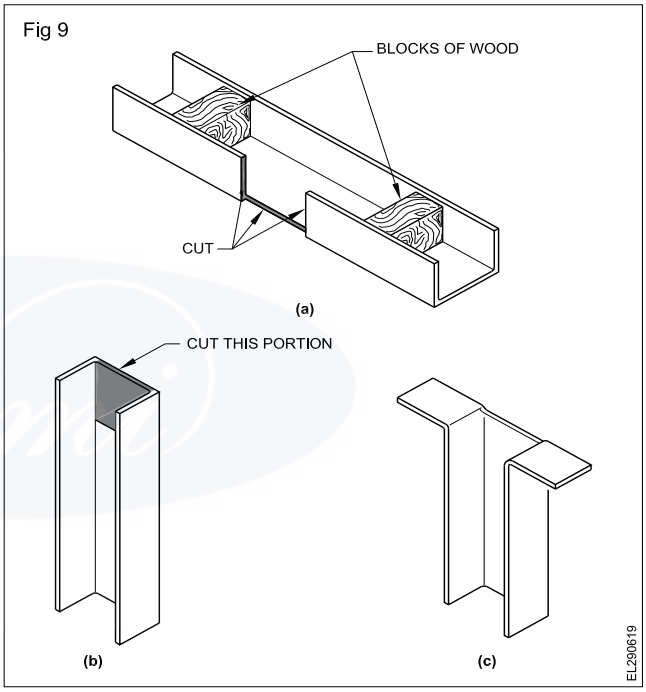


6 Secure assembly with nuts and bolts or rivets (Fig 9). Alternatively joints can be spot welded.

Fabricating a Tee junction

1 Mark out the position of tee using another piece of trunking to gauge width

Fig 9

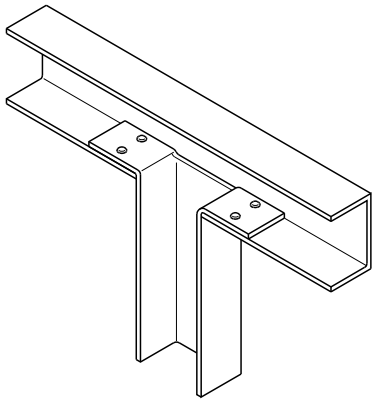


2 Cut out the space for the tee, as shown in Fig 9a. Blocks of wood should be used to support section being cut.
3 In another piece cut away the section as shown in Fig 9b to form two legs. Bend in vice as shown in Fig 9c.
4 File edges smooth and remove burrs. Check fit and adjust as necessary.
5 Mark out for holes, drill and secure with nuts and bolts or rivets or (Fig 10) may be spot-welded.

Fabricating a double set

1 Mark the position of first set as shown in Fig 11 and the angle of set required.
2 Place blocks of wood in trunking for support and make cuts with hacksaw.
3 Remove section of trunking and file the edges. (Fig 12)

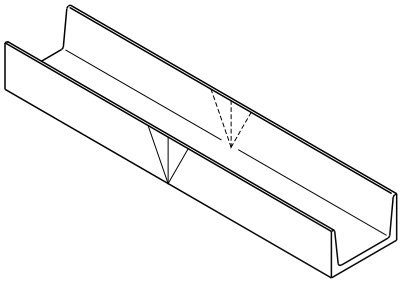
Fig 10



ASSEMBLEDTEE JUNCTION

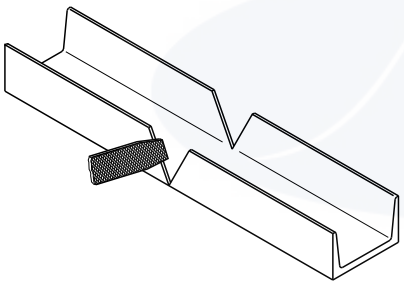
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Fig 11



EL29061B

Fig 12

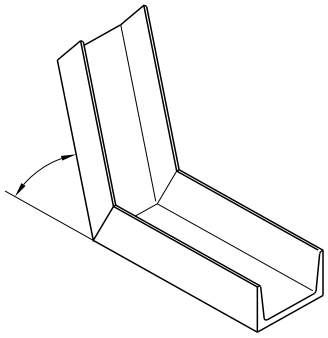


EL29061C

4 Bend into shape as shown in Fig 13. Adjust the fitting.

5 Make fish plates from scrap materials as shown in Fig 14. Drill the holes and fit with nuts and bolts or rivets, may be spot-welded.

Fig 13



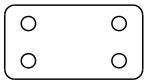
BEND IN TO SHAPE

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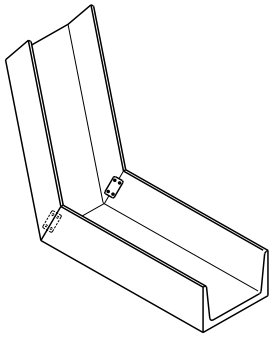
6 To complete the offset, mark out the position of the second set, and cut along centre lines. Take care to see that angles are complementary and the sections lie parallel.

7 Make fish plates from scrap material and fit into the earlier set as shown in Fig 15.

Fig 14



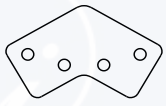
FISHPLATE



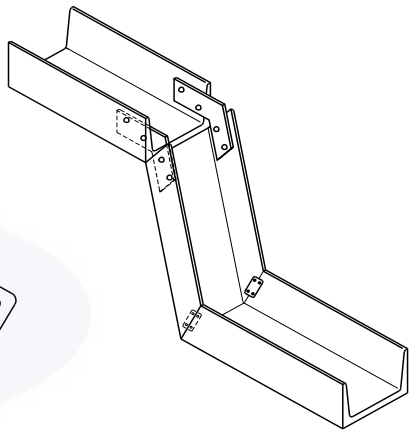
FIXING WITH FISHPLATE

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Fig 15



FISHPLATE



FULL SETTING

EL29061F

Installation of cables : Cables carrying direct current or alternate current shall always be bunched so that the outgoing and return cables are drawn in the same channel. Clamps shall be provided to hold the wires inside the channel at suitable intervals, so at the time of opening of the cover of channel, the wires do not fall out.

Attachment of cover : Cover should be attached to channel in individual sections after drawing all wires inside. No screws or nails shall be used for fixing PVC capping (cover) to the casing (channel). The capping (cover) should be slided in through the grooves. Metallic capping (cover) shall be fixed by using cadmium plated screws in a staggered manner with axial spacing not exceeding 30cm.

Earth continuity conductor : Earth continuity conductor shall be drawn inside the casing and capping (channel) for earthing of all metallic boxes of the installation as well as for connecting to earthpin of the socket.

In case of metallic casing and capping channel, there shall be a metallic link between adjacent casing with screw connections, and also connections from end channel (casing) to earth terminal of metallic boxes/outlets.

Heating appliances

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

- **list the names of appliances working on the heating effect of electric current**
- **state the factors on which heating in such appliance depends**
- **name the common materials used for the heating element**
- **state the normal temperature range of heating appliances**
- **state how a fuse functions as a protective device.**

Heat is produced by electricity when current flows through resistance. This heat-producing effect of electricity is utilized in heating appliances such as heater, iron, hot-plate, kettle, toaster etc.

In heat-producing appliances, instead of using a good conductor for the heating element, we use a wire that is made of a poor conducting material. The current, which flows through the high-resistance heating element of the appliance, produces the heat that is desired.

These materials must be able to withstand high temperatures without damage. The resistance must be constant over a wide temperature range, and expansion due to heat must be held to a minimum to prevent sagging and consequent short circuiting.

Alloys, however, are almost always used in heating elements. For heating elements that are surrounded by air and where temperatures in excess of 1035^{o}C are not required, a composition of chromium and nickel has been found to be the most durable resistor. Nickle-chromium resistors, when operated within their designed temperature limits, will last for years without any noticeable deterioration. The other materials used as heating element are Eureka and Kanthal.

Factors on which heating in appliances depends

- Current flow in the heating element.
- Resistance of the element.
- Time duration of heating.
- Ventilation i.e. cooling rate due to drought.
- Proximity (of element turns with each other)
- Shape of the element. (circular wire or ribbon).

All heating appliances do not work at the same temperature. If an electric kettle is operated without water the life of the heating element reduces considerably, whereas an open type heater element withstands the heat. The normal temperature of the heating element of appliances lies between 550^{o} C to 900^{o} C.

Operating temperature range of heating elements

Name of the appliance	Temperature range in degrees (Celsius)
Electrical stove(heater) with bare heating element	750 to 900
Electric kettle	550 to 700
Electric iron	800 to 850
Toaster	750 to 900
Hotplate	550 to 700

Heating elements are of two types.

– Bare element

Fig 1

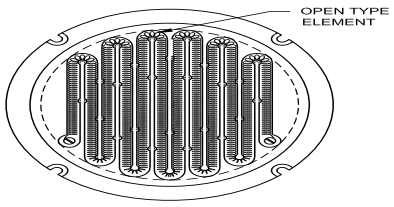
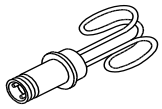


Fig 2



– Closed insulated type

An electric stove has a bare type element. (Fig 1) Closed, insulated types are used in immersion heaters, kettles etc. (Fig 2)

Fuse: Fuse is a strip of metal that melts when current reaches a certain value. The fuse is rated by the maximum number of amperes it can carry without melting. Fuses allow a small overload current for a short time. A fuse protects the system and equipment from over-current. The fuse wire has a definite cross-sectional area depending on the current it should carry for normal operation. In normal operations, the heat generated in the fuse wire (element) due to its resistance is dissipated to the surroundings.

When excess current than the rated normal value flows through the fuse, its resistance generates more heat than what can be dissipated to the surroundings. Therefore, the temperature of the fuse increases. If the increased current continues to flow , the heat developed in the fuse wire continues to increase in its temperature which causes it to melt. The melting fuse wire breaks the continuity of the circuit. The flow of current through the circuit is stopped. Any damage occuring to the appliance or wiring circuit by fire, that may be caused by the burning of the insulation, is prevented. Thus the fuse protects the circuit. As long as the heat produced by the flow of a current through an element is dissipated to the surrounding materials, sufficient heat required to melt the element is not produced. The current continues to flow through the circuit.

The following tests are carried out to check the condition of the heating appliances.

- Insulation resistance between the body of the appliances and the terminals, with and without the power cord.
- Insulation resistance between the conductors of the cord.
- Continuity of the heating element and power cord separately.

More than one megohm will be the insulation resistance of a good heating appliance.

Heating appliances

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

- **list the names of appliances working on the heating effect of electric current**
- **state the factors on which heating in such appliance depends**
- **name the common materials used for the heating element**
- **state the normal temperature range of heating appliances**
- **state how a fuse functions as a protective device.**

Heat is produced by electricity when current flows through resistance. This heat-producing effect of electricity is utilized in heating appliances such as heater, iron, hot-plate, kettle, toaster etc.

In heat-producing appliances, instead of using a good conductor for the heating element, we use a wire that is made of a poor conducting material. The current, which flows through the high-resistance heating element of the appliance, produces the heat that is desired.

These materials must be able to withstand high temperatures without damage. The resistance must be constant over a wide temperature range, and expansion due to heat must be held to a minimum to prevent sagging and consequent short circuiting.

Alloys, however, are almost always used in heating elements. For heating elements that are surrounded by air and where temperatures in excess of 1035°C are not required, a composition of chromium and nickel has been found to be the most durable resistor. Nickle-chromium resistors, when operated within their designed temperature limits, will last for years without any noticeable deterioration. The other materials used as heating element are Eureka and Kanthal.

Factors on which heating in appliances depends

- Current flow in the heating element.
- Resistance of the element.
- Time duration of heating.
- Ventilation i.e. cooling rate due to drought.
- Proximity (of element turns with each other)
- Shape of the element. (circular wire or ribbon).

All heating appliances do not work at the same temperature. If an electric kettle is operated without water the life of the heating element reduces considerably, whereas an open type heater element withstands the heat. The normal temperature of the heating element of appliances lies between 550° C to 900° C.

Operating temperature range of heating elements

Name of the appliance	Temperature range in degrees (Celsius)
Electrical stove(heater) with bare heating element	750 to 900
Electric kettle	550 to 700
Electric iron	800 to 850
Toaster	750 to 900
Hotplate	550 to 700

Heating elements are of two types.

– Bare element

Fig 1

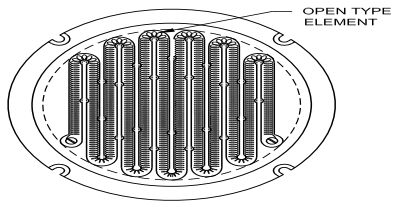
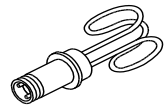


Fig 2



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More than one megohm will be the insulation resistance of a good heating appliance.

Thermostat heat controls in automatic electric iron

Objectives: At the end of this lesson you shall be able to
- **describe the construction of a bimetal thermostat**
- **illustrate the working of an adjustable thermostat**
- **list the applications of a thermostat**
- **explain the cause of pitting and oxidation of contacts.**

Thermostats

Thermostat is a device for keeping the temperature steady. One of the simplest and most dependable components in the modern heating appliances is a bimetal thermostat. It controls the temperature in stoves, toasters, food warmers, irons and so on. When combined with some other small components, it forms the basis for automatic and variable heat switches. It serves as a safety device to prevent overheating in many appliances when used by themselves with no adjustment provisions.

Bimetal thermostat: It is made of two strips of metal with different expansion rates welded together. Metal strips expand when heated and contract when cooled. One metal in the bimetal strip has a high rate of expansion when heated, and the other has a low rate. When a bimetal strip is heated, both the metals in the strip expand but the one at the bottom (with a higher rate of expansion) expands faster and forces the upper half to curl up or bend away from the contact point. (Fig 1) The strip curls or bends enough to break contact, opening the circuit. As the strip cools, it straightens and restores contact with the stationary point. The bending of the bimetal strip on heating is towards the side that has the smaller expansion rate. (Fig 2)

Fig 1

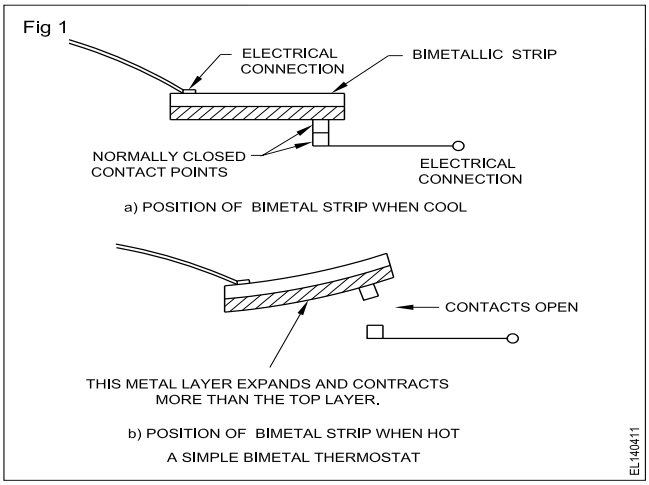
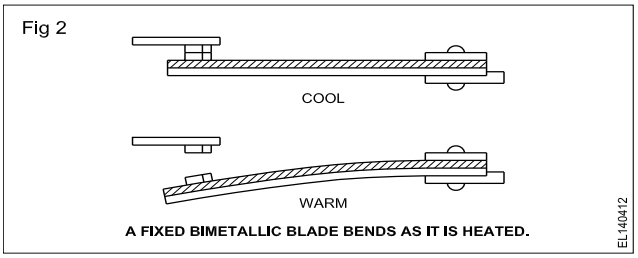
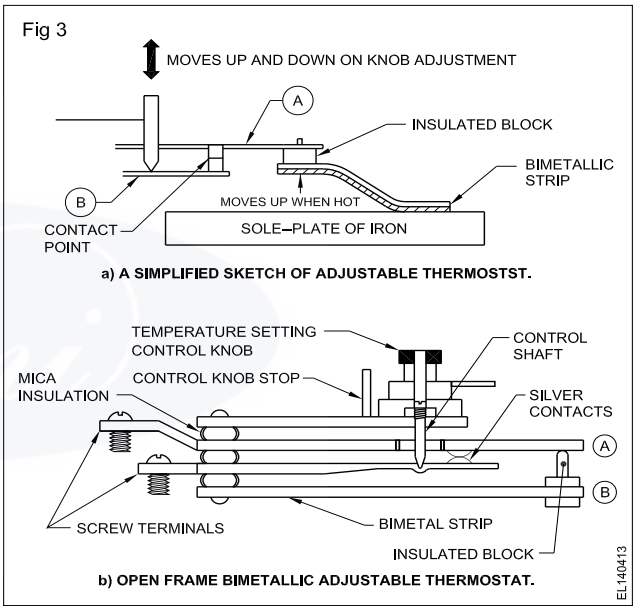


Fig 2



Adjustable thermostat: The operating temperature of a small, thermostatically - controlled heating appliance (e.g. electric iron) is varied by altering the distance the bimetallic blade must travel to close or open a set of contacts. By sliding or turning a control knob, the user adjusts the heat of the appliance only within specified limits. That is, through a linkage from the user's control knob, the distance between the thermostat's bimetallic blade and its associated electric contacts is varied. (Fig 3)

Fig 3



The user adjustment does not determine the amount of current that flows into the appliance but usually controls the ON-OFF cycle of the unit.

The bimetallic blade of the thermostat seldom is the source of a problem. Most often, trouble occurs because of contact points getting pitted and oxidised through repeated use. Remember that thermostats, as employed in small appliances, are switches.

Bimetal thermostats open and close slowly, and as a result, contacts are prone to arcing. Each time the contacts open, they cause a small arc which leaves a deposit of oxide on the contact surface. Arcing corrodes the contacts, increases through the point and causes even more severe arcing. Eventually the contacts no longer allow the current to flow. This can occur even though the contacts may seem to be touching each other.

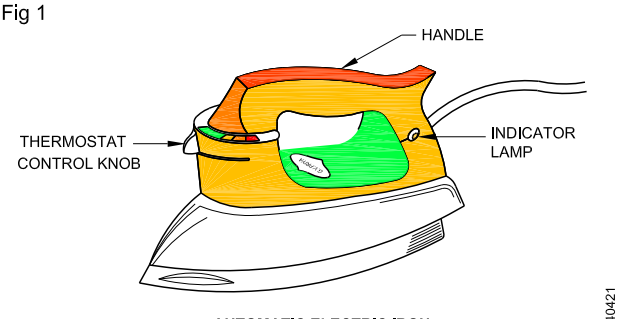
Generally, a good thermostat will show zero ohms resistance, or at most a few ohms. When a thermostat indicates high resistance or infinity, it should be replaced. Remember to isolate the thermostat from the circuit.

Automatic electric iron

Objectives : At the end of this lesson you shall be able to
- **name the different parts of an automatic iron from its constructional diagram**
- **list the possible faults, the causes and corrective action to be taken in an automatic iron.**

The difference between an automatic iron and the ordinary one (non-automatic) is that the automatic type has a thermostatic device to regulate the temperature. The principal parts are the same as in an ordinary iron except that it has a thermostat and a setting knob. (Fig 1)

Fig 1



AUTOMATIC ELECTRIC IRON

Parts of an automatic iron

Handle: Scientifically designed bakelite handle with thumb hollows for right or left handers and pilot lamp.

Sole-plate and cover: Surface ground, chrome plated, cast iron sole-plate resists corrosion and heat damage. Heavily plated steel cover.

Thermostat: Built in for automatic heat adjustment to suit different types of fabrics. Construction is identical to the one shown in Fig 3 of thermostat heat controls.

Heating element: Made of ribbon shaped, nickel-chromium, resistance element wound on high grade mica affords maximum electrical contact with connecting leads and thermal contact with the sole- plate, giving longer element life.

Flex: Cotton-braided 3-core, unkinkable flex with provision for earthing.

Automatic irons are fitted with a thermostatic switch to regulate the heat to a specific predetermined value, thus disconnecting it when sufficiently hot and reconnecting when cold. A turning dial just below the handle, marked as rayon, cotton, silk, wool, operates at a pre-set temperature, depending upon the particular fabric to be ironed. A lamp fitted into the handle goes off when the desired temperature is attained.

The electric components of the dry iron include a heating element, a thermostat, terminals, a terminal insulator and a cord-set.

The main causes of trouble in an iron are the cord-set, thermostat, heating element and connections to the element and thermostat.

The sole-plate needs to be cleaned and maintained as prescribed by the manufacturer.

Steam/spray irons (IS 6290)**:** Electrically there is no difference between steam irons and dry irons. A steam iron has a small reservoir mounted above the heating element. A control valve on this allows the water to drip in to recess in the sole plate. Check valve prevents the water and stem going back to the reservoir. When the water drips on the hot sole plate it is convered into steam and goes out through the holes in the bottom of the sole plate. The heating element s concealed with the sole plate. The amount of steam can be controlled by the contact knob on the iron located on the handle. Like automatic iron a thermostat is also provided to control the temperature.

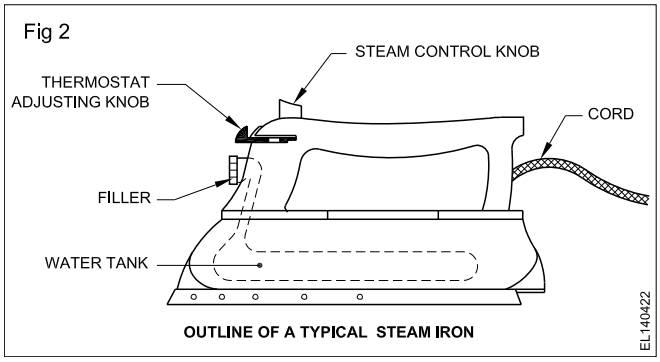
When the element is found to be defective, sole plate alongwith the sealed heating element has to be replaced.

Distilled water is recommended for filling in to the tank. Ordinary water, if used, may result in deposition of salts in the tank and clog the entry and exit ports.

It is recommended to flush the water in the tank by pressing the steam control knob fully for some time before the iron is switched off for keeping it till next use.

Salt deposits can be removed by filling the tank with water diluted vinegar and plugging the iron to supply. A number of attempts may be made to flush the iron by pressing steam control knob.

Fig 2



OUTLINE OF A TYPICAL STEAM IRON

Some of the common problems, possible causes and suggested corrective actions are given in the chart.

Troubleshooting Chart

Dry Iron

Problem	Possible cause	Corrective action
No heat	No power at outlet. Defective cord or plug. Broken lead in iron. Loose thermostat control knob Defective thermostat. Defective heater element Open thermal fuse.	Check outlet for power. Repair or replace. Repair or replace the lead. Clean and tighten. Replace the thermostat. Replace the heater if separate. If cast in, replace the sole-plate assembly. Replace.
Insufficient heat	Low line voltage. Incorrect thermostat setting. Defective thermostat. Loose connection.	Check voltage at the outlet. Adjust and re-calibrate the thermostat. Replace the thermostat. Clean and tighten connections.
Excessive heat	Incorrect thermostat setting Defective thermostat.	Adjust and re-calibrate the thermostat. Replace the thermostat.
Blisters on the sole-plate	Excessive heat. repair condition.	After repair of the control replace or the sole-plate, depending on its
Tears clothes.	Rough spot, nick, scratch, burr on the sole-plate.	Remove with fine emery; then buff polish the area.
Shocks user.	Electric circuit grounded to iron. thermostat for insulation breakdown,	Check: Cord and wiring for bare spot, heater element for ground. Repair or replace as indicated.
Cord sparks.	Loose connection. Broken wire.	Clean and tighten. Repair or replace.
Sticks to clothes.	Dirty sole-plate Excessive starch in clothes. starch next time. Iron too hot for the fabric being ironed.	Clean. Iron at a lower temperature. Use less Lower the thermostat setting.
Iron does not turn off automatically	• Welded thermostat contacts • defective thermostat	Replace thermostat

Testing the iron

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

- **test the automatic iron in a systematic way to find the defective part.**

Besides the obvious physical damages, such as a broken handle, dented shell (a leak tank), or a scratched sole-plate, you will have to make electrical tests to locate the trouble spot. All electrical tests can be made with an appliance tester or ohmmeter. When an iron does not heat or when it operates erratically, the first part to suspect is the cord. Test it by plugging it into the outlet with a lamp in series. Turn the thermostat all the way on, and the bulb should light. If it does not, then connect the jumper lead across the two terminals of the cord to short them. If the cord is good, the bulb will light and remain lighted while you shake, wiggle or work over the cord with your hands. If the light flickers or goes out while you are working over the cord, it means that there is an intermittent break in the cord, and it should be replaced. Having checked the condition of the cord, we move on to the iron itself.

The next part to test is the thermostat. Remove the jumper from the cord terminals and connect it across the heating element terminals. Turn the thermostat from OFF to ON and rotate its entire range. The test bulb light should come on somewhere in the first third of the control's rotation and remain ON steadily throughout the rest of the turning. It should go OFF at about the same point it came ON. Look the thermostat over carefully. Note the condition of the contact-points, leaf springs and insulators. Clean out any lint or other foreign matter that may have collected. Make certain that the terminals are tight and that contact areas are clean. A defective thermostat must be replaced. Contact points can be cleaned to some extent but generally such repairs are not satisfactory. The next step in electrical testing is the heater element. Remove the jumper lead from the heater element terminals and turn the thermostat all the way ON. The bulb should light. If it does not and everything else up to this point is good, the heater is defective. To double check this diagnosis, remove the plug of the iron cord from your tester and plug in the tester leads. Connect the test leads, one to each heater terminal. The bulb will light if the element is all right. No light, or a dim light, will indicate a defective element. There is no repair for this problem. The heater element must be replaced.

Finally, all parts and the assembled iron must be ground-tested before you can say that the iron is electrically workable.

Magnetic circuit parameters

Objectives : At the end of this lesson you shall be able to
- **name the factors that decide the strength of an electromagnet**
- **explain what is a magnetic circuit**
- **state flux and its unit**
- **state the magnetomotive force and its units**
- **state the magnetic reluctance and its units**
- **state the magnetic field intensity and its units**
- **state the relative and absolute permeability.**

In a coil magnet or solenoid, the strength of the magnetic field depends on,

- the magnitude of current through the coil and
- the number of turns in the coil.

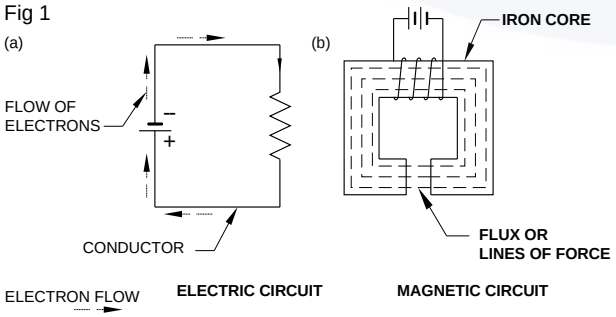
The more the current, stronger the magnetic field. Also, the more the turns, the more concentrated are the lines of force. A more detailed analysis of the strength of the magnetic field and the terms used can be understood by considering a magnetic circuit.

Magnetic circuit

As shown in Fig 1a and Fig 1b, a magnetic circuit is a closed-loop path for magnetic lines of force like an electric circuit is a closed-loop path for the flow of electrons.

In an electrical circuit, electrons travel from the negative to

Fig 1



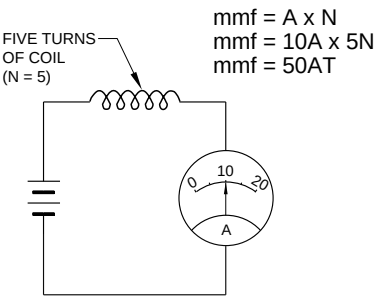
the positive terminal of the voltage source as shown in Fig 1a. Similarly, in a magnetic circuit, the lines of force travel from the North pole to the South pole of the electromagnet as shown in Fig 1b.

The rate of flow of electrons in the electrical circuit is called current (I) and is measured in amperes (A). The lines of force in the magnetic circuit is called the magnetic flux (ø) and is measured in webers (wb).

MAGNETOMOTIVE FORCE(mmf)

As electric current is the result of an electromotive force (emf) acting upon an electric circuit, a magnetic flux is the result of a magnetomotive force (mmf) acting upon a magnetic circuit. The magnetomotive force of a current-carrying coil is the product of the current in amperes (I) and the number of turns (N) on the coil as shown in Fig 2.

Fig 2



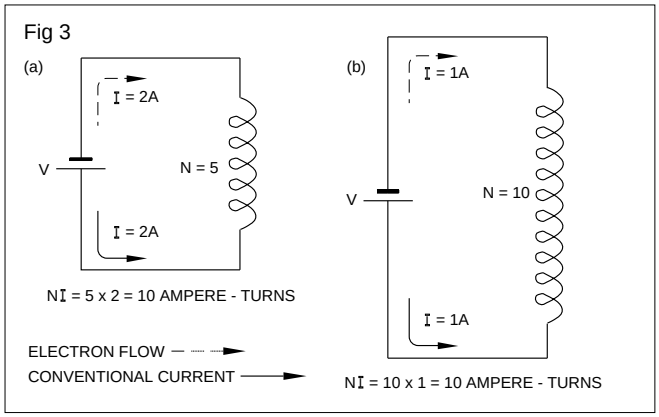
The approved SI unit of mmf is the ampere-turn. Some times the abbreviation of ampere-turns, At is used.

Magnetomotive force(mmf) =
Current through the coil(I) x No. of turns in coil(N)
mmf = I x N ampere-turns.

As shown in Fig 3, a solenoid with 5 turns carrying 2 amperes has the same magnetizing force (mmf) as that of a coil with 10 turns, carrying 1 ampere of current. This is because the product of current and turns is 10 in both cases. The amount of current through a coil depends on the resistance of the wire and the applied source voltage.

Depending upon the required At (magnetic field strength), the required number of turns of the coil can be decided.

Fig 3



Example 1 : *Calculate the ampere-turns for a coil with 2000 turns (N) and a 5-mA current (I).*

$NI = 2000 \times 5 \times 10^{-3} = 10$ At

Example 2 : *A coil with 4 amperes is to provide a magnetizing force (mmf) of 600 At. Calculate the number of turns required.*

Given NI = 600 At
and I = 4 Amps

$$\therefore N = \frac{600\ At}{4A} = 150\ turns.$$

Example 3 : *A coil with 400 turns must provide 800 At of magnetizing force. Calculate the amount of current required.*

Given NI = 800 At
and N = 400 turns

$$\therefore I = \frac{800\ At}{400\ t} = 2\ Amperes.$$

Example 4 : *The wire in a solenoid of 250 turns has a total resistance of 3W. Find (a) How much is the current will flow through the coil when connected to a 6-V battery? (b) Calculate the ampere-turns.*

a) $I = \frac{V}{R} = \frac{6V}{3\Omega} = 2\ Amps$

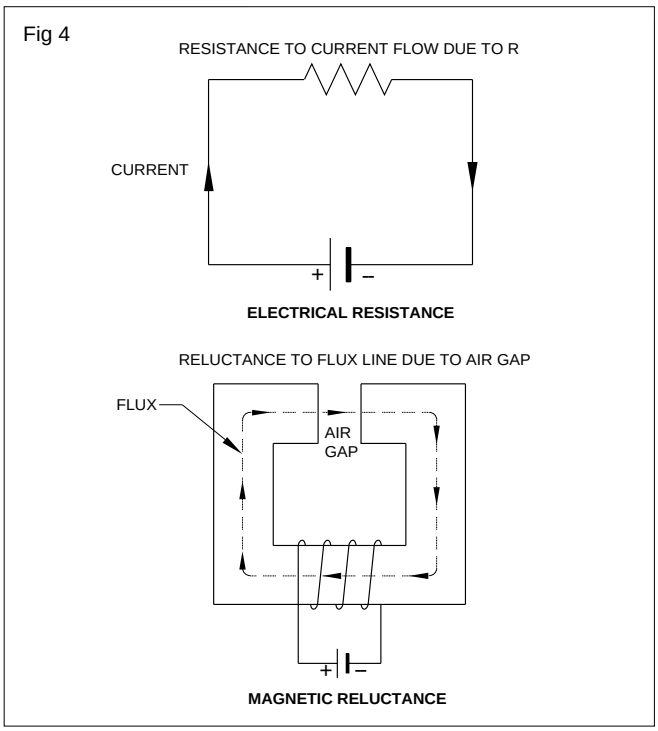
b) NI = 250 turns x 2 Amps = 500 At

The *ampere-turn(At)* is a SI unit of measure of mmf. The CGS unit of mmf is Gilbert, abbreviated as Gb. One ampere-turn (At) equals 1.26 Gilbert (Gb).

RELUCTANCE

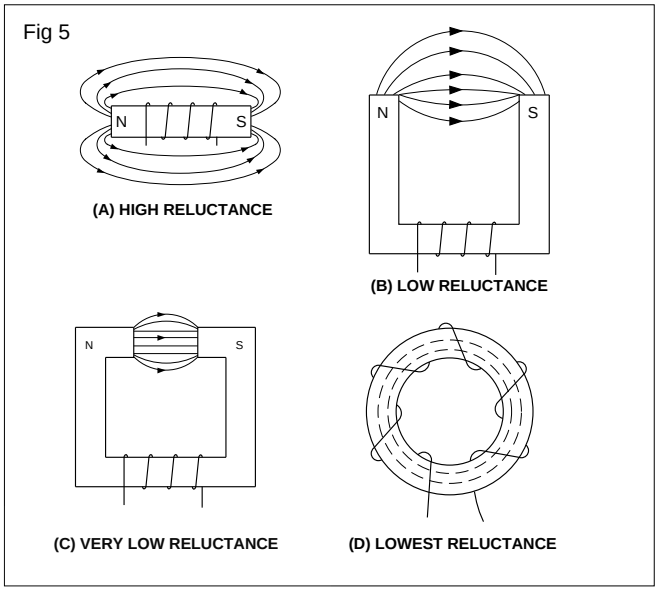
The counterpart of the term resistance (R) in an electrical circuit is called reluctance in a magnetic circuit as shown in Fig 4. Therefore, *reluctance is a measure of the opposition offered to the setting up of flux in a magnetic circuit,* just as resistance is the opposition to current flow in an electric circuit. The symbol for reluctance is $\mathbf{R_m}$.

Fig 4



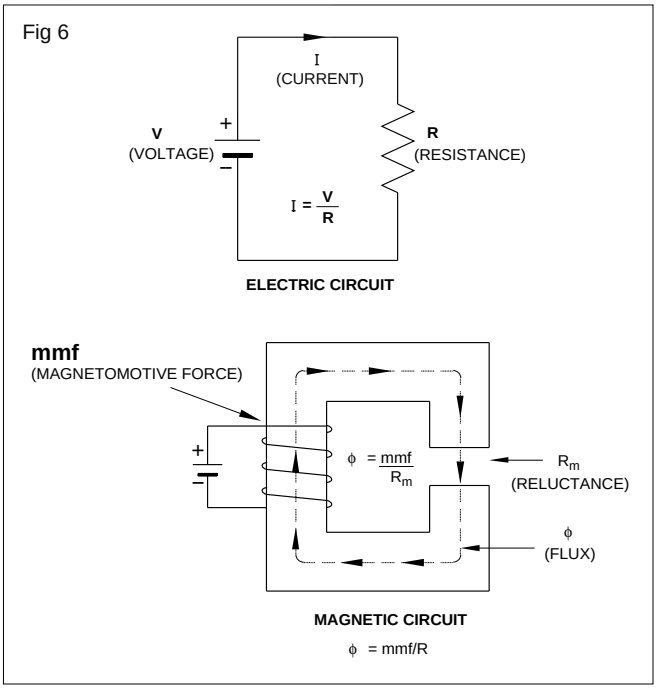
The reluctance of a magnetic circuit depends upon the width of the air gap, and the type of magnetic material used. Air gap is the air space between the poles of a magnet. Since air has high reluctance, a magnetic circuit having widely spaced poles will have high reluctance. Fig 5 shows the effect of air gap on reluctance in different shapes of magnets. Reluctance is measured in At per Weber (At/Wb).

Fig 5



The similarity between magnetic and electric circuits extends even to Ohm's Law as shown in Fig 6. The same relationship exists between magnetomotive force, flux and reluctance as that exists between voltage, current and resistance. *Ohm's Law for magnetic circuit states that, the flux produced by a magnetic circuit is directly proportional to the magnetomotive force (mmf) and inversely proportional to the reluctance(R_m).*

Fig 6



Example : *A coil has a mmf of 500 At and a reluctance of 2 x 10^6 At/Wb.Find the total flux ø.*

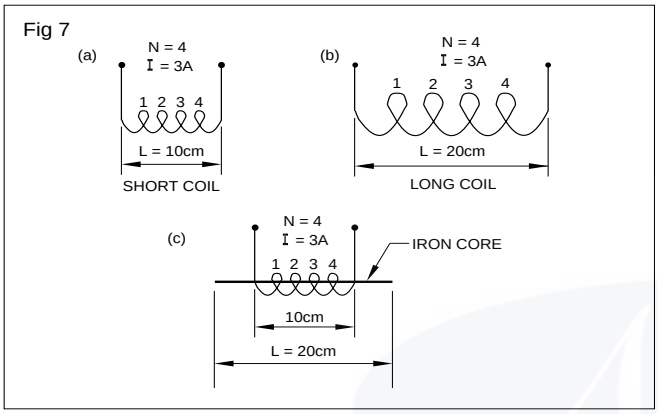
$$\phi = \frac{mmf}{R_m} = \frac{500\ At}{2 \times 10^{6}\ At/Wb} = 250\ \mu Wb.$$

Calculation and measurement of electrical parameters such as voltage, current and resistance is relatively easy in an electrical circuit. The same is not true for the magnetic circuit parameters. Although meters are available for measuring different parameters of a magnetic circuit, they are most expensive and hence often used in the test laborateris only.

FIELD INTENSITY (H)

If a coil with a certain number of turns is stretched to twice its original length as shown in Fig 7a and 7b, the intensity of the magnetic field, that is, the concentration of lines of force will become one-half. The field intensity at any point in space around a magnetic circuit depends on the length of coil.

Fig 7



Hence, at any point in space, a specific value of ampere-turns will produce less field intensity for a long coil than for a short coil. The symbol for field intensity is H. The field intensity H in SI system for a solenoid is given by,

$$H = \frac{NI\ At}{L\ metre}\ \text{Ampere - turns per metre.}$$

Where,

H = Magnetic field intensity in ampere-turns per metre(At/m)

NI = Magnetomotive force in ampere-turns(At)

L = Length between poles of the coil in metres

For an air core solenoid, H is the intensity at the centre of the air core.

For a solenoid with an iron core, H is the intensity through the entire core and L is the length or distance between poles of the iron core as shown in Fig 7c.

As can be seen from the formula for field intensity, the field intensity (H) is nothing but the magnetomotive force (mmf) per unit length. In SI units, H is At/m. The CGS unit for H is the oersted, abbreviated as oe. One oersted equals one gilbert of mmf per centimetre.

The magnetic field intensity for both electromagnets and permanent magnets as specified either in At/meter or in oersted.

Example:

(a) Find the field intensity (H) of a 4-turn, 10-cm-long coil, with 3 A flowing through it as shown in Fig 7a.

(b) If the same coil is stretched to 20 cm as shown in Fig 7b, with the same number of turns and current, what is the new value of field intensity?

(c) The 10cm coil in Fig 7a with the same 3 A flowing is now wound around an iron core of 20cm long as shown in Fig 7c. What is the field intensity?

Solution:

(a) Apply the equation, $H = \frac{NI}{L}$,

In the given example, N = 4 turns, L = 10 cm = 0.1m, and I = 3A.

$$H = \frac{NI}{L} = \frac{4(3)}{0.1} = 120\ \text{At/meter}$$

(b) As the coil is stretched from 10 to 20 cm. Though the wire length is the same, the length between poles will now be 20 cm = 0.2 m. So H in this case will be,

$$H = \frac{4(3)}{0.2} = 60\ \text{At/meter}$$

Stretching out the coil to twice its original distance has reduced the mmf by one-half.

(c) The length L in this case is between the poles at the ends of the iron core although the winding is 10 cm long. So L in this case will be 20 cms.

NOTE: *Case (b) and (c) have the same H value.*

PERMEABILI $H = \frac{4(3)}{0.2} = 60$ At/meter

Permeability refers to the ability of a magnetic material to concentrate the magnetic flux. Any material that is easily magnetized is said to have high permeability. Air or vacuum has very low permeability. A measure of permeability of materials in comparison with air or vacuum is called **relative permeability.** The symbol of relative permeability is μ_r, where r stands for relative. μ_r has no units because, it is a comparative ratio of flux densities.

A good magnetic material with high relative permeability can concentrate flux and produce a large value of flux density for a specified H. These factors are related by the formula:

$$B = \mu \times H \text{ or } \mu = \frac{B}{H}.$$

The factor μ is known as the **absolute permeability.** This means, the permeability not referred to the permeability of any other material.

Recall that in SI system,

B is the flux density in webers per square metre, or teslas, and H is the field intensity in ampere-turns per metre.

In CGS system,

B is the flux density in gauss, and H is the field intensity in oersteds.

In CGS system the units for B is Gauss and for H is oersted. These units are defined to give μ the value of 1 G/Oe, for vacuum or air. Hence, the values of relative permeability μ_r are the same as those for absolute permeability in B/H units in CGS system. As an example, if μ_r for an iron sample is 600, the absolute μ is also 600 G/Oe because μ is 1 for air or vacuum.

In SI, however, the permeability of air or vacuum is not equal to 1. Specifically, this value is 4þ x 10^{-7}, or 1.26 x 10^{-6} Wb/At-m with the symbol μo. Therefore, values of relative permeability μ_r must be multiplied by 1.26 x 10^{-6} with μ_o to calculate μ.

For example; if the relative permeability (μ_r) of a material is 100, the SI value of μ can be calculated as follows;

$\mu = \mu_r \times \mu_o$

where,

μ = absolute permeability of the material
μ_r = relative permeability of the material
μ_o = permeability of air or vacuum (free space)

$$\mu = 100 \times 1.26 \times 10^{-6} \frac{Wb}{At - m} \text{ or } \frac{T}{A.t / m}$$

Example : *A magnetic material has a μ_r of 500. Calculate the absolute permeability μ (a) in CGS units, and (b) in SI units.*

a) $\mu = \mu_r \times \mu_o$

In CGS units, μ_o = 1 Gauss/oersted

$$\mu = 126 \times 10^{-6} \frac{Wb}{At - m} \text{ or } \frac{T}{A.t / m}$$

$$\mu = 500 \times 1 \frac{G}{Oe}$$

b) $\mu = \mu_r \times \mu_o$ in SI units.

In SI units, $\mu_o = 1.26 \times 10^{-6}$ Wb/At-m

$$\mu = 500 \frac{G}{Oe}$$

$$\mu = 500 \times 1.26 \times 10^{-6} \frac{Wb}{At - m} \text{ or } \frac{T}{At / m}$$

Example : *For μ = 630 x 10^{-6} in SI units, calculate the flux density B that will be produced by the field intensity H equal to 1000 A.t/m.*

B = μ x H

$$\mu = 630 \times 10^{-6} \frac{Wb}{At - m} \text{ or } \frac{T}{At / m}$$

B = 630 x 10^{-3} T = 0.63 T.

A summary of magnetic quantities along with their symbols, units in SI and CGS systems, formulae and conversion from one system of units to other is given pocket table book table number 12.

Electromagnets - Solenoid

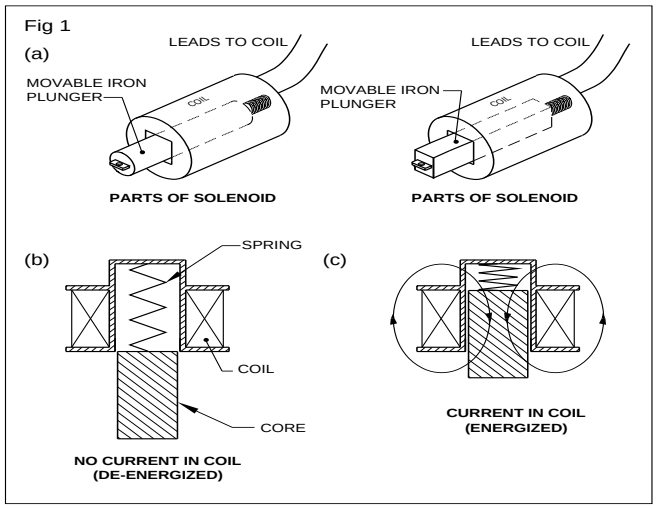
Objectives : On completion of this lesson you shall be able to

- **explain the construction of a typical solenoid**
- **explain the principle of working of a solenoid**
- **list a few uses of a solenoid**
- **list the points to be noted while making solenoids**
- **explain the use of solenoids in motor starter circuits.**

SOLENOID

As already discussed solenoids are nothing but electromagnets. The word solenoid is usually applied to those devices that have thin coils wound on a air core former with a movable iron core acting against an internal spring as shown in Fig 1. The air core and coil may be rectangular or circular in shape as shown in Fig 1a.

A solenoid is constructed by winding enameled copper wire on a hollow fiber or plastic former. The core, more commonly called a plunger is made of such a material that is easily magnetized but does not retain its magnetism when the current no longer flows through the coil.

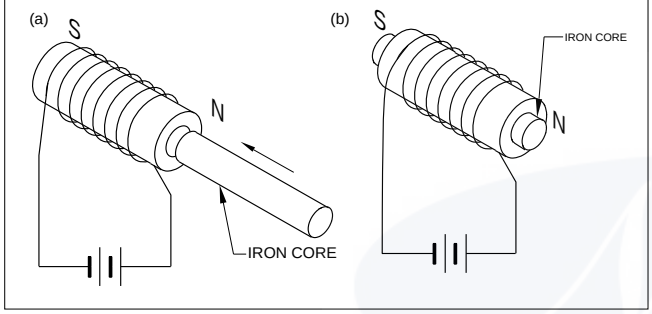


A solenoid enables an electric current to control a mechanical part. The movable iron core or plunger can be used to operate, for example, water valves (to control water flow), a mechanical brake, a clutch and so on. Solenoids are generally made to operate on DC supply. But solenoids can be made to operate on AC supply also. The AC operated solenoids are commonly used in door chimes.

Principle of operation

As already discussed, when current flows through a coil, the coil becomes a magnet. The coil concentrates the magnetic field inside the coil, and acts like a bar magnet. It will have North and South poles similar to a bar magnet. If a core of soft iron is placed along the axis of the coil, it will be attracted by the coil as shown in Fig 2a. The core will be drawn into the centre of the coil. The movement of the core will stop when the forces at each end of the coil are balanced. This balance occurs when the core has centered itself in the coil as shown in Fig 2b where the magnetic fields are strongest.

Fig 2



Pulling power of a solenoid

The pulling force or power of the solenoid on the core depends on the magnetic properties of the core material. In general, increasing the mmf (At) or decreasing the reluctance of the magnetic circuit, increases the pulling power of the solenoid.

The pulling power of a given solenoid can be found by making a small jig. The setup of such a test jig is given in exercise 5.04. The pulling power is generally found in terms of weight (grams). By increasing the mmf, i.e by increasing the current through the coil or/and the number of turns of coil, the pulling power of a solenoid can be increased for a given core material. The pulling power can also be improved by choosing a core material having low reluctance or high permeability.

Points to be noted while making solenoids

1 Use a thin wire gauge to accommodate more number of turns for a given length of the former. This increases the mmf for lesser value of current.

2 Ensure that the hollow portion of the solenoid is friction-free to avoid unwanted waste of energy while pulling the plunger.

3 Choose a core material having high permeability and very low retentivity. This reduces the reluctance of the magnetic circuit and improves the pulling power of the solenoid and frequency of operation.

4 Choose the dimensions of the core such that it is not abnormally heavy and large. A heavy core reduces the net pulling power of the solenoid.

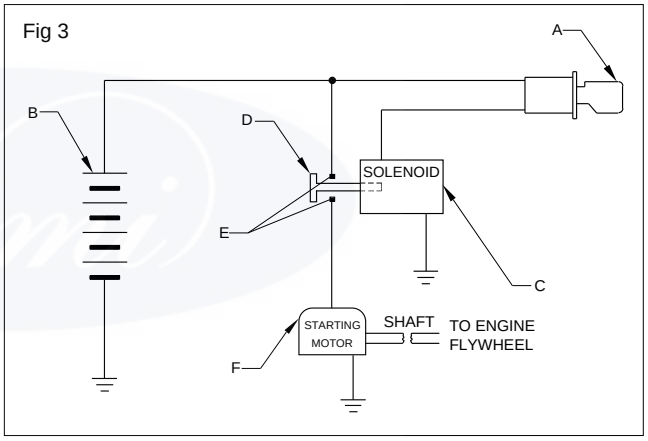
5 Ensure a firm fixing of the solenoid coil to some base to get maximum benefit of the core movement.

Application of solenoid in motor starters

A typical application of solenoid connected to an automobile starter is given below:

The starting system is used to start the engine in all four wheel vehicles. A typical starting system is shown in Fig 3.

Fig 3



When the starter switch(A) is pressed or turned, battery(B) gets connected to solenoid(C) and current flows through the solenoid. The solenoid plunger(D) is attracted and the plunger shorts the terminals(E) connecting the battery to the starting motor(F). Now the starter motor shafts rotates. The shaft of the starter motor coupled to the engine flywheel turns ON the engine by rotating the engine flywheel till the engine starts working. Once the engine starts working, switch(A) is released. The current through the solenoid is cut-off and the plunger(D) is released and the terminals(E) become open, switching OFF the starting motor.

Dynamically induced EMF

Objectives : At the end of this lesson you shall be able to
- **state the principle of the DC generator**
- **explain Faraday's Laws of Electromagnetic Induction**
- **explain the method of producing dynamically induced EMF, its magnitude and direction.**

Generator:An electrical generator is a machine which converts mechanical energy into electrical energy.

Principle of the Generator:To facilitate this energy conversion, the generator works on the principle of Faraday's Laws of Electromagnetic Induction.

Faraday's Laws of Electromagnetic Induction: There are two laws.

The first law states:

- whenever the flux linking to a conductor or circuit changes, an emf will be induced.

The second law states:

- the magnitude of such induced emf(e) depends upon the rate of change of the flux linkage.

$$e \alpha \frac{\text{Change of flux}}{\text{Time taken for change}}$$

Types of emf: According to Faraday's Laws, an emf can be induced, either by the relative movement of the conductor and the magnetic field or by the change of flux linking on a stationary conductor.

Dynamically induced emf: In case, the induced emf is due to the movement of the conductor in a stationary magnetic field as shown in Fig 1a or by the movement of the magnetic field on a stationary conductor as shown in Fig 1b, the induced emf is called dynamically induced emf. As shown in Figs 1a & 1b, the conductor cuts the lines of force in both cases to induce an emf, and the presence of the emf could be found by the deflection of the needle of the galvanometer `G'. This principle is used in DC and AC generators to produce electricity.

Statically induced emf: In case, the induced emf is due to change of flux linkage over a stationary conductor as shown in Fig 2, the emf thus induced is termed as statically induced emf. The coils 1 and 2 shown in Fig 2 are not touching each other, and there is no electrical connection between them.

According to Fig 2, when the battery (DC) supply is used in coil 1, an emf will be induced in coil 2 only at the time of closing or opening of the switch S. If the switch is permanently closed or opened, the flux produced by coil 1 becomes static or zero respectively and no emf will be induced in coil 2. EMF will be induced only when there is a change in flux which happens during the closing or opening of the circuit of coil 1 by the switch in a DC circuit.

Fig 1

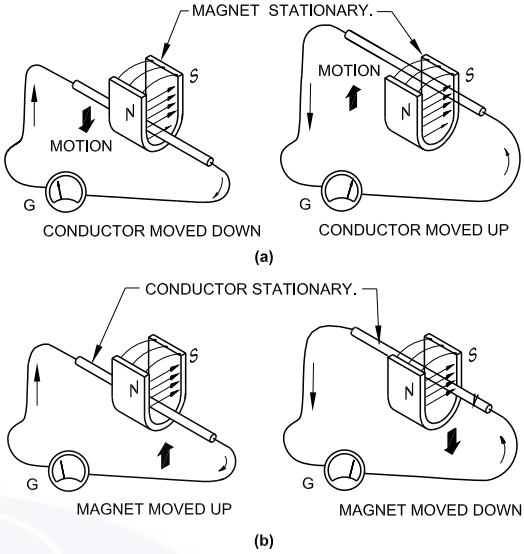
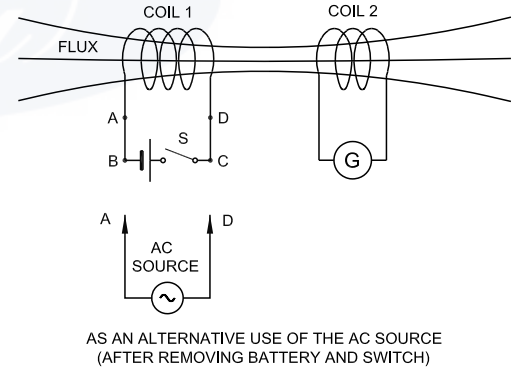


Fig 2



Alternatively the battery and switch could be removed and coil 1 can be connected to an AC supply as shown in Fig 2. Then an emf will be induced in coil 2 continuously as long as coil 1 is connected to an AC source which produces alternating magnetic flux in coil 1 and links with coil 2. This principle is used in transformers.

Production of dynamically induced emf: Whenever a conductor cuts the magnetic flux, a dynamically induced emf is produced in it. This emf causes a current to flow if the circuit of the conductor is closed.

For producing dynamically induced emf, the requirements are:

- magnetic field
- conductor
- relative motion between the conductor and the magnetic field.

If the conductor moves with a relative velocity 'v' with respect to the field, then the induced emf `e' will be

= BLV Sinq Volts

where

B = magnetic flux density, measured in tesla
L = effective length of the conductor in the field in metres
V = relative velocity between field and conductor in metre/second
q = the angle at which the conductor cuts the magnetic field.

Let us consider Fig 3a in which conductors A to I are placed on the periphery of the armature under magnetic poles. Assume for this particular generator shown in Fig 3a, the value of BLV = 100V.

Accordingly the conductor A induces an emf

= BLV Sin q where q = zero and Sin zero is equal to zero
= 100 x 0 = zero.

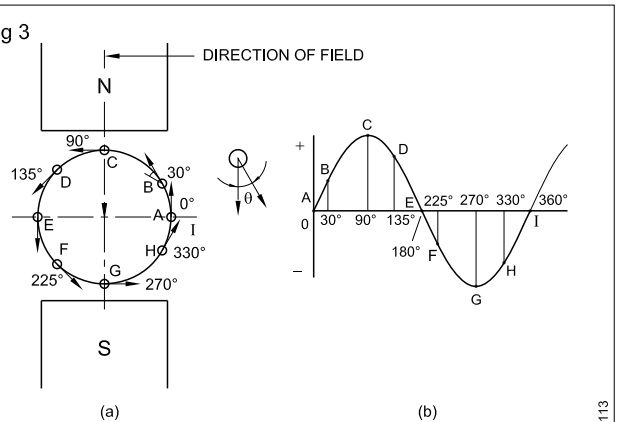
emf induced in
Conductor B = BLV Sin 30°
= 100 x 0.50
= 50 volts.

emf induced in
Conductor C = BLV Sin 90°
= 100 x 1
= 100 V.

emf induced in
Conductor D = BLV Sin 135°
= BLV Sin 45°
= 100 x 0.707
= 70.7 volts.

emf induced in
Conductor E = BLV Sin 180°
= Sin 180°= 0
= 100 x 0
= zero.

Fig 3



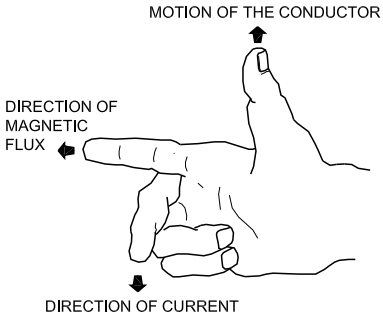
PRODUCTION OF THE SINEWAVE

Likewise for every position of the remaining conductors in the periphery, the emf induced could be calculated. If these values are plotted on a graph, it will represent the sine wave pattern of induced emf in a conductor when it rotates under N and S poles of uniform magnetic field.

The emf induced by this process is basically alternating in nature, and this alternating current is converted into direct current in a DC generator by the commutator.

Fleming's right hand rule: The direction of dynamically induced emf can be identified by this rule. Hold the thumb, forefinger and middle finger of the right hand at right angles to each other as shown in Fig 4 such that the forefinger is in the direction of flux and the thumb is in the direction of the motion of the conductor, then the middle finger indicates the direction of emf induced, i.e. towards the observer or away from the observer.

Fig 4

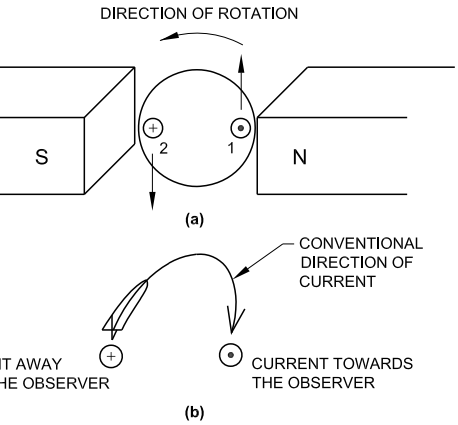


Imagine a conductor moving in between north and south poles in an anticlockwise direction as shown in Fig 5a.

Applying Fleming's right hand rule, we find that the conductor 1 which is moving upwards under the north pole will induce an emf in the direction towards the observer indicated by the dot sign and the conductor 2 which is moving down under the south pole will induce an emf in the direction away from the observer indicated by the plus sign.

Fig 5b indicates the current direction in the form of an arrow. The dot sign indicates the pointed head of the arrow showing the current direction towards the observer and the plus sign indicates the cross-feather of the arrow showing the current direction away from the observer.

Fig 5



DIRECTION OF THE INDUCED CURRENT

A simple electrical generator

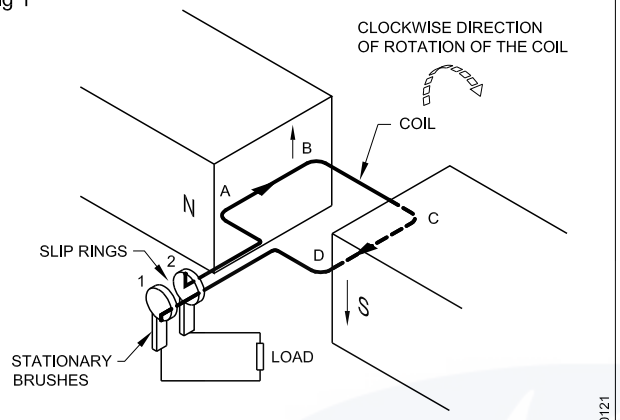
objectives: At the end of this lesson you shall be able to
- **explain the function of the split rings (commutator) and slip-rings.**

Introduction

A generator produces electrical power with the help of the rotation of a group of conductors in a magnetic field. It uses the principle of electromagnetic induction to convert the input mechanical power into electrical power.

Slip rings: Let us consider a simple AC generator having a single loop of wire and rotated within a fixed magnetic field, as shown in Fig 1.

Fig 1



SIMPLE AC GENERATOR

Let each end of the single loop coil be connected to copper or brass rings called slip rings. These slip-rings are insulated from each other, insulated and mounted on the shaft. In a broader sense this rotating assembly (coil,shaft & slip-ring) is called armature. The wire loop (armature coil) is connected to an external circuit by means of two brushes which are positioned to rub against the slip-rings. As the armature is rotated at a uniform angular velocity, the generated voltage in the loop conductor will actually be of alternating voltage.

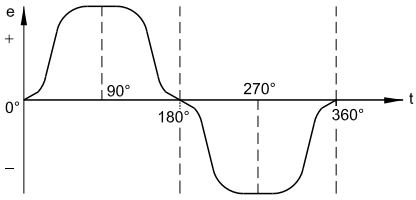
For the clockwise rotation indicated, the direction of generated voltage and the resulting current in the coil side under the north pole will be directed from A to B making the slip-ring 2 negative. This is readily confirmed by using Fleming's right hand rule. Similarly the direction of the induced voltage and the resulting current under the south pole is to be directed from C to D making the slip- ring 1 as positive. When the conductor AB moves from the north pole to the south pole, the direction of induced emf in it will reverse, so that the current will now flow from B to A making the slip-ring 2 positive. At the same time coil side CD has moved into the north pole region and its induced emf is reversed and current will flow from D to C making the slip-ring 1 negative.

Thus for one half of a revolution (for a two-pole generator) the emf is directed around the coils A to B & C to D. For the other half of the revolution the emf is directed around the coil D to C and B to A. The current in the externally connected load resistor via the stationary brushes in contact with the pair of slip rings `1'and `2' will be alternating (AC) in nature.

Wave-shape of the induced voltage: When the output voltage is plotted against electrical degrees we get the output wave-form.

The output wave-form obtained across the load, according to the pole shape shown in Fig 1, will not be of sinusoidal shape due to un-uniform magnetic field but of rectangular shape as shown in Fig 2.

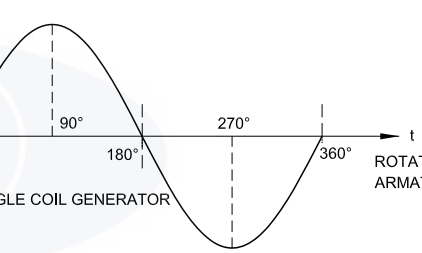
Fig 2



WAVE-FORM SHOWS COIL ROTATES UNDER UN-UNIFORM MAGNETIC FIELD

However, if the magnetic field is uniform, the output wave-form will be of sinusoidal shape as shown in Fig 3.

Fig 3



WAVE-FORM SHOWS COIL ROTATES UNDER UNIFORM MAGNETIC FIELD
(SINE WAVE)

Simple generator with split-rings: A direct current generator is simply an AC generator provided with split rings instead of slip-rings.

The split ring is a ring made up of hard drawn copper cut into two segments, insulated from each other and the shaft in which it is mounted. A commercial generator uses a number of split rings called commutators. The split ring is a device for reversing the brush contact with the armature coil terminals, every time the induced current in the coil reverses, so that the output current taken by the brushes remains always in the same direction.

As shown in Fig 4a, if the armature rotates clockwise the split ring rotates with it, and the brushes and the poles are stationary in their position. As shown in Fig 4a, when the moving coil is in the horizontal position, the induced current will flow through the coil from ABCD to the segment `B' via the positive brush and load to the negative brush and segment A. The direction of current flow in the external circuit is shown in Figures 4a and c.

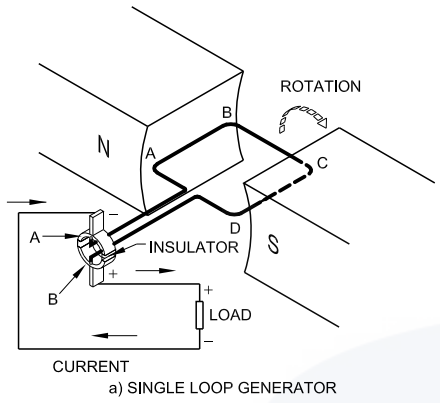
When the armature rotates so that the coil just assumes a vertical position as in Fig 4b, the brushes will short-circuit both the segments. The induced emf is zero and no current flows through the load circuit for a short moment.

When the armature rotates and the coil assumes the position as indicated in Fig 4c, the coil side AB will enter the south pole region and its induced emf will reverse, compared to the direction it had while moving under the north pole region as shown in Fig 4a.

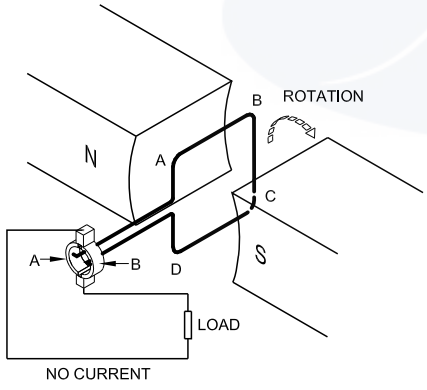
But when this happens the split ring segments `A' and `B' will also have exchanged their positions since they rotate along with the coil.

As the emfs in the coil sides AB and CD reverse their polarity, the split ring segments to which they are connected simultaneously change their positions under the stationary brushes. As a result, the polarity of the brushes remains fixed and the current direction through the load remains as shown in Fig 4c which is the same as shown in Fig 4a.

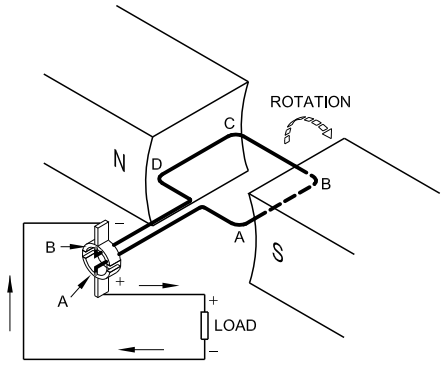
Fig 4



a) SINGLE LOOP GENERATOR



b) SINGLE LOOP GENERATOR



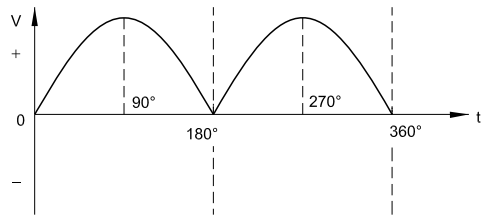
c) SINGLE LOOP GENERATOR

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Figure 5 represents the generated voltage of a simple DC generator. The voltage is uni-directional due to the split ring action.

The induced emf by a single loop (one turn) coil is very small in magnitude and pulsating in nature as shown in Fig 5. Coils, having a number of turns in series, multiply the generated emf by the same number. However to get a steady (DC) current it is necessary to increase the pulses produced in the armature; thereby their average value is constant.

Fig 5



VOLTAGE PRODUCED IN A LOOP UNDER UNIFORM MAGNETIC FIELD

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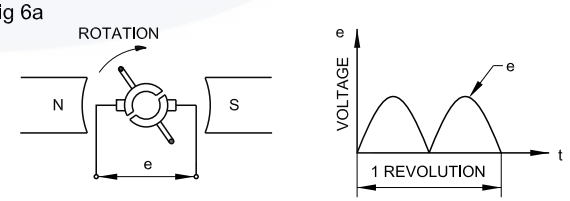
There are two ways to increase the number of pulses during each rotation of the armature.

- Increase the number of field poles.
- Increase the number of separate coils (multi-coil) in the armature.

The multi-coils necessitate a multiple segment split-rings which is called a commutator.

Fig 6 represents the generated voltages and their wave shapes when the armature has different number of split rings, i.e. commutator segments. The practical generator will have more number of commutator segments as shown in Fig 6c, and the induced emf will be as shown in the adjoining graph.

Fig 6a

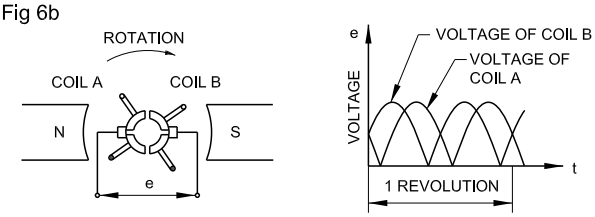


ONE SET OF SPLIT RINGS

OUTPUT WAVE-FORM

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Fig 6b

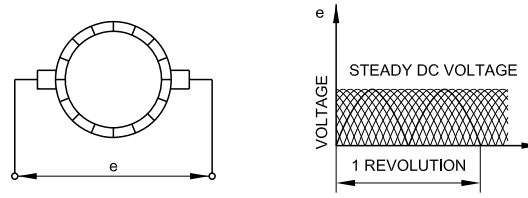


TWO SETS OF SPLIT RINGS

OUTPUT WAVE-FORM

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Fig 6c



A NUMBER OF SPLIT RINGS (COMMUTATOR)

OUTPUT WAVE-FORM

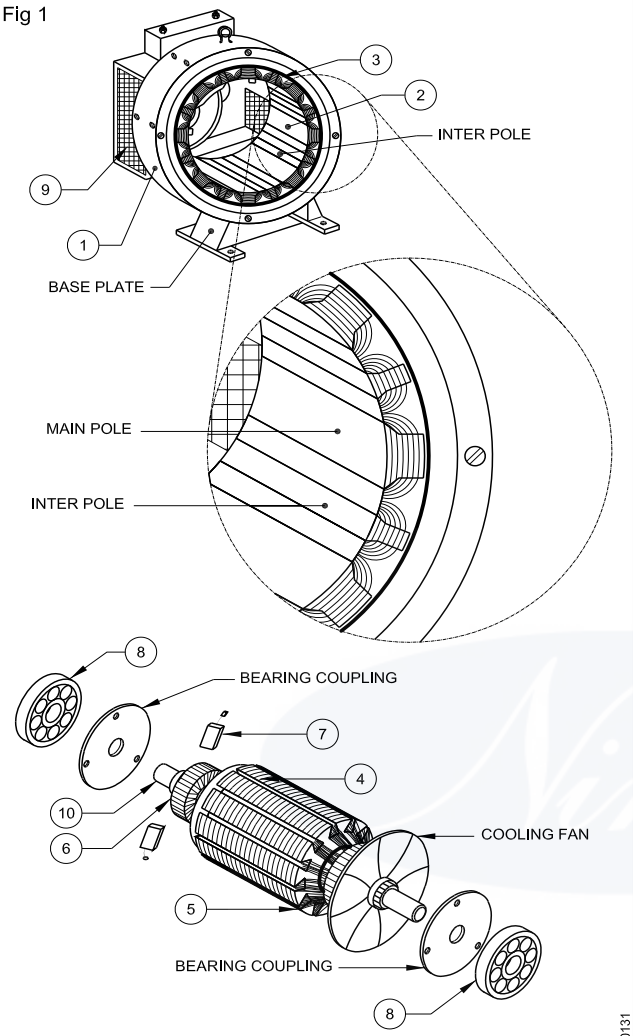
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Parts of a DC generator and their functions

Objectives: At the end of this lesson you shall be able to
- **describe the parts of a DC generator and their functions.**

A DC generator consists of the following essential parts as shown in Fig 1.

Fig 1



PARTS OF A DC MACHINE

1 Frame or yoke
2 Field poles and pole-shoes (Figs 3,4 & 5)
3 Field coils or field winding (Fig 6)
4 Armature core
5 Armature windings or armature conductors
6 Commutator
7 Brushes
8 Bearings and end plates (Figs 14 & 15)
9 Air filter for fan
10 Shaft

The yoke, the pole cores, the armature core and the air gaps between the poles and the armature core form the magnetic circuit, whereas the armature conductors, field coils, commutators, and brushes form the electrical circuit.

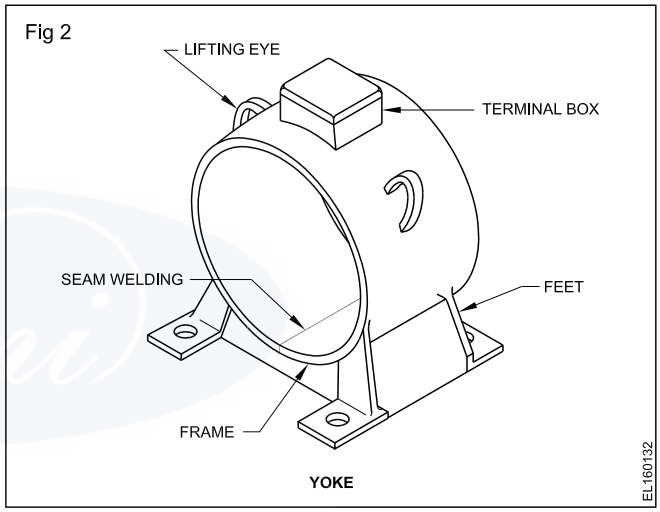
Yoke: The outer frame or yoke serves a dual purpose.

Firstly, it provides mechanical support for the poles and acts as a protecting cover for the whole machine as shown in Fig 1. Secondly, it allows the magnetic circuit to complete through it.

In small generators where cheapness rather than weight is the main consideration, yokes are made of cast iron. But for large machines usually cast steel or rolled steel is used. The modern process of forming the yoke consists of rolling a steel slab round a cylindrical mandrel, and then welding it at the seams. The feet, the terminal box etc. are welded to the frame afterwards as shown in Fig 2. Such yokes possess sufficient mechanical strength and have high permeability.

Poles cores and pole shoes (Fig 3): The field magnets consist of pole cores and pole shoes. The pole shoes serve two purposes; (i) they spread out the flux in the air gap uniformly and also, being of a larger cross-section, reduce the reluctance of the magnetic path, and (ii) they also support the field coils.

Fig 2

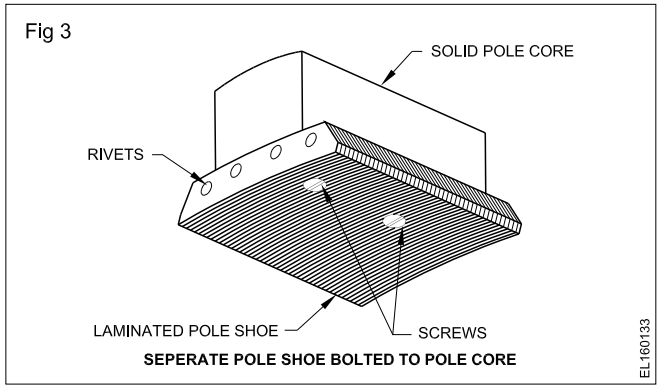


YOKE

There are two main types of pole construction.

The pole core itself may be a solid piece made out of either cast iron or cast steel but the pole shoe is laminated and is fastened to the pole face by means of countersunk screws as shown in Fig 3.

Fig 3

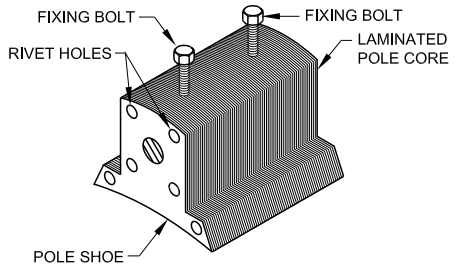


SEPERATE POLE SHOE BOLTED TO POLE CORE

In modern designs, the complete pole cores and pole shoes are built of thin laminations of annealed steel which are riveted together under hydraulic pressure. The thickness of laminations varies from 1mm to 0.25mm. The laminated poles may be secured to the yoke in any of the following two ways.

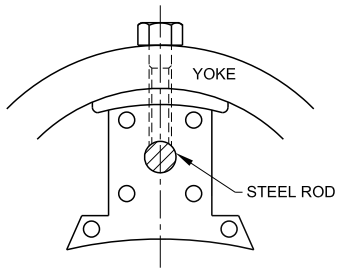
Either the pole is secured to the yoke by means of screws bolted through the yoke and into the pole body as in Fig 4 or holding screws are bolted into a steel bar which passes through the pole across the plane of laminations as in Fig 5.

Fig 4



LAMINATED POLE CORE

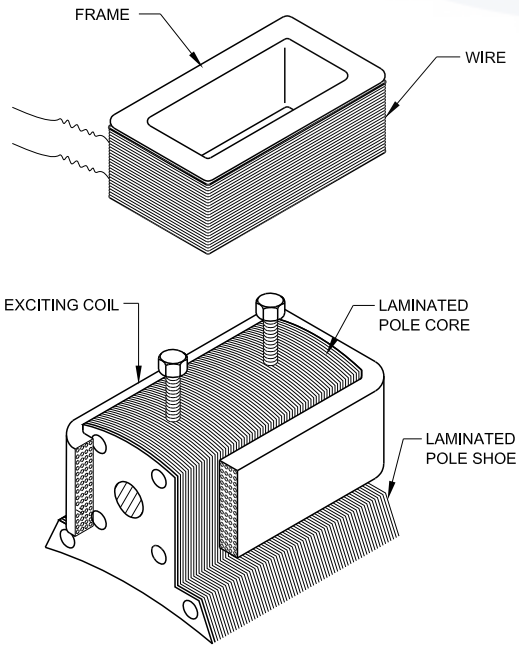
Fig 5



HOLDING SCREW BOLTED IN TO STEEL BAR POLE CORE ASSEMBLY

Pole coils (Field coils): The field coils or pole coils, which consist of copper wire or strip are former-wound for the correct dimension. Then the former is removed and the wound coils are put into place over the core as shown in Fig 6.

Fig 6



POLE ASSEMBLY

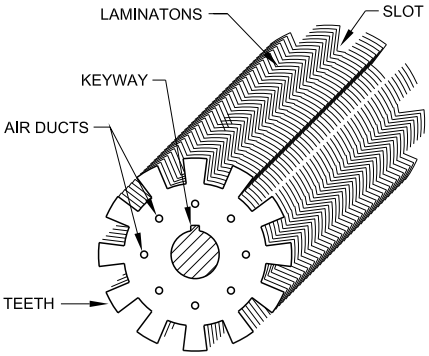
When a current is passed through the coils, they magnetise the poles which produce the necessary flux that is cut by revolving armature conductors.

Both thick gauge wire winding (series) and thin gauge winding (shunt) are wound, one over the other with separate insulations, and the terminals are brought out separately.

Armature core: The armature core houses the armature conductors and rotate in the magnetic field so as to make the conductors to cut the magnetic flux. In addition to this, its most important function is to provide a path of very low reluctance to the field flux, thereby allowing the magnetic circuit to complete through the yoke and the poles.

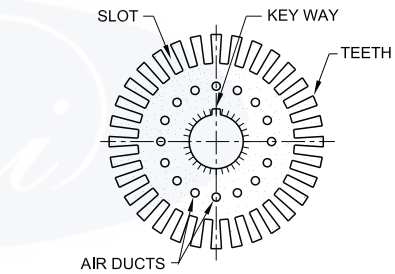
The armature core is cylindrical or drum-shaped as shown in Fig 7, and is built up of circular sheet steel discs or laminations approximately 0.5mm thick as shown in Fig 8.

Fig 7



ARMATURE CORE MADE OF LAMINATION

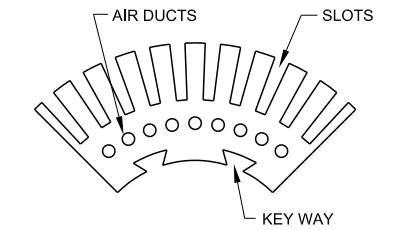
Fig 8



ARMATURE CORE LAMINATIONS

The slots are either die-cut or punched on the outer periphery of the disc and the keyway is located on the inner diameter as shown. In small machines, the armature stampings are keyed directly to the shift. Usually these laminations are perforated for air ducts which permit axial flow of air through the armature for cooling purposes. Such ventilating holes are clearly visible in the laminations shown in Figs 7,8 and 9.

Fig 9



SEGMENTAL LAMINATION

Up to armature diameters of about one metre, the circular stampings are cut out in one piece as shown in Fig 8. But above this size, these circles, especially of very thin sections, are difficult to handle because they tend to distort and become wavy when assembled together. Hence, the circular laminations, instead of being cut out

in one piece, are cut in a number of suitable sections of segments which form part of a complete ring.

A complete circular lamination is made up of four or six or even eight segmental laminations. Usually, two keyways are notched in each segment and are dovetailed or wedge-shaped to make the laminations self-locking in position as shown in Fig 9.

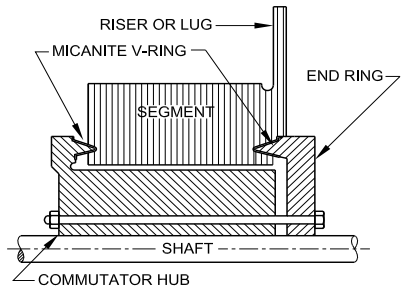
The purpose of using lamination is to reduce the loss due to eddy currents. Thinner the laminations are, greater the resistance offered against eddy current loss.

Armature windings: The armature windings are usually former-wound. These are first wound in the form of flat rectangular coils and are then pulled into their proper shape with a coil puller. Various conductors of the coils are insulated from each other. The conductors are placed in the armature slots which are lined with tough insulating material. After placing the conductors in the slot, this slot insulation is folded over the armature conductors, and is secured in place by special, hard, wooden or fibre wedges.

Commutator: The function of the commutator is to facilitate collection of current from the armature conductors. It rectifies i.e. converts the alternating current induced in the armature conductors into uni-directional current for the external load circuit. It is of cylindrical structure and is built up of wedge-shaped segments of high conductivity, hard-drawn or drop-forged copper. These segments are insulated from each other by thin layers of mica. The number of segments is equal to the number of armature coils.

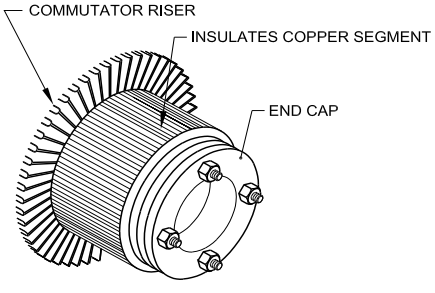
Each commutator segment is connected to the armature conductor by means of a copper lug or riser. To prevent them from flying out under the action of centrifugal forces, the segments have V-grooves, these grooves being insulated by conical micanite rings. A sectional view of a commutator is shown in Fig 10, whose general appearance when assembled is shown in Fig 11.

Fig 10



SECTIONAL VIEW OF COMMUTATOR

Fig 11

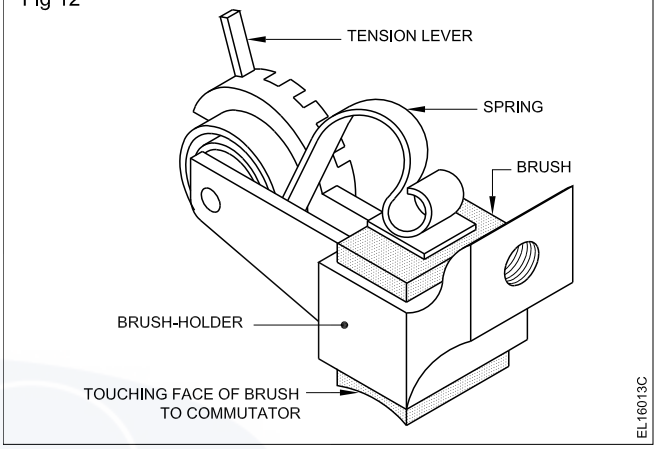


COMPLETE ASSEMBLY OF COMMUTATOR

Brushes: The brushes whose function is to collect current from the commutator are usually made of carbon and graphite and are in the shape of a rectangular block.

These brushes are housed in brush-holders, shown in Fig 12, which have a box-holder for the brush, a spring to maintain the brush tension and a hole to fix the holder to the rocker arm. The brushes can slide in the rectangular box, open at both ends. The brushes are made to bear down on the commutator by a spring whose tension can be adjusted by changing the position of the tension lever in the notches. A flexible, copper pigtail mounted at the top of the brush conveys the current from the brushes to the holder. The number of brushes per spindle depends on the magnitude of the current to be collected from the commutator.

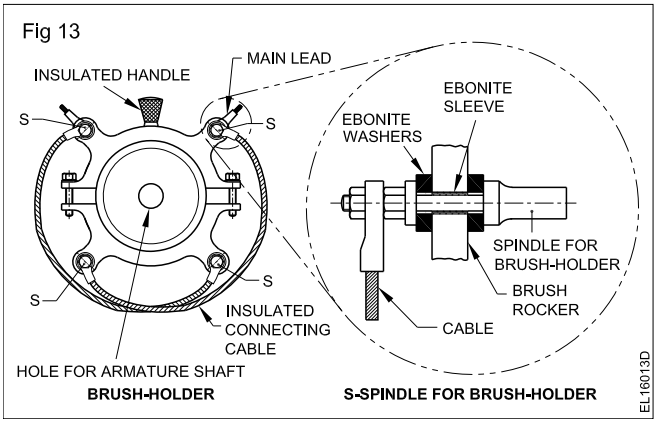
Fig 12



Brush-rocker: The spindle is used to have a number of brushes connected in a large machine. There may be only two brushes for a small machine. All the spindles are insulated and attached to the brush rocker.

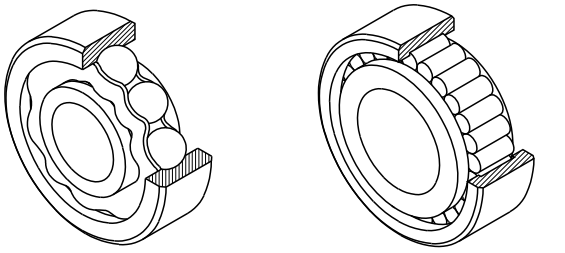
The brush-rocker may either be supported by a bearing cover in a small machine or by brackets attached to the yoke as shown in Fig 13. The brush position to the neutral axis can be set by changing the position of the brush-rocker.

Fig 13



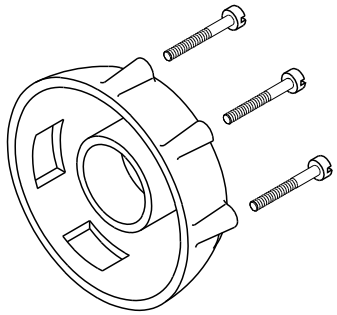
Bearings (Fig 14): Because of their reliability, half-bearings are frequently employed, though for heavy duties roller bearings are preferable. The ball and rollers are generally filled with hard oil for quieter operation and for reduced bearing wear. When sleeve bearings are used, these are lubricated by ring oilers fed from an oil reservoir in the bearing bracket.

Fig 14



End plates (Fig 15): The bearings are housed in these end plates, and they are fixed to the yoke. They help the armature for frictionless rotation and to position the armature in the air gap of the field poles.

Fig 15

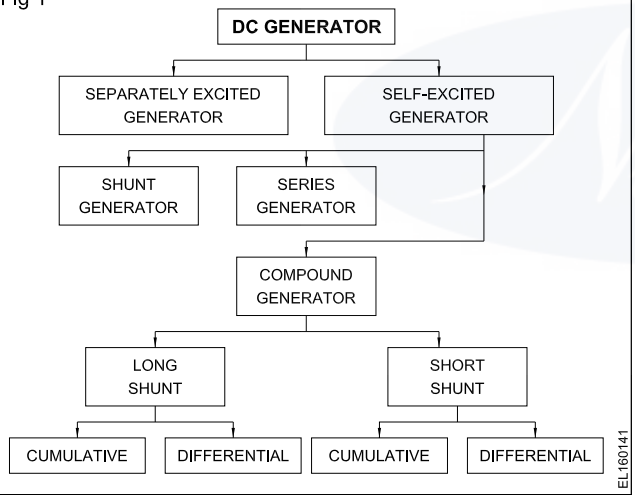


Types of DC generators

Objectives: At the end of this lesson you shall be able to
• classify and identify the different types of DC generators and their terminal markings.

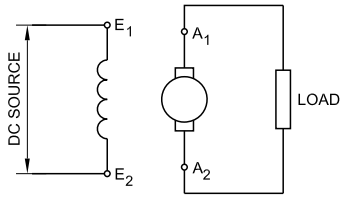
Types of DC generators: The type of a DC generator is determined by the manner in which the field excitation is provided. In general, the methods employed to connect the field and armature windings, fall into the following groups. (Fig 1)

Fig 1



Separately excited generator: The field excitation for a separately excited generator, shown in Fig 2, is supplied from an independent source, such as storage battery, separate DC generator or rectified DC supply from an AC source.

Fig 2



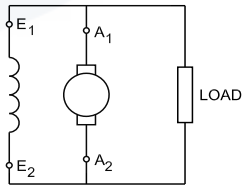
CONNECTION DIAGRAM OF SEPARATELY EXCITED DC GENERATOR

The field excitation voltage may be the same as that of generated (armature) voltage or may differ. Generally, the excitation voltage will be of low voltage, say 24, 36 or 48V DC.

Self-excited generator: The field excitation is provided by its own armature. In this type of generators, initially the voltage is built up by residual magnetism retained in the field poles. Self-excited generators may be further classified as shunt, series and compound generators.

Shunt generator: The field winding is connected to the armature terminals as shown in Fig 3. (i.e. shunt field winding is connected in parallel with armature winding). The shunt field contains many turns of relatively fine wire and carries a comparatively small current only which is a small percentage of the rated current of the generator.

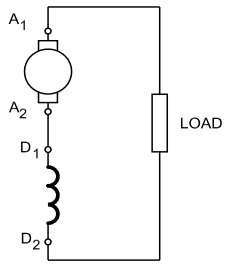
Fig 3



SHUNT GENERATOR

Series generator: The field winding is connected in series with the armature winding as shown in Fig 4. The series field winding has a few turns of heavy wire. Since it is in series with the armature it carries the load current.

Fig 4

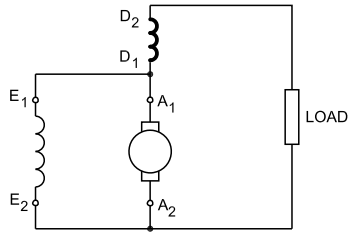


SERIES GENERATOR

Compound generator: The field excitation is provided by a combination of shunt and series field windings.

Short-shunt compound generator: This is a generator in which the shunt field is directly across the armature as shown in Fig 5.

Fig 5

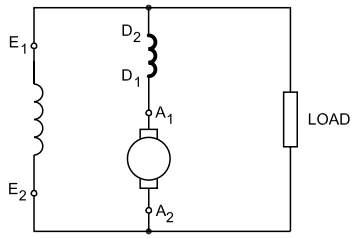


SHORT SHUNT COMPOUND GENERATOR

EL160145

Long-shunt compound generator: This is a generator in which the shunt field is connected after the series field as shown in Fig 6.

Fig 6

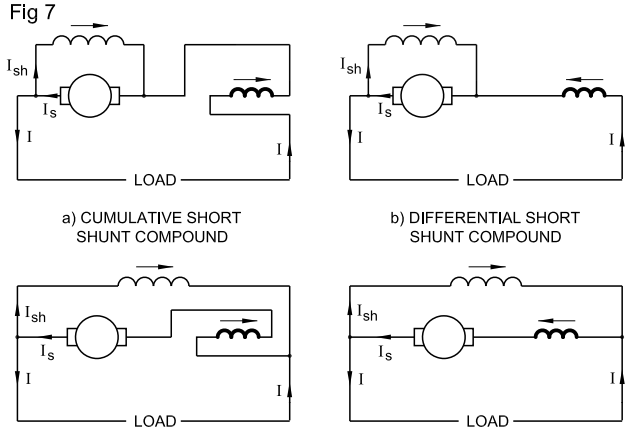


LONG SHUNT COMPOUND GENERATOR

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Differential and cumulative compound generator: The compound generators can also be further classified as cumulative and differential. In cumulative compound generators the magnetising forces of the shunt and the series field ampere-turns are cumulative, i.e. they both tend to set up flux in the air gap in the same direction. However, in case the ampere turns of the shunt widning oppose those of the series winding, the machine is said to be differentially compound would generator. Both the types are shown in Fig 7.

Fig 7



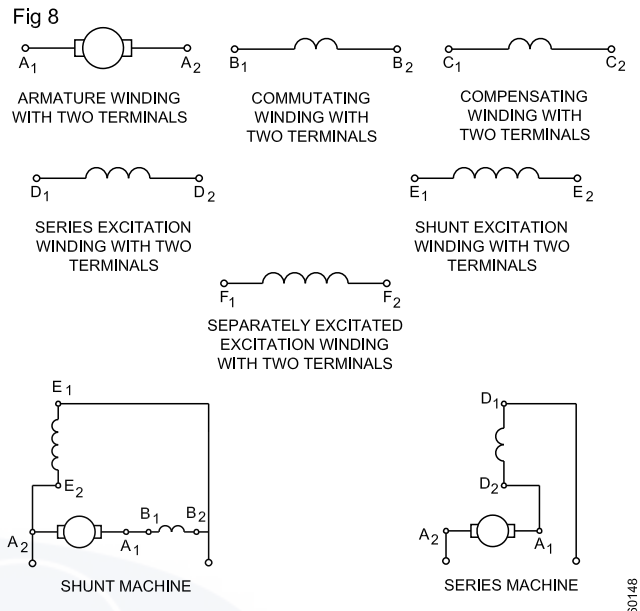
TYPES OF DC COMPOUND GENERATORS

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Terminal markings : As per BIS 4718-1975 the terminal markings for DC commentator machines shall be according to the marking principles stated below.

- Windings are distinguished by capital letters.
- End points and intermediate points of windings are distinguished by a numerical suffix.
- Winding letters for DC windings are chosen from the earlier part of the alphabet.(Fig 8)

Fig 8



TERMINAL MARKING OF DC MACHINES AS PER BIS

EL160148

Armature circuit resistance and its relation with different types of windings and brush resistance

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

- **state the different types of armature winding and determine the number of parallel paths in armature**
- **explain the armature circuit resistance - total armature conductor resistance - parallel path - brush resistance - brush voltage drop - grade of brushes.**

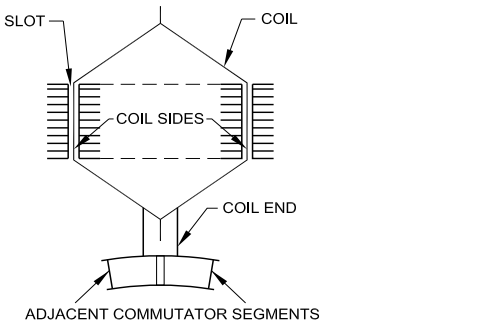
Armature windings: We have seen earlier, when a single loop conductor is rotated through a magnetic field, an alternating voltage is induced in it. This alternating voltage can be changed into direct voltage (rectified) by the commutator. In practice, there are several coils in the armature, each with a large number of turns laid in the slots of the armature core. This arrangement of the coil is called armature winding. The ends of the coils are soldered to the commutator raisers, depending on the kind of winding i.e. lap or wave, which decides the number of parallel paths in the armature.

A preliminary knowledge about the different types of winding is essential to tackle problems related to the calculation of induced voltage in various types of generators.

Lap and wave windings could readily be identified by the manner in which the coil ends are connected to the commutator bars. As shown in Fig 1, in a simplex lap winding, the ends of a coil are connected to adjacent commutator segments. Fig 2 shows the simplex wave winding in which the coil ends are connected to the commutator segments almost equal to the distance between poles of the same polarity.

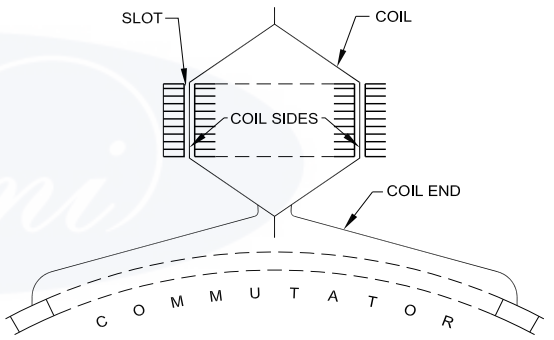
Table 1 shows the main differences between lap and wave winding.

Fig 1



COIL END CONNECTION TO THE COMMUTATOR OF A SIMPLEX LAP WINDING

Fig 2



COIL END CONNECTION TO THE COMMUTATOR OF A SIMPLEX WAVE WINDING

TABLE 1

Lap winding	Wave winding
The two ends of each armature coil are connected to adjacent commutator segments in the case of simplex, two segments apart in duplex and three segments apart in triplex.	The two ends of each coil connect to the commutator segments placed between adjacent poles of the same polarity.
There are as many parallel paths for current as there are field poles in the case of lap winding No. of parallel paths = Number of poles x plex of the winding.	There are two parallel paths regardless of the number of field poles in the case of simplex wave winding. Number of parallel paths in wave windings = 2 x plex of the winding where plex for-simplex is 1, duplex is 2 and triplex is 3.
The number of brush positions is equal to the number of poles.	Only two brush positions are required regardless of the number of field poles.
Used for machines having low voltage and high current capacity.	Used in machines having low current and high voltage capacity.

DC armature circuit - voltage drop and its importance: One of the major reasons for the drop in voltage at the terminals of a loaded generator is due to armature voltage drop. This depends on the armature circuit resistance and the armature current. A thorough understanding of the armature resistance, apart from helping an

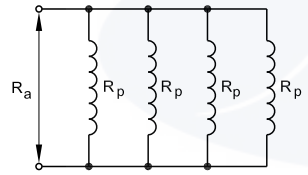
electrician to calculate the efficiency of a DC machine, is of great help to check the correctness of the rewound armature without physically checking the number of turns and the size of the winding wire. This is done in all established factories, where a record is maintained to indicate voltage drop across the armature of each DC machine, at a specified armature current. Any variation from this recorded value to the value obtained from the rewound armature (having the same grade of brushes), clearly indicates either the size of the winding wire or the number of turns has changed, and the performance of the machine will not be the same as earlier. Normally armature circuit resistance will be in the order of one ohm or below.

Voltage drop: This could be calculated by finding the total resistance of the armature conductors in series per parallel path and dividing it by the number of parallel paths, but in actual practice it is calculated by the voltage drop method.

Refer to the circuit shown in Fig 3.

Let 'r' be the specific resistance of the armature conductors,
'a' be the area of the cross-section of the armature conductor in sq. cm.
'L' be the length of the conductor in cms.
'R_a' - armature resistance in ohms.
'R_p' - resistance per parallel path in ohms.

Fig 3



4-POLE SIMPLEX LAP-WOUND MACHINE WITH 4 PARALLEL PATHS

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Method of calculating the armature resistance: Let P be the number of parallel paths in the armature,
Z be the total conductors in armature.
Then the number of conductors per parallel path = Z/P.

Resistance per parallel path $R_p = \frac{Z}{P} \times \frac{\rho L}{a}$

Armature resistance in ohms = R_a

$$R_a = \frac{R_P}{\text{No. of parallel paths}}$$

Example: In a DC 4-pole lap-wound machine the resistance of one conductor is 0.1 ohm; there are 48 conductors. Calculate the armature resistance.

Since it is lap-wound,

No. of parallel paths=No.of poles (assuming simplex winding).

Therefore, No. of parallel paths = 4.

Conductors per

parallel path $= \frac{\text{Total No. of conductors}}{\text{No. of parallel paths}} = \frac{48}{4} = 12.$

Resistance per parallel path = 12 x 0.1 = 1.2 ohms.

Therefore the total armature resistance for 4 parallel paths = 1.2/4 = 0.3 ohms.

In addition to this, the total armature circuit resistance includes brush resistance and brush contact resistance. Hence the value measured will be more than 0.3 ohms in the above example.

Brushes: The main function of the brushes is to transfer the energy present at the armature to the external circuit. Brushes are usually made from a compound of carbon and graphite. Graphite content provides a self-lubricating action as the brushes rub against the commutator.

The most important characteristics of brushes are specific resistance, friction coefficient, current-carrying capacity, maximum operating speed and abrasiveness.

Specific resistance is the resistivity of the brush material.

Friction coefficient is the ratio of the force on the surface to the force required to slide another surface over it, and is influenced by the brush temperature, pressure, current, atmospheric condition, mechanical condition, commutator material, surface films and speed. The resulting high brush friction often causes the brush to chatter and chip. Since friction serves no useful purpose, low brush friction is preferred. Low brush friction will have a friction coefficient in the order 0.22 or below whereas a high brush friction will have a friction coefficient above 0.4.

Current-carrying capacity: It depends on the brush material, operating conditions, type of ventilation and operating temperature. If the temperature is high due to high current density, the brush life will be shortened.

Speed: The allowable speed depends upon the characteristics of the brush material, spring pressure, current density, types of brush-holders, brush angle and the area of contact of the commutator.

Abrasiveness: The ability of the brush to prevent excessive build up of film usually caused by corrosive or oily atmosphere is called the abrasiveness or polishing action.

Grade and types of brushes: There are four major brush families classified according to the manufacturing process.

- Graphite
- Carbon and carbon graphite
- Electro-graphite
- Metal graphite

Graphite: Graphite brushes are usually made of natural or artificial graphite. Natural graphite contains impurities. Artificial graphite is usually pure. It is used in fractional HP machines.

Carbon and carbon graphite: It has high hardness, high mechanical strength, cleaning action and long brush life.

Electro-graphite: It consists of various forms of amorphous carbon. These brushes usually have higher current density, lower strength, lower hardness and lower specific resistance. They generally have good commutating characteristic but may not always be used because of the lesser requirement of high current, and the requirement of severe mechanical conditions.

Metal graphite: It is generally made from natural graphite, and finally divided into metal powders. Copper is the most common metal constituent, but silver, tin, lead and other metals are sometimes used. The metal content ranges from approximately 10 to 95% by weight. A high metal content provides greater current capacity, higher mechanical strength and also certain combined characteristics of contact drop and friction. It is used where high current and low voltages are involved. Its typical applications are for electroplating generators, battery chargers, welding generators and other high current equipment.

Whenever the brushes are to be changed, the same grade of brushes is to be procured and used to get the same performance characteristics from the machine.

As an accepted procedure, every electrician should identify the brush grade of each machine, either from service manuals or by visual inspection, and record it in the maintenance card of the machine for proper selection of replacement at a later date.

Brush contact resistance is the resistance offered between the brush and the commutator for the current flow. This resistance value depends upon the grade of brushes, material used for the commutator, contact area between the brush and commutator, and the brush tension. Normally the brush contact resistance is measured in terms of voltage drop at specific current ratings.

Table 1 shows the different grades of brushes and their characteristics.

TABLE 1

Characteristics of brushes

Grade of carbon	**Max. current density A/cm^2**	**Max.contact resistance ohms/cm^2**	**Pressure on commutator kg/cm^2**	**Voltage drop in volts**
Soft graphite	9 to 9.5 A/cm^2	–	0.12	1.6
Copper carbon	15 to 16 A/cm^2	0.00000465	0.15-0.18	0.25-0.35
Carbon	5.5 to 6.5A/cm^2	0.000062	0.22-0.27	2
Electro-graphite	8.5 to 9 A/cm^2	0.000031	0.22	1.7-1.8

Building up of voltage and magnetization characteristic of DC shunt generator

Objectives : At the end of this lesson you shall be able to
- **explain the conditions and method of building up of voltage in a DC shunt generator**
- **explain the method of creating residual magnetism in the poles of a DC generator**
- **analyse the magnetization characteristic of a DC shunt generator**
- **estimate the value of field critical resistance in the DC shunt generator.**

Condition for a self-excited DC generator to build up voltage: For a self-excited DC generator to build up voltage, the following conditions should be fulfilled, assuming the generator is in sound condition.

- There must be residual magnetism in the field cores.
- The field resistance should be below the field critical resistance value.
- The generator should run at the rated speed.
- There must be a proper relation between the direction of rotation and the direction of field current. It could be explained as stated below.

The polarity of the induced voltage must be in such a direction as to produce the field current to assist the residual magnetism.

The polarity of the induced emf depends upon the direction of rotation and the polarity of the field poles depends upon the field current direction.

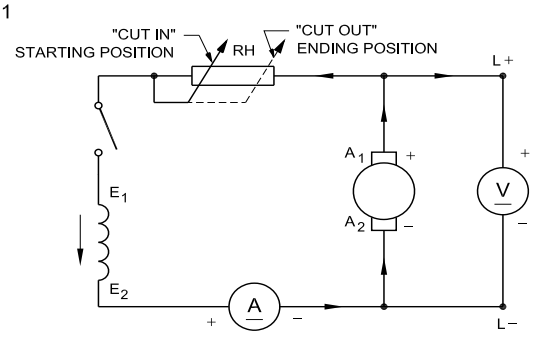
Even after fulfilling the above conditions, if the self-excited DC shunt generator fails to build up voltage, there may be other reasons as listed in Table 1.

TABLE 1

Sl.No.	Causes	Reasons	Remedies
1	A break or opening in the field or armature circuit.	Break or loose connection in the field or in the armature winding/circuit.	Locate the open circuit and rectify.
		High resistance in the field circuit beyond the field critical resistance value.	Reduce the resistance of the field regulator.
2	Loose brush connections or contacts.	Improper brush contact/loose brush connections.	Check the brushes for excessive wear, and replace them, if necessary. Check the commutator for pitting. If necessary, turn down the commutator. Always clean the commutator when poor brush contat is discovered. Check the brush tension and readjust it, if necessary Tighten any loose connections.
3	A dirty or severely pitted commutator.	Severe sparking due to overload.	In this case, follow the same procedure as outlined above.
4	A short circuit in the armature or field	Overload or excess heating.	Do a resistance check, ascertain, locate and remove the fault.

Method of building up voltage in a DC shunt generator: Fig 1 shows the circuit diagram for building up voltage in a DC shunt generator. When the generator is made to run at its rated speed initially, the voltmeter reads a small amount of voltage say, 4 to 10 volts. It is due to the residual magnetism. Since the field coils are connected across the armature terminals, this voltage causes a small amount of current to flow through the field coil. If the current flow in the field coils is in the correct direction, it will strengthen the residual magnetism and induce more voltage.

Fig 1



DC SHUNT GENERATOR

As such, the generated voltage will rise marginally. This rise in voltage, in turn, will further strengthen the increasing field current and induce more voltage. This rise in voltage, in turn, will further strengthen the increasing field current. This cumulative action will build up voltage until saturation is reached. After saturation, any increase in the field current will not increase the induced voltage. However, the whole procedure of building up of voltage takes a few seconds only.

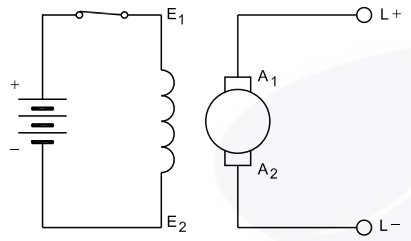
Method of creating residual magnetism: Without residual magnetism, a self-excited generator will not build up its voltage. A generator may lose its residual magnetism due to any one of the following reasons.

- The generator is kept idle for a long time.
- Heavy short circuit.
- Heavy overloading.
- The generator is subjected to too much heat.

When the generator loses its residual magnetism, it can be re-created as stated below.

Flashing of field: One of the methods to create residual magnetism is called the flashing of the `field'. This can be done by connecting the shunt field across a battery or any DC source for a few minutes as shown in Fig 2.

Fig 2



FLASHING OF THE FIELD

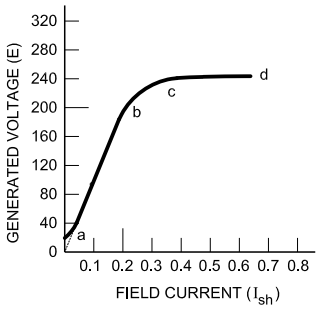
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While flashing the field, the polarity of the magnetic field, now created, should be the same as that of the residual magnetic field it lost earlier.

In practice, this checking may not be possible. Alternatively note the polarity of the DC supply used for flashing the field and the corresponding field terminals. Run the generator in the specified direction at its rated speed. Measure the residual voltage induced and its polarity. Check whether the polarity of the residual voltage is the same as that of the DC generator. If found reversed, flash the field again by connecting the supply voltage in reverse polarity.

Magnetisation characteristic of a DC shunt generator: The magnetisation characteristic curve shown in Fig 3 gives the relation between the field current and the induced voltage. Referring to the emf equation, the induced emf in a generator is proportional to the flux per pole and the revolutions per minute of the generator. At a constant speed, the generated emf becomes directly proportional to the field flux. In a given machine, the flux depends upon the field current. The graph (Fig 3) illustrates this feature. Because of the residual magnetism, the curved part below point `a' does not start at zero. Between the points `ab', the curve is in almost a straight line indicating that the voltage in the area is proportional to the field current. Between points `b' and `c' a large increase in field current causes only a slight increase in the voltage. It indicates that the field cores are reaching saturation and this part of the curve is called the `knee' of the curve. Between points `c' and `d', the curve is flat indicating that the increased field current is not able to increase the induced voltage. This is due to saturation of the field cores. Because of saturation, the field flux becomes constant, and the induced voltage will not be in a position to increase further. This curve is also called a no-load or open-circuit characteristic curve.

Fig 3

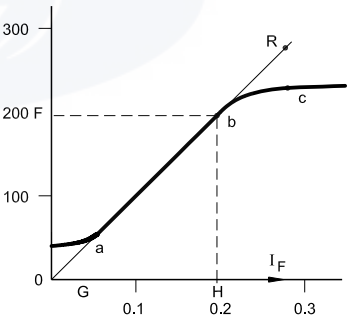


MAGNETISATON CHARACTERISTIC OF A DC SHUNT GENERATOR

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Critical resistance: If the shunt field circuit resistance is too large, it does not allow sufficient current to flow into the field to build up its voltage. In other words, it acts like an open field. Therefore, the field circuit resistance should be smaller than a value called critical field resistance. Critical field resistance is the highest value of resistance of the shunt field circuit with which a DC shunt generator can build up voltage. Beyond this value of resistance, the generator fails to build up voltage. The value of the critical resistance can be determined by drawing a tangential line to the open circuit characteristic curve as shown in Fig 4.

Fig 4



FIELD CRITICAL RESISTANCE

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For example, by drawing the tangent on the open-circuit characteristic curve as shown by line OR of Fig 4, we find the tangent is parting at point `b' from the curve. By drawing ordinates from point `b' to x and y axis, the value of critical resistance (R_c) can be determined as below.

R_c = Field critical resistance

$$= \frac{\text{voltage represented by the tangent}}{\text{current represented by the tangent}}$$

$$= \frac{OF}{OH} = \frac{200\ V}{0.2\ A} = 1000 \text{ ohms.}$$

Field circuit resistance is the sum of the field resistance and field rheostat resistance. This value should be less than, say 1000 ohms (field circuit resistance) to enable the generator to build up voltage, if the generator is intended to self-excite. Normally this happens when the field regulator resistance is set at a high value.

DC Shunt generator - Load characteristics and application

Objectives: At the end of this lesson you shall be able to
- **describe the external and internal characteristics of a DC shunt generator and their application**
- **estimate the value of critical resistance of the load when the DC generator has to start with load.**

The external/load characteristic of a shunt generator:The external/load characteristic is important for judging the suitability of a generator for a particular purpose. When the DC shunt generator is loaded, it is found that the terminal voltage drops with increase in the load current. In a shunt generator, the field current appears to be constant, and, hence, `V' also should remain constant and be independent of the load. But, it is not so practically. There are two main reasons for the drop in terminal voltage. They are :

– armature resistance drop (directly)
– armature reaction drop (indirectly).

Because of the above two reasons, the terminal voltage is reduced. This in turn affects the field current also. The decreased field current reduces the field flux which further reduces the induced emf.

Armature resistance drop: According to formula

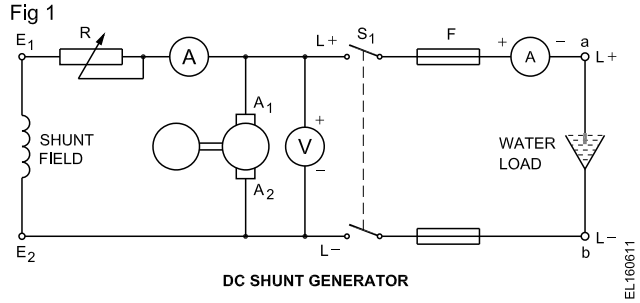
Terminal voltage = Induced emf – armature voltage drop
$V = E - I_a R_a$
where I_a is the armature current
and R_a is the armature circuit resistance.

As such, when the load current is increased, more voltage is dropped in the armature circuit. Hence, the terminal voltage `V' decreases, under load condition.

Armature reaction drop: Due to the demagnetising effect of armature reaction, the main pole flux is weakened, and the induced emf (E) will be reduced in its magnitude.

The external characteristic gives the relation between terminal voltage and load current. Fig 1 gives the circuit diagram to determine this characteristic. The generator is first built up to its rated voltage. Then it is loaded in suitable steps up to full load. The terminal voltage and the corresponding load currents are noted for each step.

Fig 1

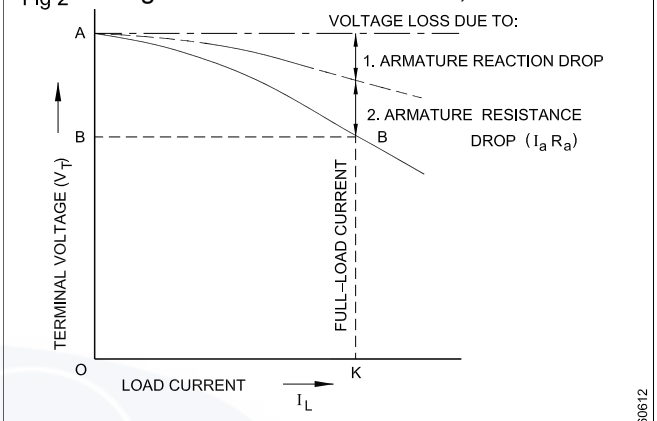


DC SHUNT GENERATOR

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In this experiment, the field current has to be kept constant. This is due to the fact that when terminal potential decreases on load, the field which is connected across the armature will have a decreased current. This effect, if allowed, will reduce the field flux, thereby, decreasing the induced voltage. This effect cumulatively reduces the terminal voltage further. From the obtained values of the terminal voltage V_T and load current I_L, the external characteristic curve is plotted as shown in Fig 2, keeping in V_T on `Y' axis and I_L on X axis. From the curve it will be observed that the no-load voltage OA is maximum, and it falls to OB when loaded, to indicate that the full load current value is OK as noted in the name-plate of the generator.

Fig 2

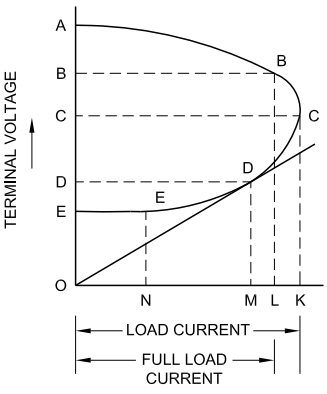


EXTERNAL CHARACTERISTIC CURVE OF DC SHUNT GENERATOR

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Fall of voltage from no load to full load, which is due to armature reaction, and the armature voltage drop are found to be not appreciable. Normally the generators are designed to deliver full load current I_L, and the fall of voltage will be about 5 to 8 percent of the no-load voltage which can be regarded as negligible. If the load current is further increased by decreasing the load resistance, the curve reaches a point `C' as shown in Fig 3. At this point, the terminal voltage falls to OC which will be an appreciable fall when compared to the no-load terminal voltage. At this point `C', though the load current is maximum (OK), the terminal voltage will be much less than the no-load voltage.

Fig 3



EXTERNAL CHARACTERISTIC CURVE (FULL CURVE)

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However, when the load resistance is further decreased the load current decreases to OM and V_T is reduced to `OD', that means the load current cannot be increased beyond OK and the point `C' is called the breakdown point. It is the maximum possible current that a generator can supply. Beyond this point `C', the curve drops rapidly with decrease in the load resistance, indicating that the load current is also decreasing, instead of increasing. At point `E' the generator is virtually short-circuited, and all the voltage induced is dropped to near zero due to IaRa drop and armature reaction. Rather, we can say OE is the residual voltage of the generator. Practically all the generators operate only on the portion `AB' of the curve where the efficiency of the generator is maximum.

Internal characteristic: The internal characteristic gives the relation between induced voltage and the armature current. In a shunt generator,

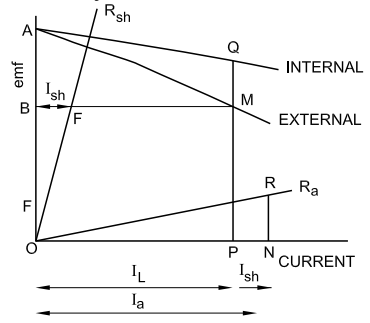
$Ia = I_L + I_{sh}$ $\quad E = V_T + I_aR_a$

$$I_{sh} = \frac{V_T}{R_{sh}}.$$

So, E/I_a curve can be obtained from the external characteristic shown in Fig 2. By plotting `$I_{sh}$' horizontally against `V', we get Rsh line which is a straight line through the origin, but because of the high resistance of the shunt field it has a very steep gradient as shown in Fig 4. Also draw the armature resistance(R_a) line by plotting the drop in voltage against the armature current as shown in Fig 4. Take any point `M' on the external characteristic (Fig 4) and draw the perpendicular `MP'. Then for the given terminal voltage the load current I_L = OP. Draw 'MB' horizontally, then BF = I_{sh}, and mark off PN = BF in the 'X' axis.

Then ON = OP + PN = $(I_L + I_{sh}) = I_a$.

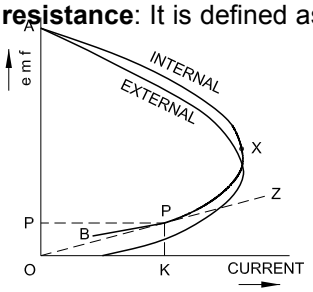
Fig 4



Draw a line vertically from N to meet the armature resistance line Ra at `R'. Then, the vertical line `RN' is equal to the drop in the armature and, therefore, if the line PM is extended further to point `Q', making MQ = RN, the total length `PQ' is the sum of the terminal voltage and total armature drop, which is equal to the emf generated. Thus a point `Q' on the internal characteristic is obtained, and the total (internal) characteristic can be drawn by joining points A and Q.

If the load resistance is decreased, then the curve turns back as in Fig 5. If the load resistance is too small, then the generator is short-circuited and there is no generated emf due to heavy demagnetisation of the main poles.

Fig 5



INTERNAL & EXTERNAL CHARACTERISTIC CURVE

Load critical resistance: It is defined as the minimum value of load resistance with which the generator builds up voltage, and, just below this value of load resistance the DC shunt generator will fail to build up its voltage when started with the load. When the DC shunt generator is started with the load, the terminal voltage may not raise beyond about 10V, the reason is the load resistance is so low, as if the generator is short-circuited. In Fig 5 the tangent line `OZ' to the internal characteristic APB is drawn. Its slope will give the value of the load critical resistance. As the DC shunt generator will not build up emf when made to build up with load below this value of resistance, it is called the load critical resistance.

Load critical resistance in ohms =

$$\frac{\text{Voltage at point 'P'}}{\text{Load current at point 'P' (amps)}} = \frac{OP}{OK}$$

There are thus two critical resistances for a shunt generator, one for the field circuit and the other for the load external circuit.

Applications of DC shunt generator: According to the load characteristic of the DC shunt generator, the drop in voltage from no load to full load is not appreciable, up to its rated value of load current. Hence, it can be called a constant voltage generator. Therefore, it can be used for constant loads like:

- centrifugal pump
- lighting load
- fans
- battery charging and electroplating.

Continuity testing and insulation resistance in D.C. machine

Objectives: At the end of this lesson you shall be able to
- **state the necessity of measuring the insulation resistance of an electrical machine**
- **state the frequency of tests**
- **state the required conditions for the tests**
- **state the reasons for the low value of insulation resistance in the machines**
- **state the method of improving the insulation resistance of DC machines.**

Necessity of measuring insulation resistance: The most important aspect in the maintenance of DC machines is taking care of the insulation. Electrical insulation of DC machine windings is designed for the satisfactory operation at the specified voltage, temperature and to retain the electrical and mechanical strength and the dimensional stability over many years of operation. The insulation resistance of DC machines in service should be checked periodically, preferably every month. The possibility of reduction in the value of insulation resistance is due to the continuous working of the machine under full load condition, the heat generated in the winding and local atmospheric moisture, dust and dirt. If they are not checked in time, the insulation becomes weak and the winding will loose its dielectric property, and will ultimately lead to failure of the machine. Periodical checks and measurement of insulation resistance and improvement thereof to the required level will ensure prevention of failure of insulation, and thereby, the breakdown of the machine.

A common device for measuring insulation resistance is a direct indicating insulation tester or Megger. The measurements are made at voltages 500/1000 volt DC depending upon the voltage rating of the machine.

Measurement of insulation resistance: Insulation resistance shall be measured between the winding and frame (earth), and between windings.

For low and medium voltage rated machines, the insulation resistance, when the high voltage test is applied, shall not be less than one megohm as per B.I.S. 9320 - 1979. The insulation resistance shall be measured with a DC voltage of about 500 V applied for a sufficient time for the reading of the indicator to become practically steady, such voltage being taken from an independent source or generated in the measuring instrument.

When it is required to dry out windings at site to obtain the minimum value of insulation resistance, it is recommended that the procedure for drying out as specified in IS:900-1965 may be followed.

Frequency of test: Periodical checks or tests are predetermined in preventive maintenance programmes with a forethought. The planning of the preventive maintenance (PM) schedule should be based on the past experience of maintenance personnel, and the recommendations made by the machine manufacturer. Usually the measurement of insulation resistance is a must during the period of overhauls. The duration of overhaul will be once in 6 months, ideal for DC machines where they are working continuously. Overhauling is done once a year, for such of those machines as are not working continuously. The overhauling is done during plant shut-down periods.

However in DC machines where the overhaul interval is too long, or delayed, it is advisable to have constant vigil and check the insulation resistance at least once a month regularly, and maintain a record of the values of the insulation resistance tests as shown in Table 1.

Required conditions for test: The high potential dielectric test and the insulation resistance test are the principal methods of evaluating insulation capability and condition of the machine. The insulation resistance test is often used as a measure of the condition of the winding. Insulation resistance is the ratio of the applied voltage to the leakage current which passes in the circuit at some specified time after the voltage is applied. Direct, rather, than alternating voltages are used for measuring insulation resistance.

The principal currents affecting insulation resistance on application of the test potential for sufficient time are (1) leakage current over the winding surface (2) conduction in current through the insulation material and (3) absorption current in the insulation. The first two currents are steady with time, but the last current delays approximately exponentially from an initial high value. Such insulation resistance measurements are affected by surface conditions (dirt or moisture on the windings), moisture within the insulation wall and the insulation temperature. The magnitude of the test potential may also affect the insulation value, especially if the insulation is not in good condition. Therefore, it is desirable to use insulation resistance as a

TABLE 1

Insulation resistance test

Date	Time	Weather condition	Duty cycle	Test between terminals	Insulation resistance	Remarks

measure to determine the condition of the machine over a period of years, and to make readings under similar conditions each time and record the values in the test card of the machine in a table similar to Table 1. However, before testing the winding for insulation resistance, it is recommended that the continuity test should be conducted in the armature and field windings to ensure soundness of the respective circuits. As sometimes continuity tests will not reveal internal short circuits, resistance measurement test is recommended, and a record should be maintained for comparison at intervals.

Reasons for low value insulation resistance: The low value of insulation resistance in DC machines is due to excess heat developed in the winding due to their routine working with full load condition or overloading at times or frequent starting with loads. In addition to this, high ambient temperatures are also the reason for low insulation resistance. The other possibility is accumulation of unnecessary local dust and dirt, carbonisation due to brush, local atmospheric moisture, acids and alkalies present in the surroundings of the machine etc. All these are collectively or individually responsible for the weakening of insulation resistance of the winding. Because of these conditions the dielectric property of the insulating material gets reduced, which, in turn, results in low or poor insulation resistance, responsible for the breakdown of the winding due to insulation failure.

Method of improving insulation resistance: On identifying the weak insulation resistance, during the course of preventive maintenance observation in a DC machine, it is necessary to improve the insulation resistance to restore it to a safe value.

Improvement of insulation resistance could be done by any one of the following methods after cleaning the dust and dirt from the machinery.

- By blowing hot air through the machines.
- By heating the machine with carbon filament or incandescent lamps.
- By dismantling and varnishing the winding of the machine.

The following steps are to be adopted for dismantling and varnishing.

- Measure the insulation resistance value between the windings and the frame of the machine and record the value.
- Mark and dismantle the machine.
- Remove dirt and dust in the field winding by blowing dry air with the help of an electric blower.
- Clean and remove dirt, dust and carbon on the armature with special attention to the commutators.
- Clean the brushes, brush-holders and rocker arms.
- Measure the insulation resistance of the winding with an insulation tester; note the values.
- Heat and dry the field coils and armature by external measures.
- Apply insulating varnish of air-drying type to field coils and armature conductors.
- Dry the varnish coating on field coils and armature by external means.
- Measure the insulation resistance and note the improved value of insulation resistance.
- Assemble the machine.
- Measure the insulation value between the windings and the frame of the machine; record the values. Compare these results with those of the first step and make sure the present value shows improvement.
- Connect the machine to the system and run it to check its normal working condition.

Measurement of Power

Objectives: At the end of this lesson you shall be able to
- **state the advantages of measuring power directly**
- **state the types of single phase wattmeters**
- **explain the construction and working of the induction type single phase wattmeter**
- **choose the correct method of connecting pressure and current coils of the wattmeter in a circuit to reduce measurement errors**
- **explain the method of connecting wattmeters through instrument transformers.**

Power in a single phase AC circuit can be calculated by using an ammeter, a voltmeter and a power factor meter with the help of the formula

Power in a single phase circuit = EI Cos ø watts.

In the same way power in a 3-phase balanced circuit can be measured by using one ammeter, one voltmeter and one power factor meter with the help of the formula

Power in a balanced 3 - phase circuit = $3E_P I_P \cos\phi$

or $\sqrt{3}\, E_L I_L \cos\phi$

where $E_P I_P$ are the phase values and

$E_L I_L$ are the line values

This indirect method of measuring power in an AC circuit has the following disadvantages.

- Low accuracy due to a number of meters.
- Reading errors due to a number of meter readings.
- Cumbersome connections.
- Involves calculation every time the load changes and hence not suitable for changing loads.

To get an on the spot true power reading, a wattmeter is used. The power dissipated in the circuit can be read directly from the scale of the meter. The wattmeter takes the power factor of the circuit into account and always indicates the true power.

The power in a DC circuit can be calculated by using the formulae.

- $P = E \times I$ watts
- $P = E^2/R$ watts
- $P = I^2R$ watts

The use of the above formulae in AC circuits will give true power only if the circuit contains pure resistance. Note that the effect of reactance is present in AC circuits.

Power in AC circuit: There are three types of power in AC circuits.

- Active power (True power)
- Reactive power
- Apparent power

Active power (True power)**:** The calculation of active power in an AC circuit differs from that in a direct current circuit. The active power to be measured is the product of $V \times I \times \cos\theta$ where $\cos\theta$ is the power factor (cosine of the phase angle between current and voltage). This indicates that with a load which is not purely resistive and where the current and voltage are not in phase, only that part of the current which is in phase with the voltage will produce power. This can be measured with a wattmeter.

Reactive power: With the reactive power (wattless power)

$$P_q = V \times I \times \sin\theta$$

only that part of the current which is 90° out of phase (90° phase shift) with the voltage is used in this case. Capacitors and inductors, on the other hand, alternatively store energy and return it to the source. Such transferred power is called reactive power measured in volt-ampere reactive or vars. Unlike true power, reacitve power can do no useful work.

Apparent power: The apparent power, $P_a = V \times I$.

The measurement can be made in the same way as for direct current with a voltmeter and ammeter.

It is simply the product of the total applied voltage and the total circuit current and its unit is volt-ampere (VA).

The power triangle: A power triangle identifies three different types of power in AC circuits.

- True power in watts (P)
- Reactive power in vars (P_q)
- Apparent power VA (P_a)

The relationship among the three types of power can be obtained by referring to the power triangle. (Fig 1)

Therefore

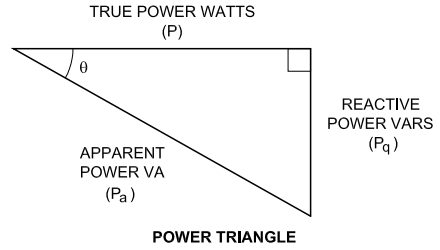
$P_a^2 = P^2 + P_q^2$ volt-amperes (VA)

where `P_a' is the apparent power in volt-ampere (VA)

`P' is the true power in watts (W)

P_q is the reactive power in volt-amperes. reactive. (VAR)

Fig 1



Wattmeter

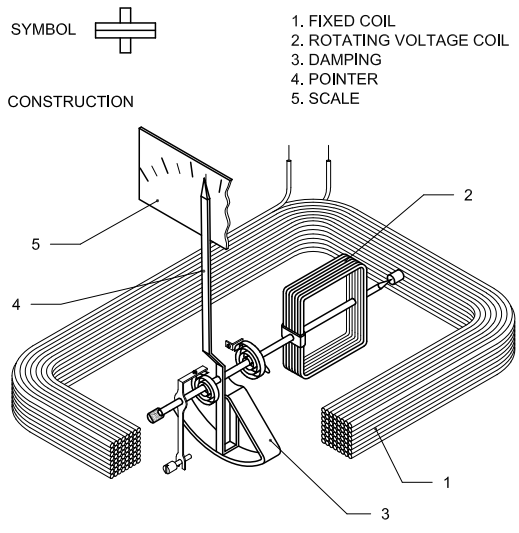
A power measuring meter, called a wattmeter, can be connected into a circuit to measure power instead of making two measurements and then calculating the power. The power dissipated can be read directly from the scale of the meter.

The wattmeter takes the power factor of the circuit into account and always indicates true power.

Principle: A wattmeter consists of two stationary coils connected in series, and one moving coil. (Fig 2) The stationary coils, wound with many turns of thick wire, have a low resistance. The moving coil. (Fig 2) wound with many turns of fine wire, has high resistance. For power measurements, the moving coil is connected across the source voltage with a series resistance of high value which determines the current through this coil in phase and proportional to voltage. The fixed coil is connected in series with the load, which can carry the load current.

The interaction of the two magnetic fields, produced by the fixed and moving coils, will cause the moving coil and its pointer to rotate in proportion to the voltage (across the load) and current (through the load).

Fig 2



Types of wattmeters

There are three types of wattmeters in use as stated below.

- Dynamometer wattmeter
- Induction wattmeter
- Electrostatic wattmeter

Dynamometer type, single phase wattmeter: This type is commonly used as a wattmeter. Construction details and the working of this type of meter have already been discussed in Ex.6.11. Hence the trainees are advised to read the information before proceeding further.

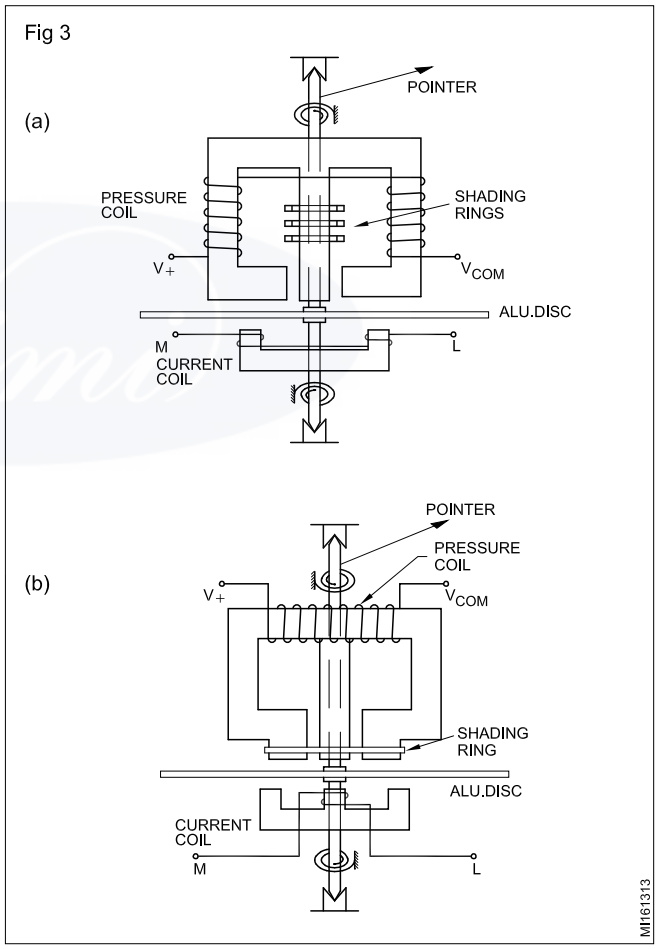
Induction type single phase wattmeter: This type of wattmeters could be used only in AC circuits whereas a dynamometer type wattmeter could be used in both AC and DC circuits.

Induction type wattmeters are useful only when the supply voltage and frequency are almost constant.

Construction: Induction wattmeters having two different types of magnetic cores are shown in Figs 3a and 3b.

Both the types have one pressure coil magnet and one current coil magnet. The pressure coil carries a current proportional to the voltage whereas the current coil carries the load current.

Fig 3



A thin aluminium disc is mounted on a spindle in between the space of the magnets and its movement is controlled by springs. The spindle carries a weightless pointer at one end.

Working: The alternating magnetic fluxes produced by the pressure and current coils cut the aluminium disc and produce eddy currents in the disc. Due to the interaction between the fluxes and the eddy currents a deflecting torque is produced in the disc and the disc tries to move. Control springs attached to the two ends of the spindle control the deflection and the pointer shows the power in watts on a graduated scale.

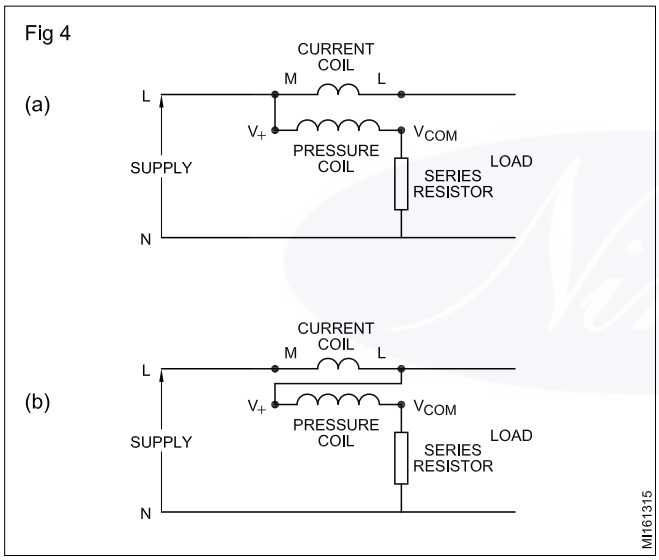
Shaded rings provided in the pressure coil (shunt) magnet could be adjusted in order to cause the resultant flux in the magnet to lag in phase by exactly 90° behind the applied voltage.

Method of connecting wattmeter in single phase circuits - pressure coil connection to reduce erroneous measurement.

There are two ways of connecting the pressure coil of the wattmeter as shown in Fig 4.

Both the methods shown in Figs 4a & b need correction in power measurement due to the reasons stated below.

Fig 4



In the method of connection shown in Fig 4a, the pressure coil is connected on the 'supply' side of the current coil, and hence, the error in power measurement is due to the fact that the voltage applied to the voltage coil is higher than that of the load on account of the voltage drop in the current coil. As such the wattmeter measures the load power in addition to the power lost in the current coil.

On the other hand, in the method of connection shown in Fig 4b, the current coil carries the small current taken by the voltage coil, in addition to the load current, thereby introducing errors in power measurement. As such the wattmeter measures the load power in addition to the power lost in the pressure coil.

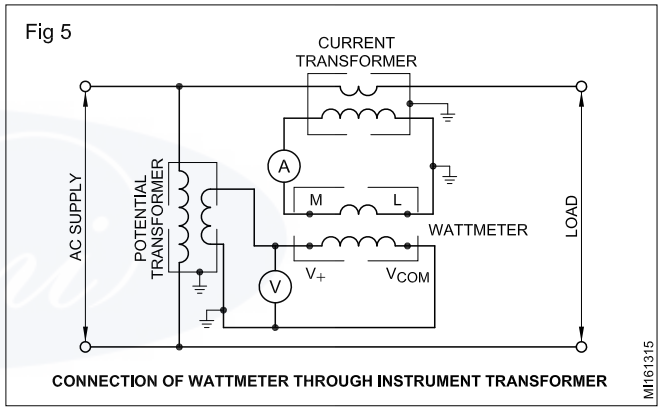
If the load current is small, the voltage drops in the current coill will be small, so that the method of connection, shown in Fig 4a, introduces a very small error and, hence, preferable.

On the other hand, if the load current is large the power lost in the pressure coil will be negligible when compared to the load power in the method of connection shown in Fig 4b, and, hence, a very small error is introduced resulting in the preference of this connection.

Connecting wattmeters through instrument transformer: Normally the rating of the current coil of the wattmeter is in the order of 1A, 5A, 10A, 20A, or 30 amps, whereas the pressure coil rating will be in the order of 110V, 220V, 300V, 500V. When the circuit in which the power to be measured has a current more than 30 amps and voltages more than 500V it is customary to use current and potential transformers along with the wattmeter to measure power in the circuit.

In practice, a wattmeter having a current coil rating of 5 amps and a pressure coil rating of 110V could be used along with the instrument transformers of different ratios to measure power in a variety of circuits having high current and high voltages. Connection of a wattmeter along with the instrument transformers is shown in Fig 5 in which an ammeter and a voltmeter are also connected in the circuit of the instrument transformers.

Fig 5



CONNECTION OF WATTMETER THROUGH INSTRUMENT TRANSFORMER

The primary winding of the current transformer is connected in series with the load and the secondary winding is connected in series with the current coil of the wattmeter and ammeter.

The primary winding of the potential transformer is connected across the supply, and the secondary winding is connected in parallel with a voltmeter and the potential coil of the wattmeter. For ensuring safety, one of the terminals of secondary winding and the casing of the instrument transformer are earthed.

Assuming there is negligible ratio and phase angle error in the instrument transformers, the power measured by the wattmeter needs to be multiplied by the C.T. and P.T. ratios to obtain the actual power consumed in the circuit.

Hence we have

Actual power consumed in the circuit = Ratio of CT x Ratio of PT x wattmeter reading.

***Example**:* A wattmeter whose current coil rating of 5 amps and the voltage coil rating of 110V is connected through an instrument transformer and reads 400 watts. The CT ratio is 20:1 and the PT ratio is 100:1. Calculate the

a) voltage of the mains supply
b) current in the main circuit
c) actual power consumed by the circuit.

a) Voltage of the main supply = Pressure coil rating of wattmeter x P.T. ratio
= 110 x 100/1 = 11000V = 11 KV.

b) Current in the main circuit = Current coil rating of wattmeter x C.T. ratio
= 5 x 20/1 = 100 amps

c) The actual power consumed in the main circuit = Ratio of C.T. x Ratio of P.T. x Wattmeter reading
= 20/1 x 100/1 x 400
= 800000 watts = 800KWatts
= 0.8 megawatts

Alternatively we have

Actual power consumed in the circuit = Multiplying factor of the instrument transformer x wattmeter reading.

As such,

Multiplying factor = Ratio of CT x Ratio of PT instrument transformer.

Electrostatic wattmeter: This form of wattmeter cannot be regarded as a commercials instrument like the dynamometer and induction forms. It is a very useful instrument for the measurement of small amounts of power. It is also useful for the calibration of wattmeter.

Calculation of power in AC single phase circuit

Objectives: At the end of this lesson you shall be able to
- **calculate power in a single phase AC circuit from the given relevant values.**

Power in pure resistance circuit: Power can be calculated by using the following formulae.

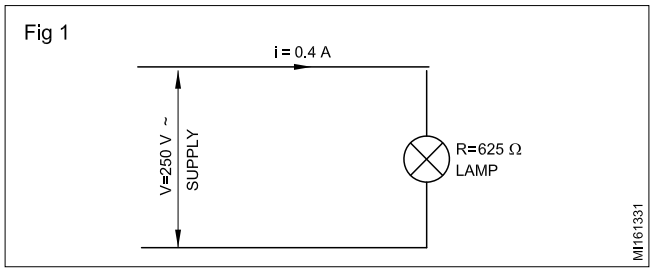
1) $P = V_R \times I_R$ watts

2) $P = I^2_R \; R$ watts

3) $P = \frac{E^2}{R}$ Watts

***Example 1**:* Calculate the power taken by an incandescent lamp rated 250V when it carries a current of 0.4A if the resistance is 625 ohms.(Fig 1)

Fig 1



$P = V_R \times I_R$
$= 250 \times 0.4$
$= 100$ watts.

Alternately

$P = I^2R$
$= 0.4 \times 0.4 \times 625$
$= 100$ watts

or $P = \frac{E^2}{R} = \frac{250^2}{625}$

$P = \frac{250 \times 250}{625}$

= 100 watts.

Since the current and voltage are in phase, the phase angle is zero and the power factor is unity. Therefore, the power can be calculated with voltage and current itself.

***Example 2**:* A wattmeter connected in an AC circuit indicates 50W. The ammeter connected in series with the load reads 1.5A. Determine the resistance of the load.

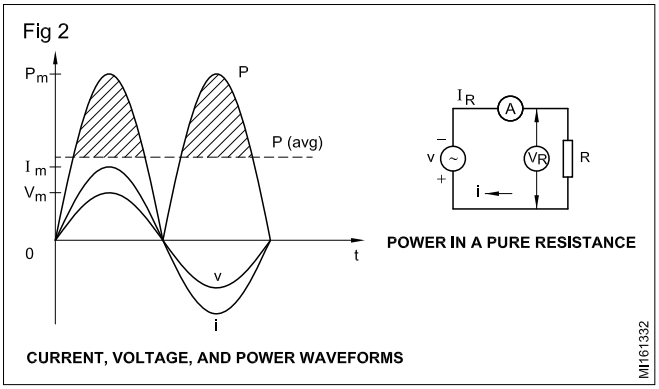
Solution

Known: $P = I_R^2R$

The circuit arrangement and wave-forms of i, v and p are shown in Fig 2.

Given: $I = 1.5$ amperes
$P = 50$ watts.

Therefore,



$$R = \frac{P}{I_R^2} = \frac{50W}{(1.5)^2} = 22.2 \text{ ohms.}$$

Power in pure inductance: If an AC circuit contains only inductance, the voltage and current are 90° out of phase, and the circuit of the instantaneous values of voltage and current gives with positive and negative power. Net result is the power consumed in a pure inductive circuit is zero.

Power in pure capacitance: If an AC circuit contains only capacitor, the voltage and current are 90° out of phase and the product of instantaneous values of voltage and current gives both positive and negative power. Net result is the power consumed in a pure capacitive circuit is zero.

Most industrial installations have a lagging PF because of the large number of AC induction motors that are inherently inductive.

Measurement of Energy

Objectives: At the end of this lesson you shall be able to
- **describe the construction and working principle of single phase energy meters**

Necessity of energy meter: The electrical energy supplied by the Electricity board should be billed, based on the actual amount of energy consumed. We need a device to measure the energy supplied to a consumer. Electrical energy is measured in kilowatt hours in practice. The meter used for this is an energy meter.

In AC, an induction type of energy meter is universally used for measurement of energy in domestic and industrial circuits.

Principle of a single phase induction type energy meter: The operation of this meter depends on the induction principle. Two alternating magnetic fields produced by two coils induce current in a disc and produce a torque to rotate it (disc). One coil (potential coil) carries current proportional to the voltage of the supply and the other (current coil) carries the load current. (Fig 1) Torque is proportional to the power as in wattmeter. The watt-hour meter must take both power and time into consideration. The instantaneous speed is proportional to the power passing through it. The total number of revolutions in a given time is proportional to the total energy that passes through the meter during that period of time.

Fig 1

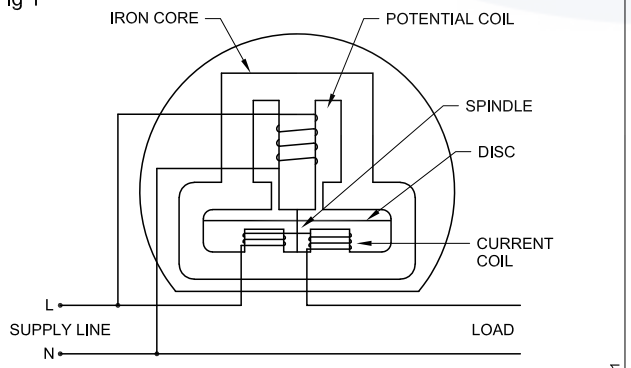


DIAGRAM OF AN INDUCTION TYPE WATT-HOUR METER

Parts and functions of an energy meter: The parts of the induction type single phase energy meter are shown in Fig 1.

Iron core: It is specially shaped to direct the magnetic flux in the desired path. It directs the magnetic lines of force, reduces leakage flux and also reduces magnetic reluctance.

Potential coil (voltage coil): The potential coil is connected across the load and is wound with many turns of fine wire. It induces eddy current in the aluminium disc.

Current coil: The current coils, connected in series with load, are wound with a few turns of thick wire, since they must carry the full load current.

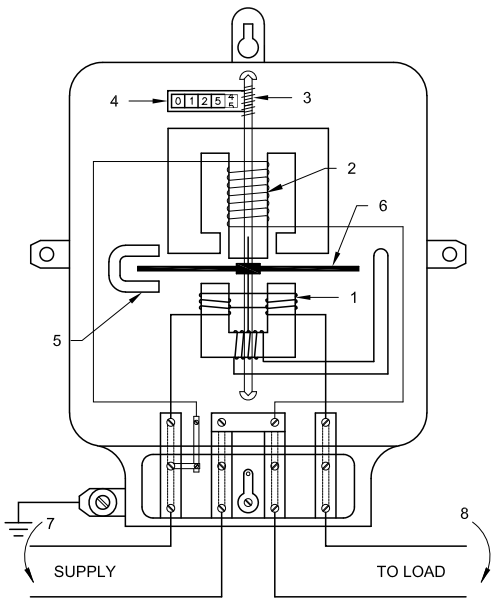
Disc: The disc is the rotating element in the meter, and is mounted on a vertical spindle which has a worm gear at one end. The disc is made of aluminium and is positioned in the air gap between the potential and current coil magnets.

Spindle: The spindle ends have hardened steel pivots. The pivot is supported by a jewel bearing. There is a worm gear at one end of the spindle. As the gear turns the dials, they indicate the amount of energy passing through the meter.

Permanent magnet/brake magnet: The permanent magnet restrains the aluminium disc from racing at a high speed. It produces an opposing torque that acts against the turning torque of the aluminium disc.

Functioning of energy meters: The rotation of the aluminium disc in Fig 2 is accomplished by an electromagnet, which consists of a potential coil and current coils. The potential coil is connected across the load. It induces an eddy current in the aluminium disc. The eddy current produces a magnetic field which reacts with the magnetic field produced by the current coils to produce a driving torque on the disc.

Fig 2



1. CURRENT COIL
2. VOLTAGE COIL
3. WORM GEAR
4. REGISTERING MECHANISM
5. PERMANENT MAGNET
6. ALUMINIUM DISC
7. SUPPLY TERMINALS
8. LOAD TERMINALS

INDUCTION TYPE ENERGY METER

The speed of rotation of the aluminium disc is proportional to the product of the amperes (in the current coils) and the volts (across the potential coil). The total electrical energy that is consumed by the load is proportional to the number of revolutions made by the disc during a given period of time.

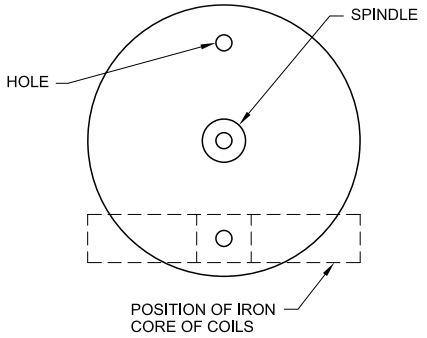
A small copper ring(shading ring) or coil (shading coil) is placed in the air gap under the potential coil, to produce a forward torque, large enough to counter act any friction produced by the rotating aluminium disc.

This counter torque is produced when the aluminium disc rotates in the magnetic field established by the permanent magnet. The eddy currents, in turn, produce a magnetic field that reacts with the field of the permanent magnet, causing a restraining action that is proportional to the speed of the disc. The faster the disc rotates, the greater the induced eddy currents, and greater the restraining action. This restraining action is necessary to make the speed of rotation proportional to the current taken by the load and also to stop the disc from further rotation due to inertia when the supply is disconnected.

Creeping error and adjustment: In some meters the disc rotates continuously even when there is no current flow through the current coil i.e. when only the pressure coil is energised. This is called creeping. The major cause for creeping is over-compensation for friction. The other causes for creeping are excessive voltage across the pressure coil, vibrations and stray magnetic fields.

In order to prevent creeping, two diametrically opposite holes are drilled in the disc (Fig 3). The disc will come to rest with one of the holes under the edge of a pole of the potential coil magnet, the rotation being thus limited to a maximum of half a revolution.

Fig 3



Types of energy meter dials

In earlier energy meters, the reading of energy had to be done by cyclometer type dials as shown in Fig 4.

In this type there are five dials each having its own pointer. Initially all the pointers will be at zero. The first dial in the left registers in 1000, 2nd dial in 100s, 3rd dial in 10s, rth dial in ones and the fifth dial in 1/10th of the KWH. When the fifth dial pointer completes one revolution, the fourth dial (one's dial) pointer moves from zero to one, further if the fourth dial (one's dial) completes one revolution, the third dial (10's dial) pointer moves from zero to one and so on.

While reading start from right to left being careful to note the direction of rotation.

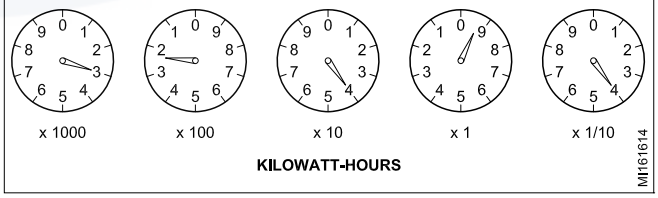
Read the right hand dial. If the pointer has moved away from one figure, read the figure behind the pointer in the direction of rotation.

Read the remaining dials in order, taking care to read the figures behind the pointer on these dials. When one the pointers is directly on a number, the procedure is to look back at the dial on the right. Has it passed the zero? If it has not passed the zero, the correct figure to read is the one behind the pointer.

Meters are read once each month or once in two months. The earlier reading is subtracted from the present reading to know the consumption in kWH.

Example

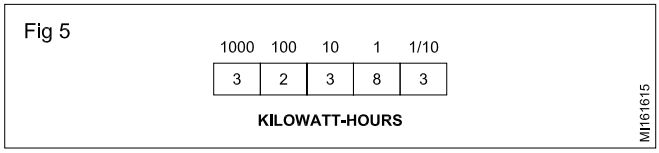
Fig 4



The reading shown by the energy meter as per Fig 4 will be 3239.3 KWH.

In the latest type of energy meters these scales have been changed from cyclometer type to direct reading system as shown in Fig 5.

Fig 5



Passive electronic components

Objectives: At the end of this lesson you shall be able to
- **state difference between the passive and active components**
- **explain the types of resistors, and their coding**
- **explain the types of capacitors and methods of testing (R)**
- **explain the types of inductors and their applications**

Resistors : The Components used in electronic circuits can broadly grouped under two headings.

- passive components
- active components

Passive components : Components like resistors, capacitors, and inductors used in electronic circuit are called as passive components. These components by themselves are not capable of amplifying or processing an electrical signal. However these components are equally important in electronic circuit as that of active components, without the aid of passive components, a transistor (active components) cannot be made to amplify electrical signal.

Circuits formed with passive components obey the electrical circuits laws such as ohm's law, Kirchoff's Laws etc.,

Active components : In electronic circuit, the components, other than passive are known as active components. Namely, transistors, diodes, SCRs Vacuum tubes etc.,

Resistors : The components whose purpose to introduce resistance in the circuit is called as resistors. Other details of resistors are dealt in earlier lessons.

Capacitor : The components whose purpose to introduce capacitance in the circuit is called as capacitor. The unit of capacitance is 'FARAD'. Commercially capacitors are available in micro farad (μF), nanofarad (nf) and pico farads (pf).

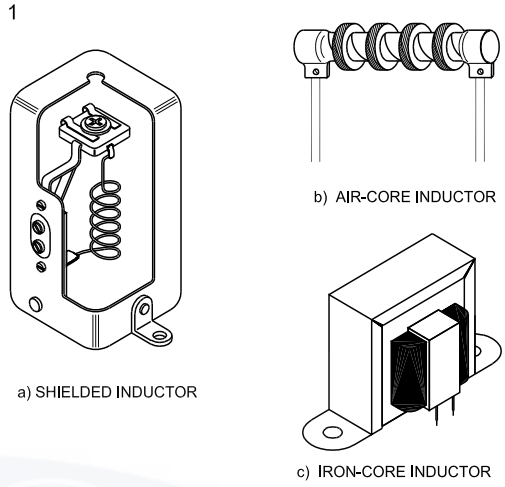
The colour coding of capacitors and resistors are same. Where as, in the case of fixed capacitors, the colour coded unit shall be in pico farads.

For letter coding, incase of capacitor, the letter 'p', 'n', 'μ' shall be used as multipliers. Where p = 10^{-12}, n= 10^{-9} and μ = 10^{-6} farads, and letter code for tolerance on capacitor is the same as in resistor.

Other details about the capacitors are already dealt in 1st year trade theory.

INDUCTOR : The ability of the conductor to induce voltage in itself, when the current changes in it is called as self inductance (or) simply inductance. A coil introduced in a circuit to have inductance is called as inductor. Different type of inductors are shown in Fig 1. The unit of inductance

Fig 1



TYPES OF INDUCTORS

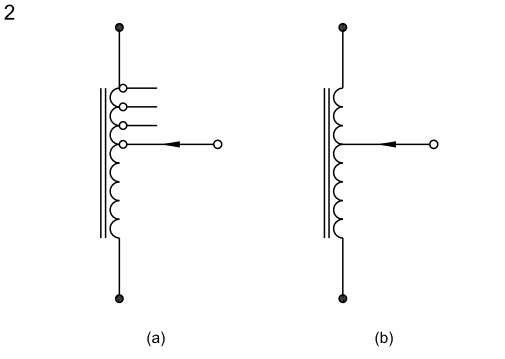
is "Henry". Commercially a coil may have inductance in milli henry (10^{-3}H), or in micro henry (10^{-6}H).

Other details about inductance are dealt in Ist year trade theory.

While specifying the inductance the following factors to be considered

- nominal value of inductance in Henry / millihenry / micro (m) henry
- tolerance in percentage (±5/10/20%)
- type of winding like single layer, double layer, multilayer and pie (p) etc.
- type of core like air core, iron core, ferrite core
- type of application like audio frequency (AF), Radio frequency (RF) coupling coil, filter coil etc.,

Fig 2



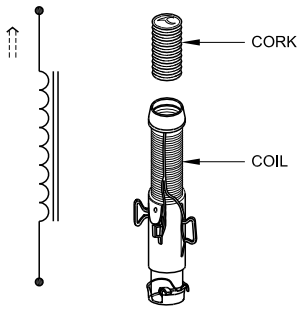
In an electronic circuit some time, it is also required to vary the inductance.

The inductance of a coil can be varied by:-

- providing tapped inductive coil, as shown in Fig 2 or
- adjusting the core of a coil as shown in Fig 3.

However, all inductor coils have inherent resistance due to the resistance of the winding wire in the coil. Further the maximum current that can be safely carried by an inductor depends upon the size of the winding wire used.

Fig 3



Semi conductors - atomic structure - active components

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

- **define the terms: intrinsic and extrinsic semiconductor, N type and P type material, dopping, holes, electrons impurity**
- **describe the atomic structure of semiconductor materials - silicon and germanium**
- **name the three types of bonding in solids with one example.**

The very tiny fundamental unit of an element which is capable of independent existence is the atom. An atom of any element consists of a central core called Nucleus. A number of small particles called electrons move around the central core. The nucleus contains protons and neutrons. A proton in the nucleus possess a positive electrical charge. An electron in an atom possess negative electrical charge. In normal state, the atom is electrically neutral, that is the number of electrons is equal to the number of protons in the nucleus.

For stability of materials (solids), the valence (outer most) shell of an atom should contain either 8 or more number of electrons, if it is to be complete. The above stability keeps the atoms and the molecules together in a solid state.

There are three important kinds of bonding amongst the atoms and the molecules of a solid. They are i) ionic ii) covalent and iii) metallic bonds.

Examples of solids under different bondings are,

Ionic bond	:	sodium chloride
Covalent bond	:	silicon and germanium
Metallic bond	:	metals like copper

Difference between conductors insulators and semi conductors : We are familiar with conducting and insulating materials. Conducting materials are good conductors of electricity. Insulating materials are bad conductors of electricity. There is another group of materials called as semiconductors, such as Germanimum and silicon. These are neither good conductors nor good insulators. On conductors the valence electrons are always free. In an insulator the valence electrons are always bound. Whereas in semi conductors the valence electrons are normally bound but can be set free by supplying a small amount of energy. Several electronic devices are made using semiconductor materials.

Semi conductors - Atomic structure : Germanium (Ge) and silicon (Si) are examples of semi conductors. Fig 1a shows a germanium atom. In the centre is a nucleus with 32 protons. the revolving electrons have distributed themselves in different orbits. There are 2 electrons in the first orbit, 8 electrons in the second orbit, and 18 electrons in the third orbit. The fourth orbit is the outer or valence orbit which contains 4 electrons.

Fig 1

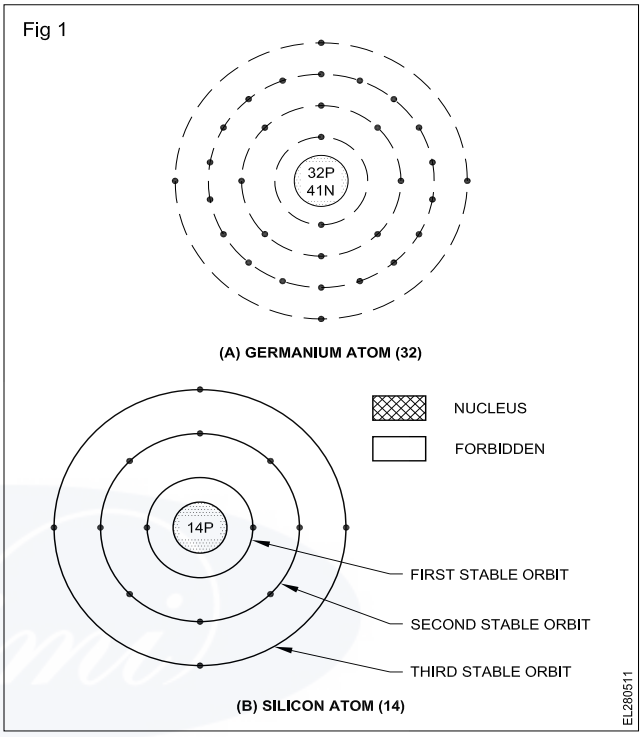
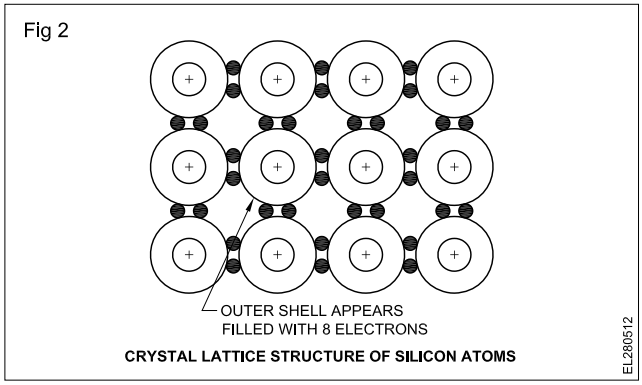


Fig 1b shows a silicon atom. It has 14 protons in the nucleus and 14 electrons in orbit. There are 2 electrons in the first orbit and 8 in the second orbit. The remaining 4 electrons are in the outer or valence orbit.

Fig 2



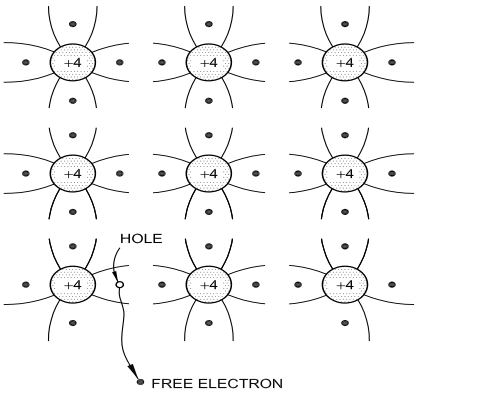
In semiconductor materials, the atoms are arranged in an orderly pattern called a crystal lattice structure. If a pure silicon crystal is examined we find that the four electrons in the outer (valence) shell of an atom is shared by the neighbouring atoms as shown in Fig 2.

The union of atoms sharing the valence electrons is called a **covalent band**. That means a valence electron being shared by two adjacent atoms. Each atom appears to have a full outer shell of eight electrons.

Types of semiconductors : A pure semiconductor is called an intrinsic semiconductor. For example, a silicon crystal is an intrinsic semiconductor because every atom in the crystal is a silicon atom. One way to increase conductivity in a semiconductor is by **'doping'**. This means adding impurity atoms to an intrinsic semiconductor. The doped semi-conductor is known as an extrinsic semiconductor.

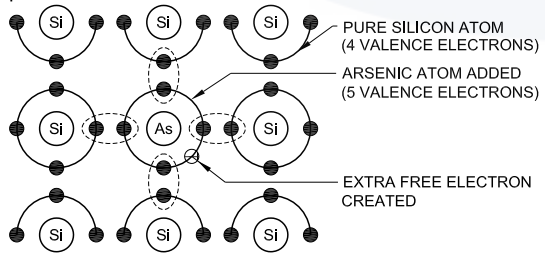
The residual heat at room temperature (300K) is sufficient to make a valence electron of an intrinsic semiconductor to move away from the covalent bond and then the covalent bond is broken, and the electron becomes a free electron

Fig 3



to move in the crystal. This is shown in Fig 3. When an electron breaks a covalent bond and moves away, a vacancy is created in the broken covalent bond. This vacancy is called a 'hole'. A hole has a positive charge. When a free electron is liberated, a hole is created.

Fig 4



FORMATION OF 'N' TYPE SEMICONDUCTOR

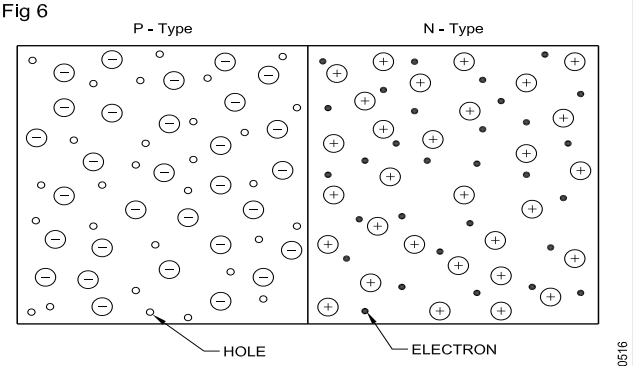
N - type semiconductor : A semiconductor with excess of electrons is called N-type. To obtain excess free electrons, the element doped with the semiconductor material is arsenic, or antimony or phosphorus. Each of these atoms has five electrons in its outer orbit. (Fig 4)

Because the outer orbits of the atoms can hold eight electrons, no hole is available for the fifth electron in the arsenic atoms to move into. It, therefore, becomes a free electron. The number of such free electrons is controlled by the amount of arsenic added to the crystals.

In N-type, the free electrons are called the **majority** carriers, and the holes minority carriers.

P-type semiconductor : To obtain more holes, a pure silicon crystal is doped with elements such as aluminum or boron or gallium. The atoms of each of these elements have three electrons only in their outer orbit. Adding gallium to pure silicon crystals allows the atoms of the two elements to share seven electrons. (Fig 5) A hole is created in the place of the eighth electron. Now that the number of holes exceeds the number of free electrons the substance becomes 'P' type material. The holes in P-type

Fig 6



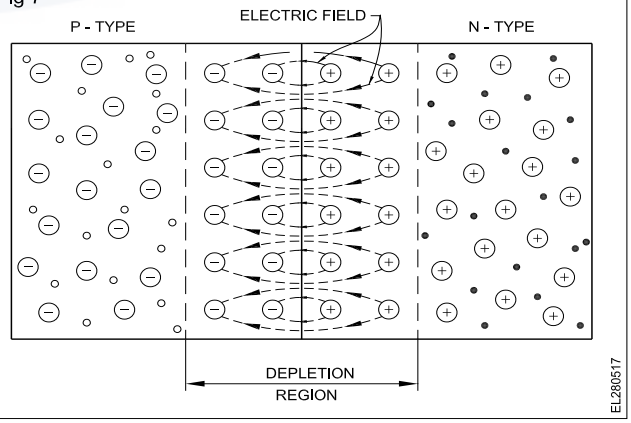
P – N JUNCTION

are the **majority** carriers, and the free electrons are the minority carriers.

PN Junction : A PN junction is formed by combining P and N type materials. The surface where they meet is called the PN junction. A PN junction is illustrated in Fig 6.

The free electrons in the N-regions diffuse across the junctions into the P-region. The free electrons lose energy and recombine with the holes in the P-regions. This

Fig 7



recombination eliminates a free electron and a hole. When the electron moved from the N-region and diffused across the junction, it leaves the atom to be a positive ion. The positive ion is not balanced by a negative charge in the N-region. The hole is eliminated in the P-region by recombination. The elimination of the hole and its positive charge leaves the atom to be a negative ion in the P-region.

The ions in the crystal structure are fixed and cannot move. Thus, a layer of fixed charges is formed on the two sides of the junctions. This is shown in Fig 7.

There is a layer of positively charged ions on the N-side and on the P-side of the junction there is a layer of negatively charged ions. An electric field is created across the junction between the oppositely charged ions. This is called a junction field. The junction field is also known as 'barrier'. The distance between the sides of the barrier is the 'width' of the barrier.

Depletion region : The carrier in the vicinity of the junction are involved in forming the junction. Once the junction field is established, no carriers can move through the junction. Hence the junction field is called 'depletion region' or 'space charge region'. This layer is called the depletion layer, because there are neither free electrons nor holes present. This depletion region prevents further movement of electrons from the N-material to the P-material and thus an equilibrium is reached. The intensity of the field is known as 'barrier height' or 'potential' hill'. The internal voltage set up due to positive and negative ions at the junction is called barrier potential. If any more electrons have to go over from the N-side to P-side, they have to over come this barrier potential. This means, only when the electrons on the N-side are supplied with energy to overcome the barrier potential they can go over to the P-side.

In order to cancel of the barrier potential and the electrons to cross over a potential difference of 0.7 V in required for a silicon diode and 0.3 V for a germanimum diode. The barrier voltage is more for silicon because its lower atomic number allows more stability in the covalent bonds. The barrier potential decreases at higher temperatures.

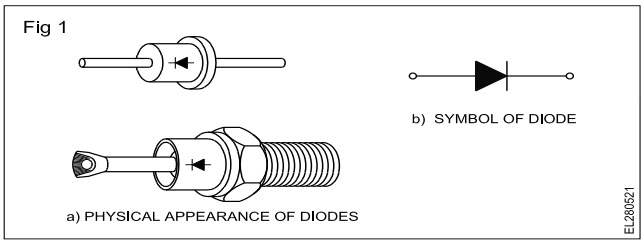
Active components

Objectives: At the end of this lesson you shall be able to
- **explain about the active components**
- **represent the components - diodes, transistors, SCRs, diac, triac, zener diode, diode bridges, UJT, FET - with standard symbols.**

Active components : In electronic circuits, components other than resistors, capacitors and inductors are also used. Namely, transistors, diodes, vacuum tubes, SCRs, diacs, zener-diode etc. Fig 1. The application of electrical circuit laws (Ohm's law etc.) in the circuit containing the above components will not give correct results. i.e. these components do not obey. Ohm's law, Kirchoff's law etc. These components are called active components.

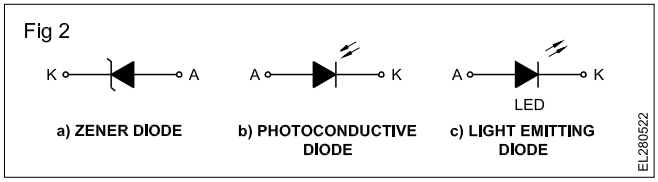
The different active components and the method of representing them by symbols in the circuit diagram are given below.

Fig 1



The different types of diodes (Fig 2) used for specific purposes are represented by the symbols given.

Fig 2



Transistor : Figure 3a shows the physical appearance of transistors. There are two symbols to represent a transistor. (Fig 3b). The selection of a symbol is based on either the NPN or the PNP type of transistor.

SCR (Silicon controlled rectifier) : Figure 4a shows the physical appearance of one type of SCR and the symbol is shown in Fig 4 b. SCRs are also called thyristors and used as switching devices.

Fig 3

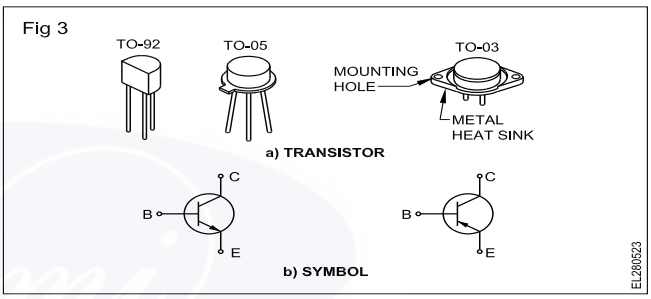
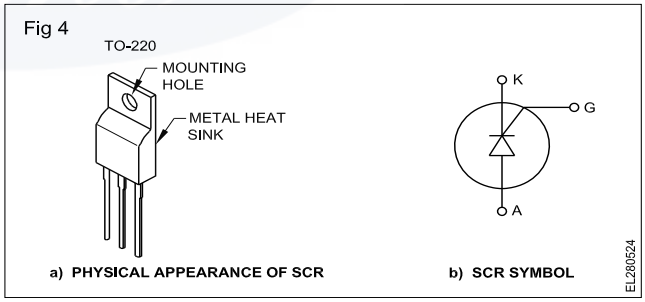
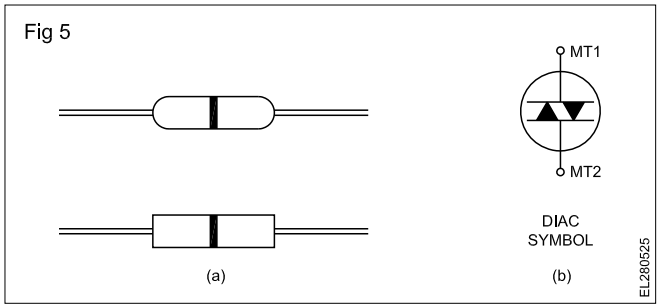


Fig 4



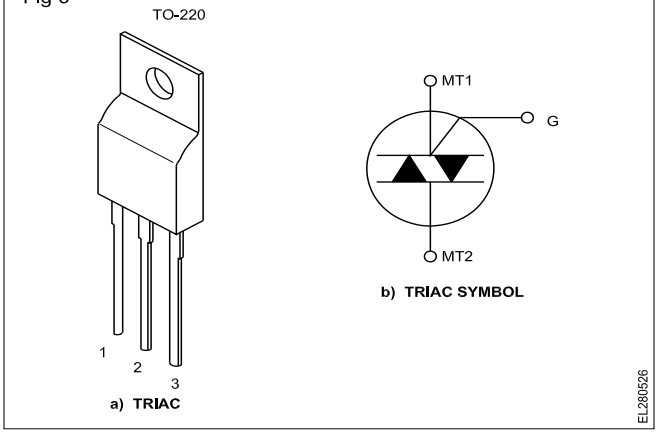
Diac : A diac (Fig 5a) is a two-lead device like a diode. It is a bidirectional switching device. Its symbol is shown in Fig 5b.

Fig 5



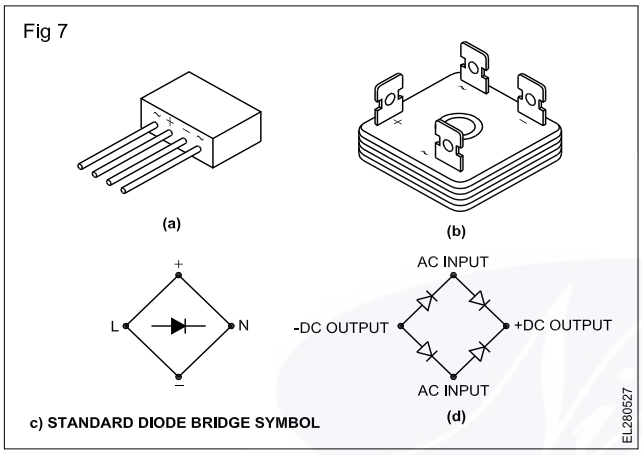
Triac : A triac is also a semiconductor device with three leads like two SCRs in parallel. The triac can control the circuit in either direction. (Fig 6)

Fig 6



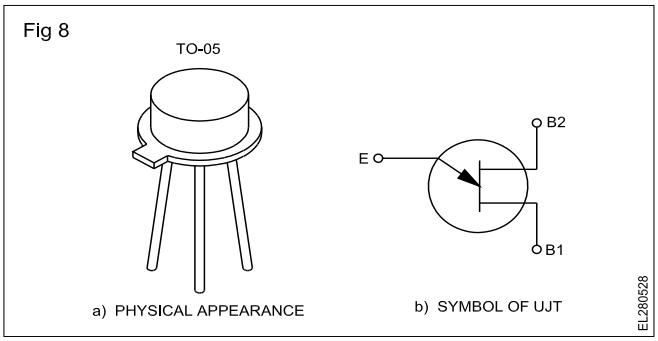
Bridge rectifier or diode bridge : It is a single package of four semiconductor diodes connected in bridge circuit. The input AC and the output DC leads are marked and terminated as shown in the Figure 7.

Fig 7



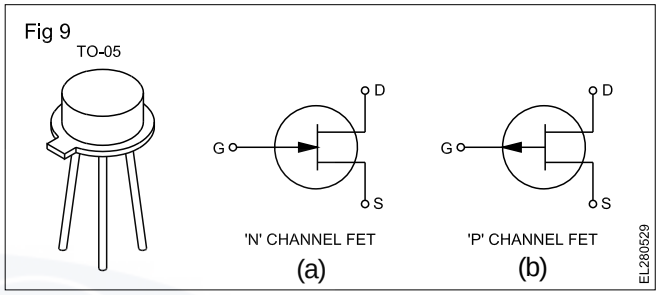
UJT (Uni-junction transistor) : It has two doped regions with three leads and has one emitter and two bases.(Fig 8)

Fig 8



FET (Field effect transistor) : Fig 9a give a pictorial view of the component, and the related symbol to represent the field effect transistor is shown in Fig 9b. The selection of the symbol is based on whether the FET is a 'N' channel or a 'P' channel one.

Fig 9



Note:- The devices like transistor, SCR triac, UJT & FET may look alike due to similarity in encapsulation. They can be identified only by the code numbers and relevant data books.

Coding of semiconductor devices

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

- **state the purpose of letters used in the old systems of coding semiconductors, by referring to the manual**
- **describe the meaning of 1N, 2N, 3N in semiconductor coding.**

Old system : Some earlier semiconductor diodes and transistors have type numbers, consisting of two or three letters followed by group of one, two or three figures. The first letter is always 'O', indicating a semiconduct device.

The second (and third) letter(s) indicate the general class of the device.

A – diode or rectifier
AP – photo-diode
AZ – voltage regulator diode
C – transistor
CP – phototransistor

The group of figures in a serial number indicating a particular design or development.

Present system : This system consists of two letters followed by a serial number. The serial number may consists of three figures of one letter and two figures depending on the main application of the device.

The first letter indicates the semiconductor material used.

A Germanium
B Silion
C Compound materials such as gallium arsenide
R Compound materials such as cadmium sulphide

The second letter indicates the general function of the device.

A detection diode, high speed diode, mixer diode
B variable capacitance diode
C transistor for I.F. applications (not power types)
D power transistor for A.F. applications (not power types)
E tunnel diode
F transistor for A.F. applications (not power types)
G multiple of dissimilar devices, miscellaneous devices
L power transistor for a.f. applications
N photo-coupler

P radiation sensitive device such as photo-diode, photo-transistor, photo-conducive cell, or radiation detector diode
Q radiation generating device such as light-emitting diode
R controlling and switching devices (e.g. thyristor) having a specified breakdown characteristic (not power types)
S transistor for switching applications (not power types)
T controlling and switching power device (e.g. thyristor) having a specified breakdown characteristic.
U power transistor for switching applications
X multiplier diode such as varactor or step recovery diode
Y rectifier diode, booster diode, efficiency diode
Z voltage reference or voltage regulator diode, transient suppressor diode.

The remainder of the type number is a serial number indicating a particular design or development, and is in one of the following two groups.

a Devices intended primarily for use in consumer applications (radio and television receivers, audio-amplifiers, tape recorders, domestic appliances, etc.) The **serial number** consists of three figures.

b Devices intended mainly for applications other than (a) e.g. industrial, professional and transmitting equipments.

The serial number consists of one letter (Z,Y,X,W etc) followed by two numbers (digits)

The international system follows letters 1N, 2N, 3N etc followed by four numbers.

1N indicates single junction
2N indicates two junction
3N indicates three junctions.

The number indicates internationally agreed manufacturer's code e.g. 1N 4007, 2N 3055, 3N 2000.

Again, manufacturers use their own codes for semiconductor devices. Manufacturers in Japan use 2SA, 2SB, 2SC, 2SD etc. followed by a group of numbers e.g. 2SC 1061, 2SA 934, 2SB 77. Indian manufacturers have their own codes too.

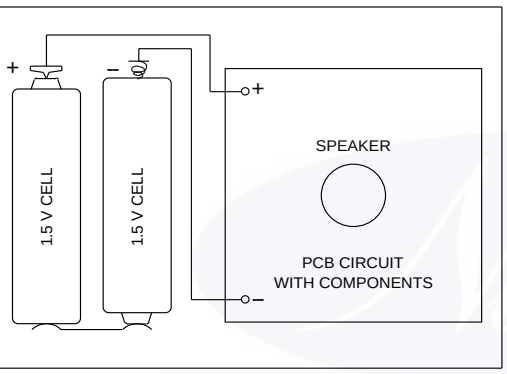
Polarity test in DC supply

Objectives: At the end of this lesson you shall be able to
- **state the importance of polarity**
- **explain the method of identifying the polarity of DC sources by MC voltmeter**
- **explain how to use a neon lamp/indicator for testing polarity.**

Polarity

The polarity of a DC supply source should be identified as positive or negative. We can also use the term to indicate how an electric device is to be connected to the supply. For example, when putting new cells in a transistor radio we must put the cells correctly such that the positive terminal of one cell connects to the positive terminal of the radio and the negative terminal of the other cell connects to the negative terminal of the radio as shown in Fig 1.

Fig 1



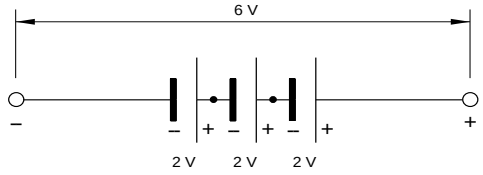
TRANSISTOR RADIO

Importance of the polarity

Direct current supply has fixed polarity, positive and negative marked as + and –. Electric devices which have positive and negative identifications on their terminals are said to be polarised. When connecting such devices to a source of voltage (such as a battery or DC supply) we must observe the correct polarity markings. That is the positive terminal of the device must be connected to the positive terminal of the source, and the negative to the negative. If the polarity is not observed correctly (that is, if +ve is connected to –ve) the device will not function and may be damaged.

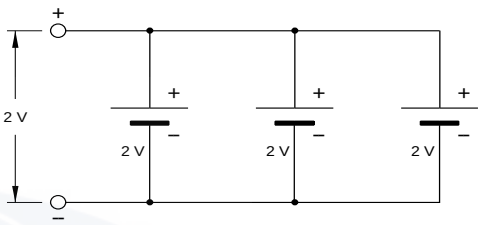
To get more voltage, current and power, the voltage sources like cells, batteries and generator are often connected in series, or in parallel or in series/parallel combination circuit. To connect them in such a manner we must know the correct polarity of the source. Fig 2 shows the method of connecting 3 cells in series to get more voltage. Fig 3 shows connection of 3 cells in parallel for getting more current.

Fig 2



CELL IN SERIES FOR GETTING MORE VOLTAGE

Fig 3



CELLS IN PARALLEL FOR GETTING MORE CURRENT.

Testing polarity by MC meter

The polarity of a cell is determined by the use of a moving coil volt-meter. The terminals of the MC meter are marked as +ve and –ve. MC meters are called as polarised as they have to be connected as per the polarity marking. By using a low range (0-3V) MC voltmeter we can find out the voltage of a cell. The connections are made as per Fig 4 the voltmeter reads 1.5 volts. The polarity of the cell is correct as per the marked polarity on the meter terminals. If the pointer of the voltmeter deflects as in Fig 5, below zero, the polarity is not correct. From this we conclude that the meter reads in forward direction only if the instrument is connected with correct polarity as per the markings on the instrument terminals.

Fig 4

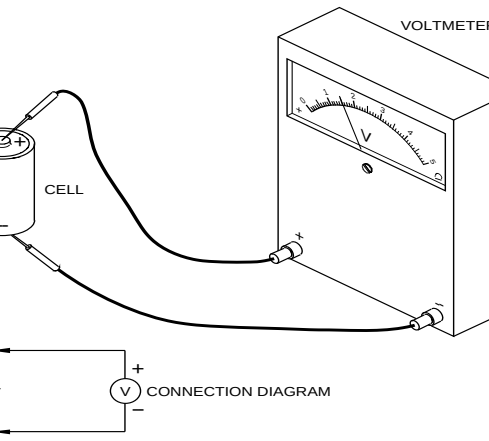
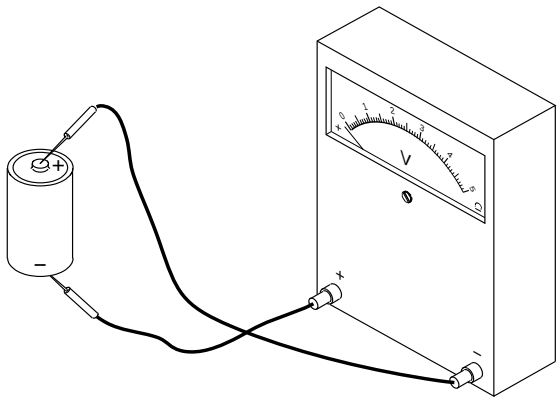


Fig 5



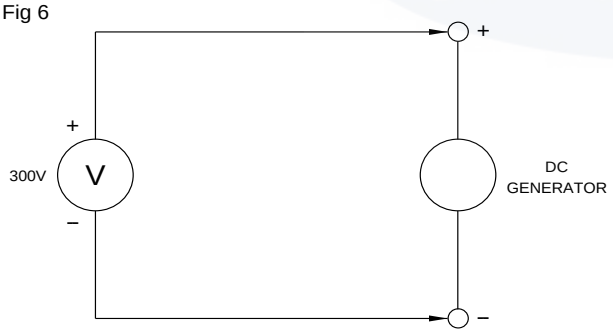
Polarity of the battery

To determine the polarity of the terminals of an unmarked battery, that is +ve and –ve we can use a low range MC voltmeter. If the voltmeter reads positive reading, say 10 or 12 volts then the polarity of the terminals are correct as per the markings on the meter terminals. If the meter reading is negative, that is below zero, the battery polarity is not correct with respect to the meter.

Polarity of DC supply

In the same way to find out the polarity of DC generator or a DC source it is advisable to use a moving coil type voltmeter with a suitable range, of say 0-300 volts. To protect the meters, always use higher range meters above the rated voltage of the generator or DC source supply (Fig 6).

Fig 6



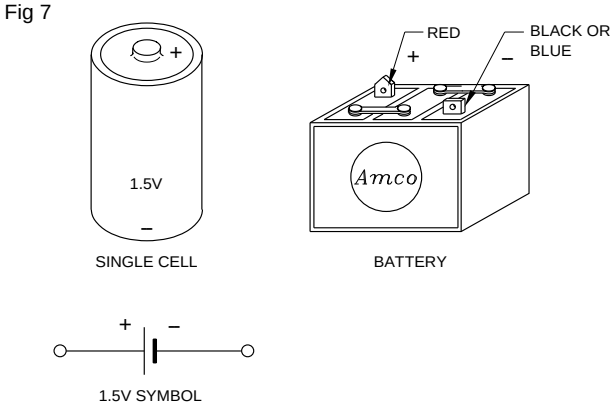
Marking made in practice

Generally in DC source the +ve terminal of the supply lead is Red in colour and –ve terminal of the supply lead is Blue or Black in colour. Battery terminals are marked as +ve and –ve on the body or on the terminal post.

i For cells on top of the cell is marked as +ve and the bottom is marked as –ve

ii The battery terminal is marked as + and is Red in colour, and the other terminal is marked as – and Black or Blue in colour. (Fig 7)

Fig 7



Neon polarity indicator

To check the polarity, a neon lamp in series with a 220 k ohms resistance could be used (as shown in Fig 8). Touch the probes of the neon lamp circuit across the circuit to be tested. The lamp will light when voltage is present. If both electrodes in the lamp glow, you have an AC power source. If only one electrode glows, the voltage is DC and the lighted electrode will be on the side of the negative polarity of the source. Therefore, you also have a polarity check on DC circuits. (Fig 8) A commercial neon polarity indicator is shown in Fig 9. It has an indicating glass window in which the polarity touched by the pointed end of the indicator will be displayed as +ve or –ve through neon signs.

Fig 8

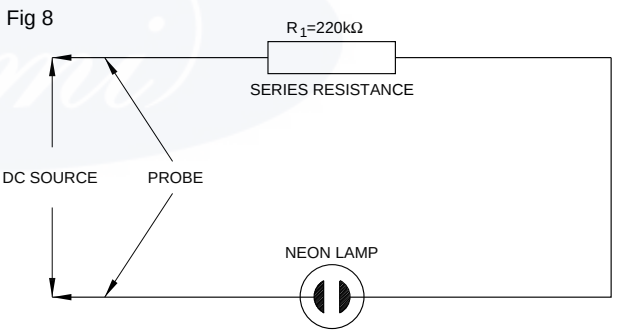
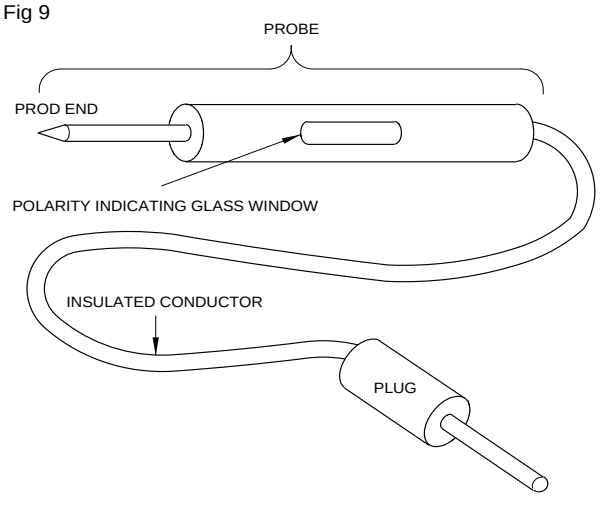


Fig 9



NEON POLARITY INDICATOR

Alternating current (A.C)

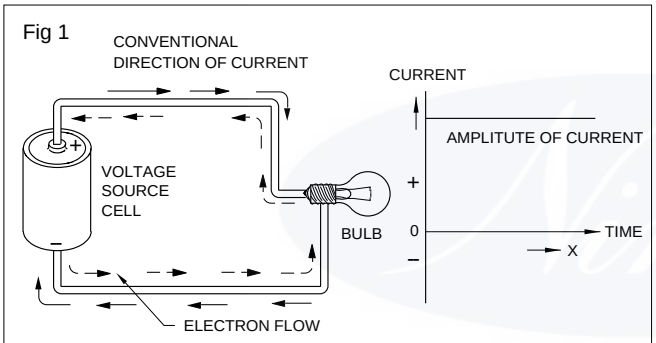
Objectives: At the end of this lesson you shall be able to
- **define alternating and direct current**
- **explain the difference between alternating current and direct current**
- **list the advantages and disadvantages of alternating current.**

Direct current (DC)

Electric current can be defined as the flow of electrons in a circuit. Based on the electron theory, electrons flow in the circuit from the negative (–) polarity to the positive (+) polarity of a voltage source. However, the conventional direction of current is assumed to flow from +ve terminal to –ve terminal of the voltage source.

In direct current (DC) circuit, the current flows only in one direction as shown in Fig 1. Current in this type of circuit is supplied from a DC voltage source (cell). Since the polarity of a DC source remains fixed, the current produced by it flows in one direction only.

Fig 1

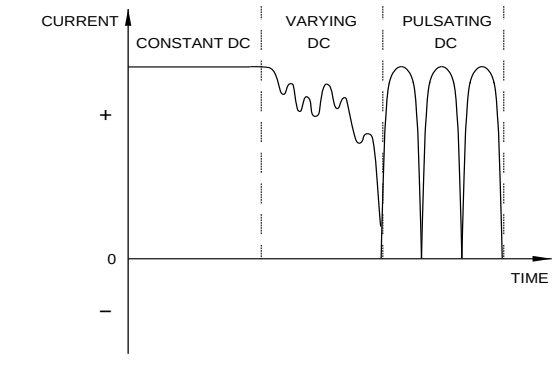


DIRECT CURRENT CIRCUIT GRAPHIC REPRESENTATION

Dry cells are commonly used as a DC voltage source in which the polarities are fixed. When connected to a load, the current produced flows in one direction at some steady or constant value.

A direct current flow need not necessarily be constant, but it must travel in the same direction at all times. There are several types of direct current varying in magnitude but the flow of current remains in one direction as shown by the current and time curve. (Fig 2)

Fig 2



TYPES OF DIRECT CURRENT

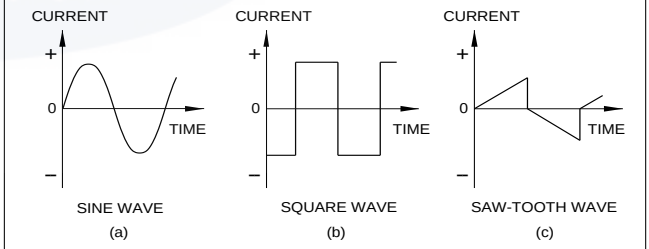
A constant DC current shows no variations in value over a period of time. Both varying and pulsating DC currents have a changing value when plotted against time. The pulsating DC current variations are uniform and repeat at regular intervals.

Alternating current (AC)

An alternating current (AC) circuit is one in which the direction and amplitude of the current flow changes at regular intervals of time. Current in this type of circuit is supplied from an AC voltage source. The polarity of an AC source changes at regular intervals resulting in a reversal of the circuit current flow.

Alternating current usually changes in both value and direction. The current increases from zero to some maximum value and then drops back to zero as it flows in one direction. This same pattern is then repeated as it flows in the opposite direction. The wave-form or the exact manner in which the current increases and decreases is determined by the type of AC voltage source used.(Fig 3)

Fig 3



DIFFERENT TYPES OF AC WAVE-FORMS

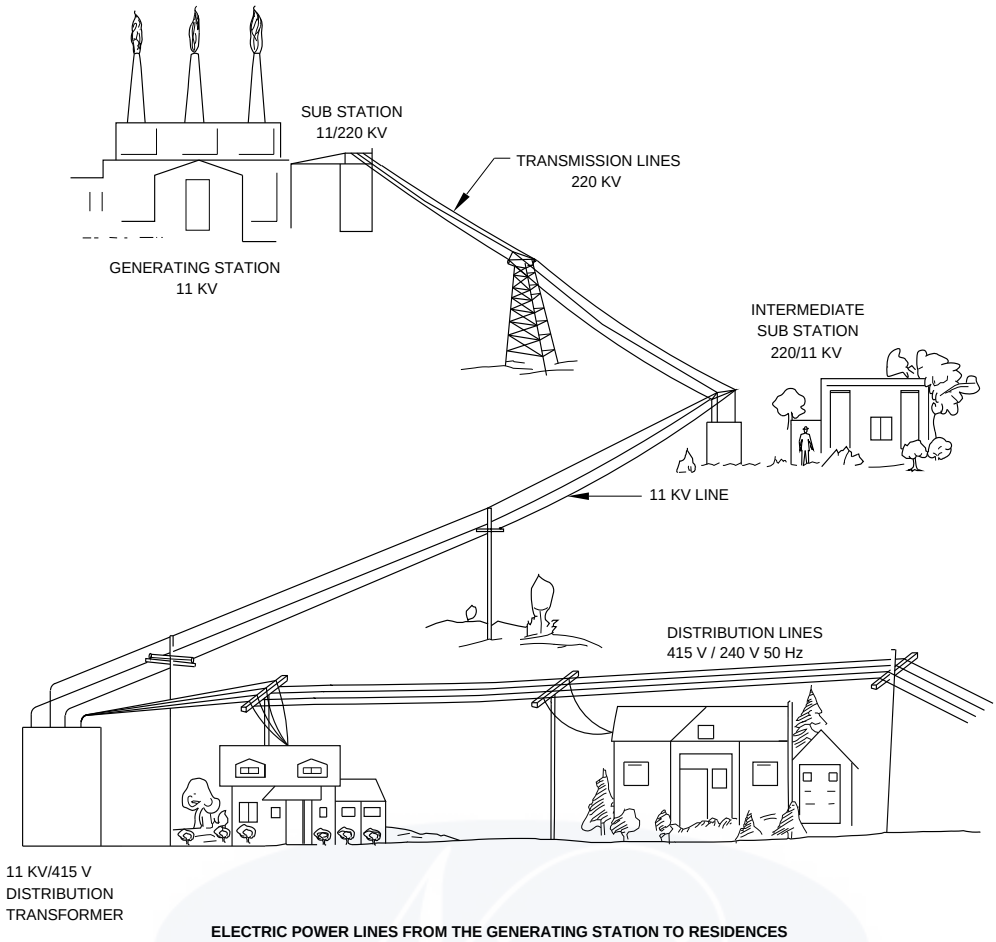
Alternating current generator

Alternating current is used wherever a large amount of electrical power is required. Almost all of the electrical energy supplied for domestic and commercial purposes is alternating current. AC voltage is used because it is much easier and cheaper to generate and to transmit over long distances, without much loss of power.

AC equipment is generally more economical to maintain and requires less space per unit of power than DC equipment.

Alternating current can be generated at higher voltages than DC, with fewer problems of heating and arcing. The commonly adopted voltages in generation are 6.6 kV (6600 V), 11 kV (11000 V) and 33 kV (33000 V). These voltages are increased to either 66 kV or 110 kV or 220 kV or 400 kV transmission over long distances. At the load area, the voltage is decreased to working values of 240 V and 415 V. The above process is shown in Fig 4.

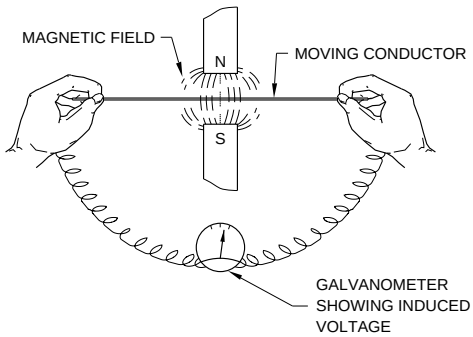
Fig 4



ELECTRIC POWER LINES FROM THE GENERATING STATION TO RESIDENCES

The basic method of obtaining AC is by the use of an AC generator. A **generator** is a machine that uses magnetism to convert mechanical energy into electrical energy. The generator principle, simply stated, is that a voltage is induced in a conductor whenever the conductor is moved through a magnetic field so as to cut the lines of the magnetic force.

Fig 5

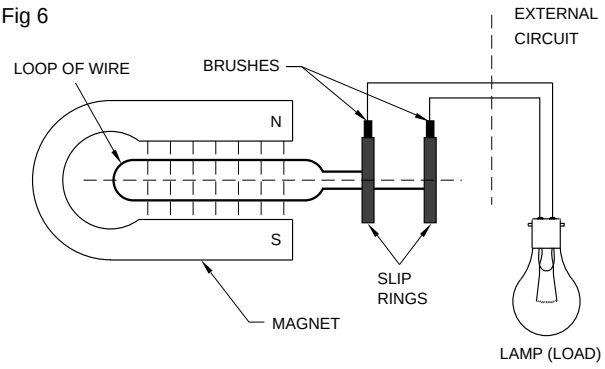


GENERATOR PRINCIPLE

Fig 5 shows the basic **generator principle**. A change in a magnetic field around a conductor tends to set electrons in motion which could be detected by using a galvanometer.

An AC generator produces an AC voltage by moving a loop of wire across a magnetic field. This relative motion between the wire and the magnetic field causes a voltage to be induced between the ends of the wire. This voltage changes in magnitude and polarity as the loop is rotated within the magnetic field. (Fig.6) The force required to turn the loop can be obtained from various sources. For example, very large AC generators are turned by steam turbines or by hydraulic turbines (water turbine).

Fig 6



SIMPLIFIED AC GENERATOR

The voltage produced by a single loop generator is too weak to be of much practical value.

A practical AC generator has many more turns of wire wound on an armature. The armature is made up of a number of coils wound on an iron core. The AC voltage induced in the armature coils is connected to a set of slip rings from which the external circuit receives the voltage through a set of brushes. (Fig 6) An electromagnet is used to produce a stronger magnetic field.

The sine wave

The shape of the voltage wave-form generated by a coil rotating in a uniform magnetic field is called a **sine wave** as shown in Fig 3a. The generated sine wave voltage varies in both magnitude (voltage value) and direction (polarity).

Advantages and disadvantages of AC

AC voltages can be increased or decreased with the help of transformers. This procedure makes AC ideal for transmission purposes. A large amount of power is transmitted at high voltage and low currents with minimum loss. Because the current is low, smaller transmission wires can be used to reduce installation and maintenance cost. A simple diagram on transmission and distribution of power from the generating station to a residence is shown in Fig 4.

DC generators limit their output voltage to 6000 V or less. The voltage cannot be increased or decreased through transformers. Long distance transmission requires heavy cables. AC generators are built with a capacity up to 500000 K.V.A. (500 M.V.A.). The DC generators' capacity is limited to 10000 KW. (10 MW)

It is less expensive to build, install and maintain AC motors than DC motors. DC motors have one distinct advantage over AC motors: they have better speed control.

Neutral and earth conductors

Objectives: At the end of this lesson you shall be able to
- **describe the purpose of earthing**
- **describe the two types of earthing**
- **differentiate between 'neutral' and 'earth' wires.**

Earthing

The importance of earthing lies in the fact that it deals with safety. One of the most important but least understood considerations in the design of electrical systems is that of earthing (grounding). The word 'earthing' comes from the fact that the technique itself involves making a low resistance connection to the earth or to the ground. The earth can be considered to be a large conductor which is at zero potential.

Purpose of earthing

The purpose of earthing is to provide protection to personnel, equipment and circuits by eliminating the possibility of dangerous or excessive voltage.

There are two distinct considerations in earthing of electrical systems: earthing of one of the conductors of the electrical supply system, and earthing of all metal enclosures which contain electrical wires or equipment.

The two types of earthing are:
– system earthing
– equipment earthing.

Neutral and system earthing through neutral

This consists of earthing one of the wires of the electrical system, such as the neutral, to limit the maximum voltage to earth under normal operating conditions. The term 'Neutral' is used in relation to AC single phase or 3-phase, 4-wire system which is the conductor connected to earth (through earth electrode) at one or more points by the electrical supply company.

Difference between neutral and earth

The basic difference between neutral and earth point should be clear to wiremen.

The neutral is the well defined return wire in single phase and 3-phase 4-wire system which is effectively involved in transmission and distribution of energy whereas earth is only functions as a protective element at the time of faults to carry the faulty current through the earth. Neutral earthing comes under system earthing whereas earthing of non-current carrying metal parts comes under equipment earthing.

Neutral conductor of the consumer end should be connected to the neutral of the electrical supply company and never should it be connected to the earth terminal though neutral from the supply company may have additional earth from the consumer electrode.

Equipment earthing

This is a permanent and continuous bonding together (i.e. connecting together) of all non-current carrying metal parts of electrical equipment to the general mass of earth through an earth electrode.

Earth electrode

A metal plate, pipe or other conductor is electrically connected to the general mass of the earth. Earth electrodes shall be provided at generating stations, substations and consumer premises (in accordance with the requirements of IS:3043-1966).

Earth wire

This is a conductor connected to earth and usually situated in proximity to the associated line conductors. The wire used for equipment earthing is called earth wire.

The purpose of equipment earthing

By connecting the metal parts 'not intended to carry current' to earth, a low resistance path is provided for leakage current which can be detected and, if necessary, interrupted by the following devices:

– fuses
– circuit breakers.

Identification of cores and cables

All cores of cables and conductors should be identified at the points of termination and preferably throughout their length to indicate their function.

Methods of identification may include coloured insulation applied to conductors during manufacture or the application of coloured tape, sleeves or discs. The colours used must be those specified for the function in Table 1 of IEE wiring regulations.

TABLE 1 - IEE REGULATIONS

Colour identification of cores of non-flexible cables and bare conductors for fixed wiring

Function	Colour identification
Protective (including earthing) conductor	Green-and-yellow
Phase of AC single or three-phase circuit	Red(or yellow or blue*)
Neutral of AC single or three-phase circuit	Black
Phase R of 3-phase AC circuit	Red
Phase Y of 3-phase AC circuit	Yellow
Phase B of 3-phase AC circuit	Blue
Positive of DC 2-wire circuit	Red
Negative of DC 2-wire circuit	Black
Outer (positive or negative) of DC 2-wire circuit derived from 3-wire system	Red
Positive of 3-wire DC circuit	Red
Middle wire of 3-wire DC circuit	Black
Negative of 3-wire DC circuit	Blue

* *As alternatives to the use of red, if desired, in large installations, on the supply side of the final distribution board.*

Flexible cables and flexible cords (Fig 1)

Every core of a flexible cable or flexible cord shall be identifiable throughout its length as appropriate to its function, as indicated in Table 2.

Flexible cables or flexible cords having the following core colours shall not be used; green alone; yellow alone or any bicolour other than the colour combination green-and-yellow.

Fig 1

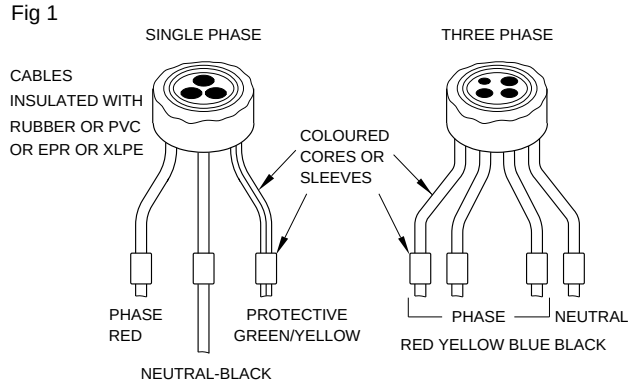


TABLE 2 - IEE REGULATIONS

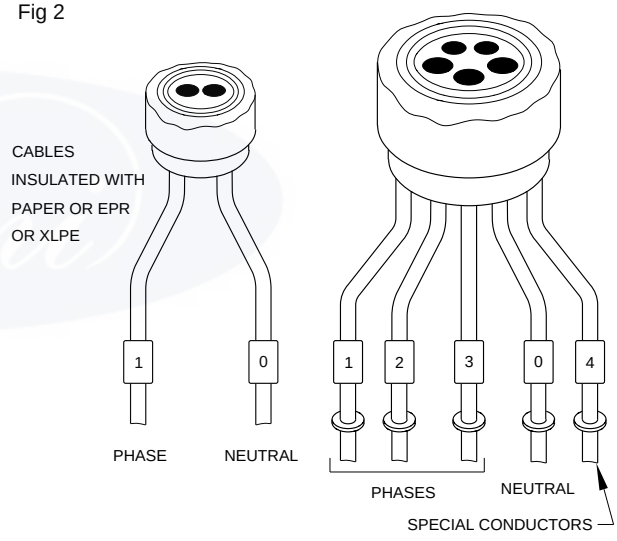
Colour identification of cores of flexible cables and flexible cords

Number of cores	Function of core	Colour(s) of core
1	Phase Neutral Protective earth	Brown Blue Green-and-yellow (combination)
2	Phase Neutral	Brown Blue
3	Phase Neutral Protective earth	Brown Blue Green-and-yellow (combination)
4 or 5	Phase Neutral Protective earth	Brown or black Blue Green-and-yellow (combination)

When armoured PVC insulated auxiliary cables or paper insulated cables are used, an alternative identification system may be used using numbers, where 1, 2 and 3 signify phase conductors and O the neutral conductor. The number 4 is used to identify any special purpose conductor. Refer to Fig 2.

The colour combination of green and yellow is to be used exclusively for the identification of protective earth conductors.

Fig 2



Practical application

Knowledge gained by this exercise can be applied

a to connect the cables in the installation/equipment following the safety rules
b to ascertain whether all switches are connected to the phase conductor in an installation/equipment and thereby proper control is possible in accordance with IE rules
c to check whether the phase or neutral conductor is open in case of open circuit in an installation.