WORKSHOP TECHNOLOGIES FOR SCHOOLS - A COMBINED STUDY

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Foreword

In compiling the content of this book the authors have been cognisant of the teacher's role in the workshop. The authors recognise that the teacher is in the best position to impart the practical skills and much of the technical knowledge students need to achieve the competencies required for successful completion of workshop courses.

This book has been written to provide students with the technical information necessary to support the practical teaching/learning program, so the blend of skills and knowledge acquired may be a foundation on which the student can build an objective but yet creative approach to technical problem solving.

Vocational education courses in secondary schools have become an integral part of the national training framework that has been developed as a joint venture between industry and education authorities.

Because these courses are offered at the senior secondary level with most students having completed workshop courses in the junior school, the author recognises the need for consistency in the resource materials that schools use to support their workshop courses at both levels.

The Workshop Technologies series has been revised to ensure that the original material is up-to-date and that all content is consistent with the training packages that have been developed for vocational education courses at senior level.

Acknowledgements

The authors and publisher acknowledge that part of the information contained in this book has been adapted from material which originated from several sources. Every effort has been made to gain permission for the direct use of copyright material, however if any infringements have occurred the author and publisher tender their apologies.

1. Illustrations of safety signs and personal safety equipment in the chapter titled Health And Safety In The Workshop have been adapted from product catalogues from the following manufacturers or distributors of safety equipment: Universal Safety Supply Pty Ltd, MSA Safety Products, Norton Safety Products and Pratt Safety Signs.

2. Illustrations of power tools have been adapted from product catalogues from the following manufacturers: Bosch, Makita, Ryobi, Hitachi.

3. Some illustrations of hand tools drawn by the author have been based on illustrations from the following product catalogues: ATC Tools, FH Prager.

4. The authors and publisher wish to thank Harristown State High School for allowing photographs to be taken of various machines and equipment for use in this book.

5. The authors and publisher wish to thank the Queensland Department Of Education for permission to use extracts from the Manual Arts Safety Notes. This permission was granted prior to publication of the first edition of the Junior Workshop books.

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HEALTH & SAFETY IN THE WORKSHOP

INTRODUCTION

Employees in industry and students in school workshops all have the right to a safe and healthy workplace. These rights are protected by law. All Australian states have occupational health and safety legislation which is administered by appropriate state authorities.

Safety programs, procedures and rules that are applied in school workshops are designed to protect the health and safety of students, teachers and visitors. These measures can be effective only when safe work practices are adopted. For example, regulations, procedures, signs and other safety measures cannot protect students unless they are observed by the students themselves.

One of the most common causes of industrial accidents is human error which could result from inadequate training, fatigue, carelessness, inappropriate behaviour, poor maintenance of equipment to name just a few of the possible causes. Another common cause of industrial accidents is failure to remedy avoidable hazards that may exist in the workshop. All of these possible causes of accidents emphasise the need for students to adopt safe work practices.

SAFE WORK PRACTICES

The following is a brief overview of some aspects of workshop safety and safe work practices.

Housekeeping

The workplace must always be maintained in a safe and clean condition. Some examples of good housekeeping are:

- Floors should be kept clean and free from obstructions or material that may be a trip hazard as well as oil, grease or other substances that may be a slip hazard.
- Machines and equipment should be kept clean and free of waste materials.
- Benches should be kept clean and tidy.

- Tools and equipment should be stored correctly when not in use.
- Combustible materials such as oil-soaked rags should never be stored in cupboards.

A dirty and untidy work area can be the cause of accidents in the workshop as well as general inefficiency in work practices.

Equipment Safety

Hand Tools: Defective tools should never be used because they can cause injury. For example, using a hammer with a loose head or broken handle could result in the head flying off and hitting someone. Using a file without a properly fitted handle could cause injury to the hand, while mushroom heads on chisels or punches can break off and become dangerous projectiles when struck with a hammer.

Machinery: All stationary and portable machines are potentially dangerous and must be treated with respect. Machine guards must always be properly fitted, adjusted and secured. Never use an unguarded machine.

Personal Protective Equipment: Protective devices such as face shields, earmuffs and gloves should be worn when necessary, depending on the equipment being used and the type of work being done. Personal protective equipment must be properly maintained and correctly stored when not in use.

Electrical Equipment: Never use defective electrical equipment and never try to repair defective electrical equipment. Defects in electrical equipment must be reported immediately.

Compressed Air: Compressed air must never be misused in any way that might cause injury or discomfort to the operator or others in the workplace. Never use compressed air to blow dust from the clothes or hair. A blast of compressed air close to the body can enter the bloodstream or intestines and cause serious injury or health problems.

Inappropriate Behaviour

Inappropriate behaviour such as practical jokes, showing off or horseplay has no place in a workshop. Someone is usually the ‘butt’ of practical jokes which often result in personal injury or damage to property.

Engaging in horseplay in a workshop is a very dangerous thing to do. The body can come into contact with stationary objects, moving parts of machines, cutting tools and hot objects, to name just a few examples that present an increased hazard when inappropriate behaviour occurs in the workshop.

Personal Protection

Correct work clothing should always be worn and protective equipment used when necessary to prevent injury. Personal protection should always be suited to the work being done, however the following can be used as a general guide:

- Wear clothes that are reasonably close fitting. Loose clothing, untucked shirts or unbuttoned overalls can be caught in revolving parts of machinery.
- Wear cuffless trousers. Cuffs may cause the wearer to trip or they may catch harmful substances.
- Footwear should be strong and in good repair. Stout soles protect against injury from sharp objects and solid uppers protect the feet from falling harmful substances.
- Long hair should be worn as required by regulations, constrained where necessary by an appropriate cap or hair net. Very serious injury can occur if hair is caught in revolving machinery.
- Rings and wrist watches should not be worn, particularly when operating machines. They can be easily caught in moving parts of machines and cause serious injury.
- Personal protective devices such as earmuffs, goggles, face shields, dust masks and gloves should be worn when necessary, depending on the type of work being done.

EYESIGHT PROTECTION

Eyesight is a vital part of everyday living as well as in the workshop and must be protected from damage that can be caused by chemicals, radiation and airborne particles.

Eye Protection Equipment

Safety glasses, goggles or face shields should be worn when necessary, in areas of the workshop where small flying fragments, dust, splashing of dangerous liquids or hot metals may be encountered.

Safety Spectacles provide protection from frontal impact injury. Side guards can be fitted where side entry protection is required.

Safety Spectacles with Side Guards

Goggles provide both front and side protection. Goggles have the advantage of being able to be worn over prescription spectacles.

Safety Goggles

Face Shield

Face Shields provide full face protection but are easily scratched. The plastic visa should be replaced when visibility is reduced.

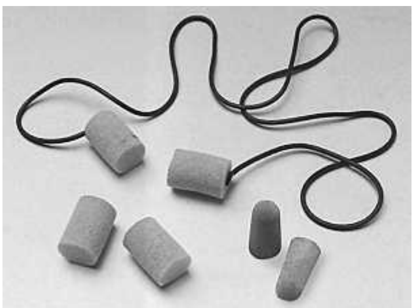
HEARING PROTECTION

Long exposure to high levels of noise may result in permanent loss of hearing. Some workshops can be very noisy, which emphasises the need to wear hearing protection when necessary.

Hearing Protection Equipment

The photographs below show typical hearing protection devices. Good quality hearing protection devices are rated to provide a stated noise level reduction. The choice between earmuffs or earplugs and the various types available will depend on:

- personal preference
- work conditions
- noise reduction required.



Earplugs

Earmuffs

SAFETY SIGNS

Safety signs provide a graphic reminder of safety requirements in the workshop and should be positioned as close as possible to the location where the hazard or safety requirement exists.

Regulatory Mandatory Signs

Regulatory mandatory signs such as the examples shown on the right are usually blue and white and are used where it is compulsory that a certain safety requirement be complied with.

HEARING PROTECTION MUST BE WORN

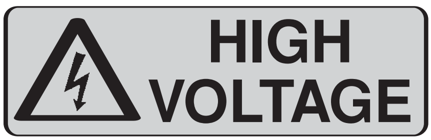
EYE PROTECTION MUST BE WORN

Regulatory Prohibition Signs

These signs consist of a red circle with oblique bar over a black image. Regulatory prohibition signs are used where a certain activity is not permitted. The 'strictly no admittance' sign on the right is a typical example. Another example is the common 'no smoking' sign.

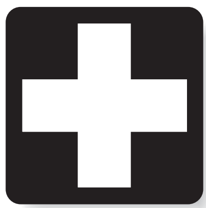
Hazard Warning Signs

Hazard warning signs consist of a black symbol in a black triangle on a yellow background. They can also be used in conjunction with a written instruction or message to provide extra information as in the 'high voltage' warning sign illustrated on the right.



Emergency Information Signs

Emergency information signs are green and white in colour and should be placed at the most appropriate location where the emergency information is required. For example, a first aid sign could be placed where the workshop first aid kit is located.



FIRST AID

Dangerous Goods Signs

Dangerous goods are grouped into nine different classes, each with its own distinctive diamond shaped sign or label. These labels are displayed where dangerous goods are stored.

Composite signs showing all the classes stored are located near points of entry to a building, room or area where dangerous goods are stored. The examples above indicate the presence of class 3 dangerous goods (flammable liquids) and class 6 dangerous goods (toxic or poisonous substances).

Hazchem Signs

Hazchem signs, which are red on a white background, indicate site storage of hazardous substances.

The HAZCHEM signs illustrated on the right are outer warning signs and should be prominently displayed at every vehicular entrance to a workplace. These signs are used in conjunction with dangerous goods signs.

FIRE PREVENTION AND CONTROL

Fire prevention is the responsibility of everyone in the school workshop. The best method of fire prevention is to obey all fire safety signs, regulations and precautions that apply in the particular situation. However, the control of fires is not usually the responsibility of students. In the event of a fire, all students must follow the school's evacuation procedures or fire drill.

Three ingredients must be present before a fire can start; oxygen, fuel and heat. Fires can be prevented by eliminating any one of these. Fuel is anything combustible and may be in the form of a solid, liquid or gas. The heat required to start a fire will depend on the properties and level of combustibility of the fuel. The sparks produced within a power tool, a discarded cigarette butt or the frictional heat generated by a neglected machine bearing could all start a fire.

Fire Safety Precautions

- Observe all safety signs and safety rules or regulations.
- Be aware of the properties of flammable materials used in the workshop.
- All unnecessary combustible materials should be disposed of properly.
- All necessary combustible materials must be safely stored and handled carefully.
- Do not store rags soiled with oil, paint or grease in cupboards or drawers. They can ignite spontaneously.
- Do not let rubbish, dust, lint, oil or other fuels accumulate in out of the way places.
- Open flames should be confined to specially designed areas.
- Keep combustible materials away from sources of heat.
- Do not use electrical equipment in the vicinity of flammable vapours or gases.
- Volatile liquids such as solvents and paints should only be used where there is adequate ventilation and well clear of any heat sources that may be sufficient to ignite vapours produced by evaporation.
- Report any detected gas leaks.
- Clean up spillages of flammable liquids immediately.
- Remove and wash clothing that becomes saturated with flammable liquid.

EVACUATION PROCEDURES

The first priority of emergency and evacuation procedures is to protect human life. The school's evacuation procedures must be followed in the event of a fire or other emergency. These procedures are usually designed to suit the layout of rooms and buildings and to facilitate the orderly movement of people to a safe location.

The second priority of emergency procedures is to minimise damage to buildings and equipment. Procedures that are designed for this purpose should be carried out only when there is no personal danger in doing so. Procedures could include shutting down machines and equipment; isolating machines; turning off the power supply; turning off gas and other fuel supplies and closing doors and windows in the event of a fire to minimise air supply.

Some of these procedures may not be the responsibility of students, however, it is the responsibility of all students to fully understand evacuation procedures and to follow them in the event of an emergency.

HAZARDOUS MATERIAL

Forms Of Hazardous Material

Hazardous materials encountered in the school workshop will vary with the type of work being done. These chemical materials are usually in the form of solvents, protective coatings, adhesives, acids or fluxes and gases.

Physical Hazards

Physical hazards presented by these materials usually involve combustion or explosion.

Combustion results in fire which requires fuel, an ignition source and oxygen to be present. The removal of any one of these elements will cause a fire to be extinguished.

Explosions are caused by the sudden formation of very large quantities of vapour which can result from a volatile liquid coming into contact with a hot material such as molten metal.

Health Hazards

Self-protective handling strategies are essential when chemicals and other dangerous substances are used in the workshop. Understanding how chemicals enter the body is a first step in the development of protective strategies.

Chemicals enter the body by any of three routes:

- Breathed in and absorbed through the lungs.
- Swallowed and absorbed through the stomach.
- Absorbed directly through the skin.

Inhaling dangerous substances is the fastest acting route of entry because the substance is taken directly to the lungs and quickly absorbed through the air sacs into the blood stream.

Swallowing dangerous substances can occur if normal hygiene practices, such as washing hands after handling chemicals, are not followed.

Absorption through the skin can occur with many dangerous substances. These chemicals get through the skin into the blood stream and travel to the vital organs where they can cause short and long term damage.

Protective Handling Strategies

- Refer to manufacturers' *Material Safety Data Sheets* for health hazard information about their products and precautions for safe use and handling of dangerous substances.
- Avoid contact with dangerous substances wherever possible.
- Understand the effects and dangers involved.
- Follow manufacturers' instructions carefully.
- Implement specified precautions (eg. ventilation).
- Always use protective equipment and clothing.
- Wash thoroughly after using chemicals even if protective clothing or equipment have been used.
- Know the appropriate first aid procedure in case of accident.

MANUAL HANDLING

A high percentage of industrial injuries are attributable to manual handling. Spinal injuries, muscle injuries and hernias can be caused by incorrectly lifting a heavy load or even light loads over a long period of time.

Spinal Injuries

Spinal injuries are usually attributable to damage of the inter-vertebral discs which are pads of fibrous tissue that function as cushions or shock absorbers between the vertebrae.

Muscular Injuries

Muscular injuries often result from muscular imbalance caused by incorrect posture when lifting; for example, using back muscles to support the body in a bent over position.

Hernias

A hernia occurs when part of the intestine protrudes through the abdominal wall. Bending over from the waist compresses the intestines. Lifting a load at the same time increases that compression and therefore increases the likelihood of a rupture of the abdominal wall.

Lifting Technique

The injuries described on the previous page can generally be avoided if correct lifting technique is used. To lift correctly bend the knees, not the back and never twist the body when lifting or carrying a load.

A load should also be lowered by bending the knees and keeping the back straight. The illustrations on the right show correct lifting technique which is described below.

Consider the load:

Assess the size, shape and weight of the load. If necessary seek assistance.

Position the feet:

The feet should be placed apart in a comfortable position with one foot in front of the other as close as possible to the load.

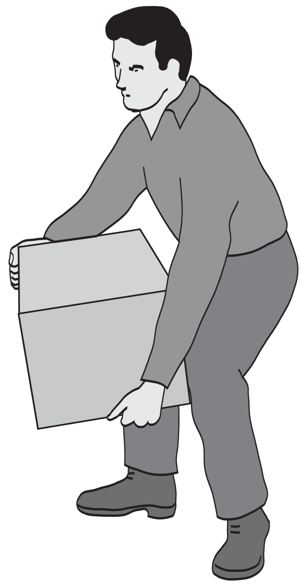
Assuming The Lifting Position

Assume the lifting position:

With the upper part of the body erect, keep the back straight and bend the knees. Keep the head up and the chin in as shown in the upper illustration. This helps to keep the back straight.

Grip the load:

Get a secure grip of the load using the full length of the fingers as well as part of the palms of the hands. Depending on the shape of the load, the hands could be placed on diagonally opposite corners.



Lifting The Load

Lift the load:

Keeping the upper body and head erect, chin in, back straight and arms close to the body, lift the load by straightening the legs. Hold the load close to the body.

TIMBER

FORESTS AND THEIR PRODUCTS

Approximately one fifth of the world's land surface is covered by forests. The majority of this area consists of two natural forest belts. The major softwood belt is in the Northern Hemisphere between the Arctic Circle and the 50th latitude.

The major hardwood belt is mainly in tropical areas. Both hardwoods and softwoods are cultivated in most parts of the world, usually in large plantations.

Australia has one of the lowest percentages of forest area to total land area in the world when compared with other timber producing countries. For example, the table below shows approximate percentages for Australia, Canada and Finland.

Australia	5%
Canada	45%
Finland	70%

Australian Forests

Australia's natural forests are mainly hardwoods. This deficiency in natural softwood forests has been reduced considerably in recent years by increased plantings of selected exotic pines in all states and native hoop pine in Queensland.

About 90% of the commercial timber producing trees in Australia are hardwoods, mainly of the genus Eucalyptus. Australia has over 600 species of hardwoods of which about 40 are considered to be of commercial value.

In addition to the hardwood forests which produce a variety of timbers such as spotted gum, forest red gum, blackbutt, grey gum, stringy bark, mahogany and ash, Queensland has an extensive inland cypress pine belt and coastal areas which produce tropical and semi-tropical rain or brush forests.

These forest areas also extend into New South Wales and contain hoop pine and a large variety of cabinet timbers such as black bean, Queensland walnut, Queensland maple, red cedar, silky oak, silver ash and many others.

All States of Australia have developed extensive plantations of predominantly exotic softwoods. Some of these are grown specifically for the paper pulp industry and for the production of particleboard and medium density fibreboard. The most common of these softwoods would be radiata pine and slash pine.

Forest Management

Generally conservation of forest resources is concerned with three aspects of forest management. These operations of thinning, pruning and fire protection allow suitable trees to grow to maturity as quickly as possible.

- Thinning is the process of removing some of the smaller and weaker trees to enable the best trees to grow to maturity. Thinnings from pine plantations are often used for pulp, particle board and case timber.

- Pruning the lower branches of trees prevents loose knots in the timber which is eventually produced. Subsequent growth on the pruned part of the tree will be knot free. Over pruning tends to slow growth, but it is usually safe to prune up to one third of the height of the tree. Besides improving the quality of the timber, pruning also helps in fire control.

- Fire protection is concerned with the removal of combustible material such as underbrush and lower branches as well as the provision of fire breaks to prevent a fire from spreading. Firebreaks are usually in the form of roads which allow access of men and equipment to all parts of the forest.

Reforestation

The term reforestation (or reafforestation) refers to the replacement of forest areas that have been previously cleared. As the Australian population grows and consumption of wood increases, forests will need to be replanted and expanded to meet the increased demand for timber and wood products.

Forest trees and plantation trees alike, take many years to grow to maturity therefore very careful planning by private industry and Government departments will be necessary to coordinate the operation of the timber industry.

Established forests actually regenerate through trees dropping seed. Under silviculture, which is the managed cultivation of trees and forests, reseeding or replanting may be carried out in a number of different ways.

- Clearfelling is the forester’s term for felling the whole of the usable crop at the one time. After clearfelling, the whole area is usually cleared and replanted. Alternatively, selected seed trees could be left to regenerate the forest naturally.

- Selection is the process of felling just the largest trees as they mature, leaving the smaller ones to develop.

- Grouping is the process of removing not single trees but whole groups of trees up to half of one hectare. The area can be cleared and regenerated as described above.

Continuity of supply in the timber industry is therefore achieved by reforestation or regeneration of established forests and expansion of plantations.

Australian Timbers

The list below sets out the main characteristics of a selection of Australian timbers, most of which are readily available.

Hoop Pine varies in colour from light yellow or pale brown to almost white, with even texture and no pronounced growth rings. It is not durable in wet conditions and is used for interior joinery, cabinet work and mouldings.

Cypress Pine is pale yellow to light brown in colour with a close texture. It is characterised by a very distinctive smell and numerous knots. Cypress Pine is termite resistant and very durable in the ground. Main uses are in building framework, flooring, etc.

Queensland Maple is a pinkish colour with reasonably close texture and is easy to work. It can be readily seasoned and is an excellent cabinet timber. Main uses are cabinet work, furniture, shop fittings and office fittings.

Silky Oak is brownish pink in colour, with a prominent flecked quarter grain pattern. It can be easily worked, is moderately soft and is reasonably durable when used in external applications. Silky oak was a popular cabinet timber in the first half of the 20th century but its main use today is in joinery.

Queensland Walnut often varies in colour from dark chocolate brown to a yellowish or reddish brown colour. It is quite hard with close texture and may have a distinctive figure. Queensland Walnut is difficult to work with hand and machine tools. Main uses are wall panels and in decorative fittings and furniture.

Red Cedar is a reddish brown colour which varies from a light shade to quite dark. It is easy to work, light in weight and reasonably durable when exposed to all weather conditions. Australian Red Cedar is very scarce and is now used mainly in the construction of high quality furniture.

Silver Ash is usually silvery white to a pale yellow colour, with close texture and can be quite hard. It is moderately easy to work and often has a ribbon-like figure. Silver Ash can be worked to a very fine finish with main uses in shop and office fittings, oars and water skis.

Black Bean is dark brown to almost black in colour with pale brown to yellowish sapwood. It has a reasonably open texture often with alternating dark and light patterns and is mainly used in cabinet work and wall panels. It is also quite hard.

Spotted Gum is an even light brown colour, has reasonably open texture, often with interlocking grain. It is tough and strong but untreated is susceptible to borers in sapwood zones. The main uses of Spotted Gum are in building construction.

Iron Bark is usually dark red in colour, close textured and often has ‘curly’ or interlocking grain. It is strong, hard and durable and is used mainly in heavy construction work.

Radiata Pine is a whitish colour and has very distinct growth rings which tend to produce a darker pattern in the face of the milled timber. It has a quite distinctive smell and often contains numerous knots.

Radiata Pine is grown specially for wood-chip industries and is now being used for house framing. It is not durable in external applications.

A currently fashionable internal application of this timber is in the construction of ‘knotty pine’ furniture and fittings. While grown extensively in Australia, Radiata Pine is native to California.

Silver Quandong is silvery white in colour, soft and close grained. It works and finishes very well. It is generally knot free and very stable. Silver Quandong is usually used for mouldings and other internal applications.

Imported Timbers

Large quantities of timber are imported into Australia to supplement local production. Much of this timber comes from South East Asia, Canada and the United States of America.

Oregon is a pale brownish colour with a darker face pattern caused by very distinct growth rings. The darker areas are usually harder than the lighter areas and have a different rate of shrinkage which makes Oregon very difficult to dress smoothly.

Oregon is very strong and has excellent load bearing capacity due to the unusually long fibres in its structure. Main uses are in building construction for joists and beams. This timber is often called Douglas Fir; however it is not a true Fir but actually belongs to the Pine family.

Meranti is usually light red or pink in colour, with very open texture and stringy grain. Less common varieties of meranti are dark red, white or yellow. Most common use is in mouldings for internal applications.

Phillipine Mahogany is very similar to light red meranti except that it often has a finer texture and finishes a little better.

Other imported (exotic) timbers widely used in Australia are Western Red Cedar, Ramin, Kwila, Parana Pine and Calantas.

By-Products Of Timber

Apart from yielding timber for general woodworking and structural purposes forest products provide the raw material for several manufacturing processes. Some of these processes are as follows.

Building Boards: The woodchip industry provides raw material for the production of a range of building boards such as particle board, hardboard, softboard and medium density fibre board. These will be dealt with in later sections of this text.

Sawdust: The utilisation of sawdust in industrial processes is an important factor in minimising waste in the timber industry. As much as 20% of a log can be converted to sawdust in some milling operations.

Sawdust may be used commercially for fuel, insulation, packing, stuffing and also has uses in the manufacture of some explosives, abrasives and sometimes as a composition ingredient in cast clay and concrete products.

Paper Pulp: Both softwoods and hardwoods are used in the Australian paper industry for the production of a variety of paper products.

In the paper making process the wood is cut into chips which are ground and pulped with water and chemicals to bind the fibres together.

After bleaching, the pulp is formed into a mat and compressed between large rollers before being further refined and processed to produce the particular paper product.

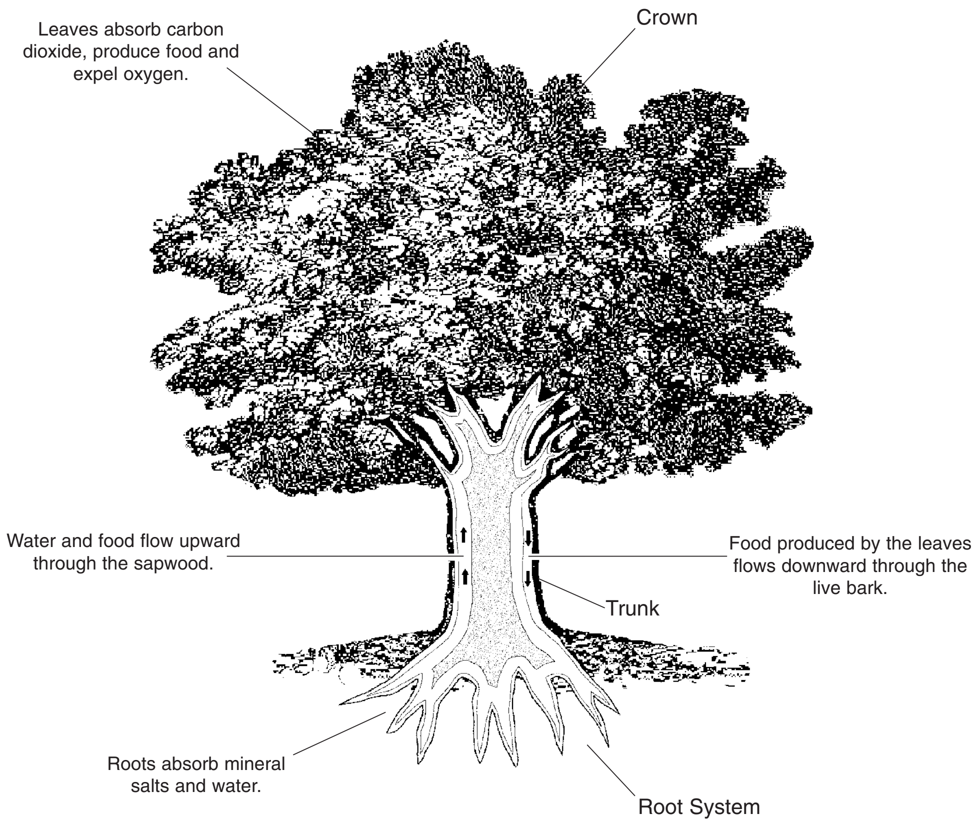
Chemicals: Some chemicals and other materials may be produced from wood by the distillation process and other allied processes. Creosote, methanol, acetone, grey acetate and tar are distilled leaving charcoal as a further by-product of wood.

Some other by-products of wood are wood alcohol for making synthetic rubber and explosives, tannin for use in the leather industry, resin and turpentine tapped from living trees and also produced from waste wood.

Plastics: Modern plastics are manufactured from crude oil or natural gas but wood still remains a source of cellulose from which a number of plastic materials may be produced.

TREE GROWTH AND STRUCTURE

The illustration below shows the root system, trunk and crown of a tree and their functions in the production and distribution of food materials.



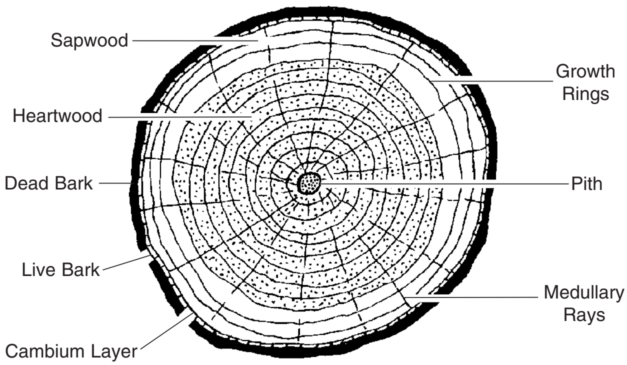
The root system of the tree acts as a firm anchorage against the elements while extracting essential water and nutrients, in the form of mineral salts, from the soil.

The trunk can be described as the main body of the tree. It provides rigid support and carries water and food materials to the crown.

The crown is the upper part of the tree made up of branches and leaves. Leaves produce food for the tree by a process called *photosynthesis* which forms sugar from carbon dioxide and water in the presence of sunlight. Photosynthesis can only occur when chlorophyll, the green colouring in the leaves, is present. The process releases oxygen to the air.

The illustration below shows a section through a tree trunk with pointers indicating its important parts.

Dead bark or outer bark is a layer of dead tissue which is a protection for the trunk and branches. It also helps to reduce water loss from the living cells of the tree. Some trees shed their dead bark each year while on others dead bark is reduced only by the weathering process.



Live Bark is a layer of living tissue under the dead bark. Food materials produced by the leaves are conducted through the live bark to the branches, trunk and roots of the tree.

The Cambium Layer is a thin layer of cells, invisible to the naked eye, positioned inside the live bark. This layer of cells facilitates all growth in the thickness of the tree trunk. The cambium grows wood cells on the inside and live bark cells on the outside.

The *annual growth* of a tree can be measured by the distance between the growth rings shown in the illustration above. As the growth rate slows down in the winter months, the new layers of wood cells (late wood) are smaller and packed more closely together forming a ring which is darker in colour than the wood grown at a faster rate earlier in the growing season (early wood).

Sapwood is the new wood under the cambium layer. It is often lighter in colour than truewood or heartwood and it conducts water and mineral salts from the root system of the tree to the leaves.

Heartwood or truewood is comprised of cells which are actually dead. It provides the strength necessary to support the tree. Heartwood is formed by blockage of the channels which conduct food materials. Blockage occurs as stored food materials are converted into tannins, resins and other related substances. Heartwood is much more durable than sapwood.

The Pith is at the centre of the tree and is a soft, pulpy zone which is usually about one centimetre in diameter. The pith is sometimes called the medulla, giving its name to the medullary rays.

Medullary rays are groups of wood cells radiating out from the pith, through the truewood and sapwood zones of the tree. Food materials are conducted horizontally in the trunk of the tree via the medullary rays which also act as food storage areas.

Growth In Height

As stated previously, growth in the trunk thickness or in the girth of the tree occurs at the cambium layer.

Growth in the height is caused by division and expansion of special cells which form at the extreme tips of all branches of the tree. Once the wood is formed it does not grow in length or height. For example, if a nail was driven into the trunk of a tree it would always remain the same height above the ground but it would be gradually covered by new growth in the girth.

CLASSIFICATION & PROPERTIES OF WOOD

The terms softwood and hardwood cause an unfortunate amount of confusion. The builder uses these terms to describe the relative ease of working of different timbers, but a botanist would apply the term hardwood to wood that contains pores or vessels in its structure. These large pores conduct the food supply to the various parts of the tree. Softwood, in the botanist's terms, does not have large pores.

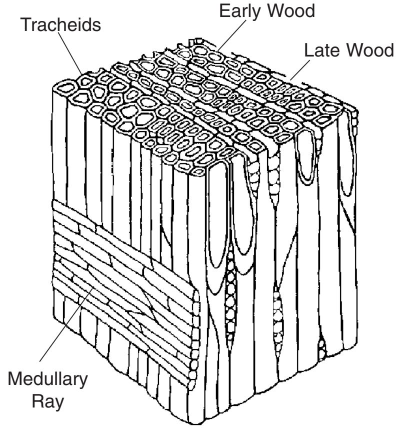
Conifers (cone-bearing trees such as pines) are all softwoods and are characterised by needle-like foliage. Broad leafed trees such as eucalypts and the majority of tropical and sub-tropical rainforest trees (even very light ones like balsa) are hardwoods according to botanical classification. The general arrangement of the pores is used by the botanist as a means of identifying the various groups of hardwoods.

Structure of Softwood

The illustration on the right represents the cell structure of a small block of softwood about 1mm high.

The upper surface of the diagram shows sections through cells which form water carriers called tracheids. The walls of the tracheids constitute the bulk of the wood substance. Tracheids are actually long thin cells, much smaller than the pores in hardwood.

The illustration also shows a group of horizontal cells which form medullary rays that store food and conduct it radially. Medullary rays radiate horizontally from the pith to the outer zones of the tree.



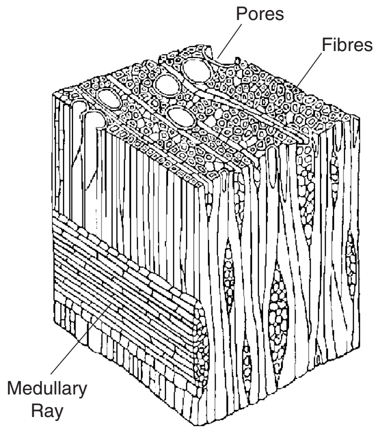
Softwood

Structure of Hardwood

The lower illustration on the right represents the cell structure of a small block of hardwood about 1mm high. Hardwoods, or pored woods, consist of large tube-like vessels (pores) which vary in size and in some species, are visible to the naked eye.

Short cells are joined together forming a continuous conduit for the food materials. The smaller, thick-walled cells shown in the diagram are wood fibres which make up the bulk of the wood substance.

Medullary rays have the same function in softwood as they do in hardwood.



Hardwood

Properties

Nature has provided many different species of wood with different characteristics and properties. The selection of a suitable timber for a particular job is usually determined by the suitability of the properties of that timber. Some of the main characteristics of timber are listed below.

Density (weight) is related to the size and thickness of cell walls and also the quantity of lignin, resins and gums present in the cell structure.

Hardness and **softness** are characteristics which are related to density and refer to the ability of wood to resist bruising and indentation.

Strength is directly related to cellular structure of the wood and is not always related to weight. The length of fibres is a very important factor in cell structure which characterises strong timber. For example Oregon has very long fibres which give the timber excellent load bearing qualities.

Durability depends to some extent on moisture content but mainly on the presence in the cells of naturally occurring chemicals which provide resistance to fungus and insect attack.

Durability can be stated simply as the ability of wood to resist decay, termites, borers and the weathering process and does not depend on hardness. The durability of some species can be improved by impregnation with chemical preservatives.

Texture generally refers to the arrangement and relative size of cells. Texture could be described as coarse, medium or fine.

Figure is the pattern formed in the timber by variations in colour, grain and texture.

Grain refers to the general direction of fibres relative to the longitudinal axis of a piece of timber and may be described as:

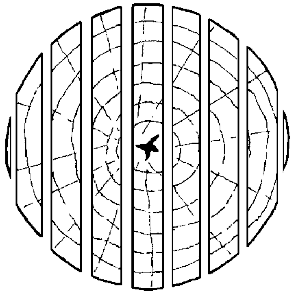
- Straight grain when fibres are parallel to each other and parallel to the face or edge of a piece of timber
- Cross grain when the direction of fibres is not parallel to a face or edge
- Interlocked grain when the angle of fibres change or reverses in alternate layers.

WOOD CONVERSION

Wood conversion is the process of sawing logs into rectangular pieces of timber suitable for use in the building and allied industries. Logs are usually sawn into commercial sizes soon after the tree has been felled to minimise damage caused by shrinkage, such as splitting at the ends of the log.

Live Sawing

The illustration on the right shows a log which has been live sawn. This form of wood conversion is the simplest and most economical method of cutting logs into boards.



Live Sawn Log

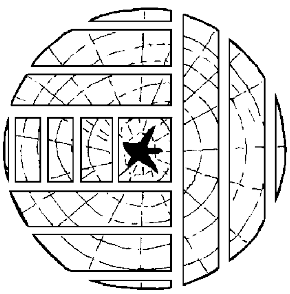
Live sawing is simply a series of parallel cuts through the log, producing wide boards, some of which are prone to excessive warping and uneven shrinkage.

Quite a lot of live sawn timber is of lesser quality and therefore only suitable for uses such as packing crates and fence palings. Live sawing produces some boards which could be classified as quarter sawn or back sawn as described in the following sections.

Back Sawing

Back sawing produces boards whose faces are generally tangential to the growth rings. This method allows for sawing around defects in the log and waste is minimal.

Fancy cabinet timbers with distinct growth rings are often back cut because this method reveals the most decorative figure on the face of the board. Back sawn boards have maximum strength and tend to shrink mostly in the width.



Back Sawn Log

They may 'cup' away from the heart (centre of the tree) as the growth rings tend to straighten themselves a little as the seasoning (drying) process takes place.

Trade practice is to class timber as back-cut when the average inclination of growth rings to the face is less than 45°.

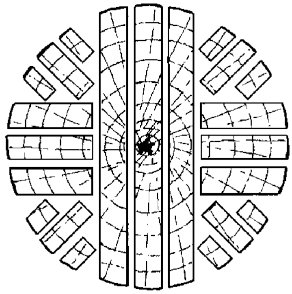
Quarter Sawing

A quarter sawn board has its faces parallel to the medullary rays and at right angles to the growth rings.

Quarter sawing is not as economical as back sawing because more timber is lost in waste.

Quarter-cut boards season very well with minimal cupping and a little shrinkage mainly in the thickness.

Timbers with pronounced medullary rays (such as silky oak) reveal a distinctively patterned figure when quarter-cut.



Quarter Sawn Log

Trade practice is to class timber as quarter-cut when the average inclination of the growth rings to the face is greater than 45° as shown in the illustration above.

TIMBER GRADING & DEFECTS

Grading

Timber is graded into categories according to suitability for particular end uses. The grade is determined by the number, size, type and position of knots, gum veins, shakes or other visible characteristics which affect its strength and/or appearance.

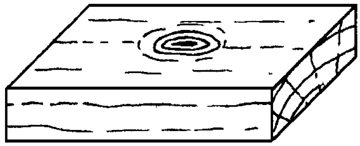
Timber standards are issued by the Standards Association of Australia. These documents are statements of quality for the various grades and sizes of milled timber. Standards are also available for codes of practice in the use of timber products.

Australian standard specifications are revised from time to time to keep pace with developments in technology and material supply.

Natural Defects

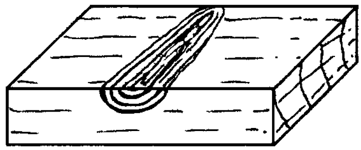
Natural defects in timber may be generally described as any irregularity which affects normal appearance, durability or strength of the timber. Some common natural defects are listed on the following page.

Knots are actually branches embedded in the tree and cut through in the milling process. Knots are characterised by a distinct change in grain direction which may cause some difficulty in working the timber.



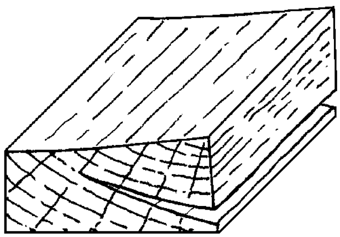
Knot

Knots tend to weaken the timber and often spoil the appearance of some cabinet timbers, however 'knotty pine' furniture seems to maintain some degree of popularity. The illustrations on the right show the effects of knots in milled timber.



Spike Knot

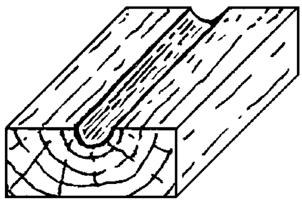
Shakes are caused by adjoining layers of wood separating either along the medullary rays or between the growth rings. Layers sometimes separate when uneven drying and shrinkage occurs in the heartwood while the tree is still standing.



Shake

The illustration on the left shows a shake caused by a separation between the growth rings of a piece of milled timber.

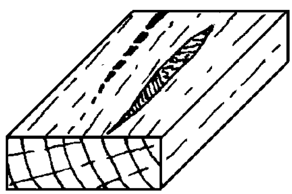
A pipe is simply the absence of wood at the centre of the tree. A cylindrical hole sometimes forms due to decay of the wood around the pith. The illustration on the right shows the effect of a small pipe on a piece of timber cut from the centre of the log.



Pipe

Gum veins are cavities in the timber which contain gum or resin substances. These veins may occur naturally or they can be caused by an injury to the tree.

Gum veins tend to disfigure and to weaken timber. The illustration on the right shows a typical gum vein.



Gum Vein

Strength of Timber

Generally two factors determine the mechanical strength of timber; the length of the fibres and the density or amount of woody material in the cellular structure for a given volume.

Knowledge of the mechanical strength of the various grades and species of timber is very important in the building industry. Architects, builders and engineers need to know the load bearing capability of structural timbers when determining sizes of materials to be used in construction.

Timber species and sizes used in construction must provide an adequate margin of safety in load bearing applications and also minimise flexing or bending under load conditions.

Australian Standard Grading Rules published by the Standards Association of Australia cover most species of timber which are available commercially. They describe decorative grades as well as stress grades.

TIMBER SEASONING & PRESERVATION

Seasoning

Seasoning is the process of drying out most of the water from the cell walls and cell cavities which form the basic structure of wood. Water is contained in the cell walls as combined moisture and in the cell cavities as free moisture.

The green moisture content (combined moisture plus free moisture) varies considerably in different species and in different zones of a tree. For example an ironbark tree could contain moisture up to 40% of the dry weight of the heartwood. A radiata pine tree might have 15% moisture in the sapwood.

Removal of all the free moisture brings the timber to fibre saturation point. At this stage the weight of water remaining is between 25% and 30% of the timber's oven dry weight.

As the combined moisture is removed during seasoning of the timber, considerable shrinkage takes place and the following changes to the properties of the wood occur:

- Stability in use is improved. When timber is seasoned to a moisture content which is approximately in equilibrium with the average humidity level of the atmosphere in that locality, future dimensional change will be small.

- The wood becomes stiffer and harder. When timber shrinks, no material is actually lost but the fibres become more compact. Allowing for the reduction in size, the total gain in the strength of seasoned timber is about 50% of the green safe working load.
- There is a considerable reduction in weight. This factor will lower costs of transport of seasoned timber compared with green timber.
- Gluing properties are improved. The adhesive is not diluted by excessive moisture in the wood. The glue has better penetration into the wood and because of improved stability of the material there is less chance of glue lines breaking.
- Paint and varnish holding properties are improved.
- The seasoned timber becomes more absorbent which is an advantage in gluing and painting operations.
- Durability is increased by improvement in decay resistance. Timber destroying fungi require moisture content above 20%.
- Electrical resistance is increased. In building practice this property may only be significant in special circumstances.

Movement In Wood

As mentioned previously, timber tends to reach a moisture content that is in equilibrium with the moisture content of the surrounding air over a period of time. Equilibrium Moisture Content is usually abbreviated to EMC in trade terms.

Changing atmospheric conditions may cause timber to move (swell or shrink) as it adjusts itself to the new EMC. Significant dimensional change only occurs in the width or thickness of a board. Length variation with change in moisture content is insignificant.

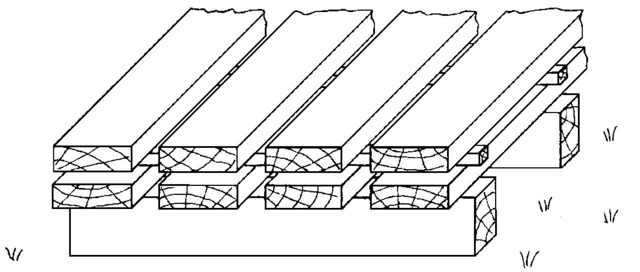
Movement, sometimes called ‘working’, occurs only with changes in relative humidity, not with temperature change. The moisture content of timber when in equilibrium with local atmospheric conditions is usually within the range 10%-15% except in very dry inland areas or wet tropical coastal districts.

Air Seasoning

Air seasoning is a natural drying method which requires green sawn timber to be ‘stripped’ in stacks out in the open where it dries slowly exposed to the prevailing weather conditions. Circulation of air among the stacked boards is the most important factor in the air seasoning method.

Air circulation is facilitated by placing the stack on bearers clear of the ground and spacing the layers of timber with strips of dry wood 25mm in thickness. The strips are positioned vertically in line so that the weight of the stack is supported by the bearers and not the boards being seasoned. Strips out of alignment would cause boards to buckle.

The boards in each layer should be spaced about 25mm apart to allow air to circulate vertically through the stack.



Air Seasoning

Ends of the boards being seasoned are sealed with a coat of paint to prevent the rapid escape of moisture from the end grain. If moisture is removed too quickly from the ends, the boards are likely to crack. Depending on the species of timber, climatic conditions and size of the boards, the air seasoning process could take from 6 months to 2 years.

Kiln Seasoning

Kiln Seasoning is an 'artificial' drying method which may produce seasoned timber in a few weeks. Small sizes in some suitable species may be seasoned in as little as one week using this method.

Timber is stacked or stripped as described in Air Seasoning above, placed on special trucks, then moved into kilns which are large oven-like rooms in which humidity and temperature can be accurately regulated. Heat is usually provided by steam heated coils and air is circulated through the stripped timber by means of fans.

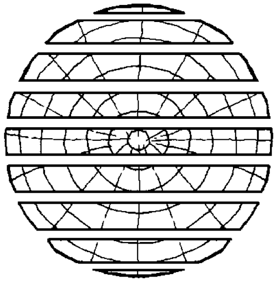
Combined Seasoning

This method, as the term suggests, is a combination of kiln and air seasoning methods. Timber is stripped in the open for a period of time allowing the free moisture to dry out slowly and naturally.

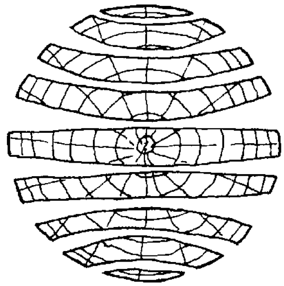
The stack is then moved into a kiln and combined moisture is dried out quickly. Combination seasoning avoids excessive hardening of outside cells which is caused by rapid drying out of the moisture content of green timber.

Shrinkage

When the free moisture in the wood cells has been dried out, shrinkage begins to occur as the remaining combined moisture dries out of cell walls. Wood fibres actually become smaller as the moisture contained in cell walls is removed.



Before Shrinkage



After Shrinkage

This causes dimensional change in the boards being seasoned. As mentioned previously very little shrinkage occurs with the grain (in the length of the board).

Most shrinkage occurs in the direction of the growth rings which tend to straighten out as moisture is removed. This causes 'cupping' as described previously under 'Back Sawing'. The illustrations above show the effects of shrinkage on sawn timber.

Preservation

The term 'preservation' usually refers to the treatment of timber to improve its durability. The main factors causing deterioration of wood are fungi, insects and weather. Preservation methods are usually based on:

- The provision of a physical barrier against attack.
- The use of chemical preservatives.

Physical Barriers

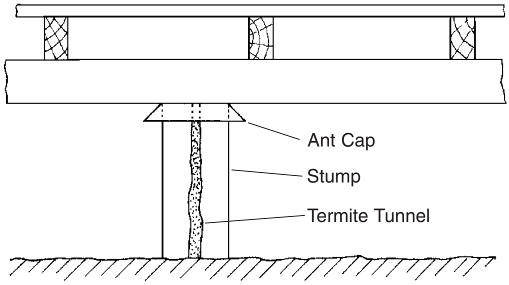
Physical barriers prevent exposure of the wood to the attacking agent as described in the examples which follow:

- Painting timber provides protection against fungal attack, insect attack and the weathering effects of the elements. Well painted timber shrinks and swells much less than unpainted timber.

  The coats of paint provide a physical barrier which minimises further loss of moisture in dry weather and absorption of excess moisture in wet weather.

- A correctly fitted termite shield would prevent wood destroying termites which live in the ground, from climbing up the foundations of a house and attacking flooring timbers.

  Termites are repelled by light and usually build a mud tunnel which allows them mobility and also protection from the light.



Termite Shield (Ant Cap)

  These insects will only build their tunnels upward and not downward, so when the termite shield is reached it acts as an effective barrier to the progress of the termites' tunnel as shown in the illustration above.

Chemical Preservatives

Commercial timber is either coated with chemicals by spraying or dipping, or pressure impregnated in large steel pressure cylinders. The long term effectiveness of these preservation methods depends largely on the degree of penetration achieved.

Impregnation under pressure is widely used in the timber industry today. The most significant advantage of chemical impregnation is that timbers which are not naturally durable and non-durable sapwood can be used for structural purposes after treatment.

Creosote and **Penta** (pentachlorophenol) are commonly used oil-type preservatives which protect timber against fungi and wood destroying insects. The main disadvantage is their dark colour and the oily residue left on the surface.

Together, these factors render the timber surface unsuitable for painting and varnishing. Timber treated in this manner is usually used in applications such as sleepers and fence posts.

Borax, which is a water soluble compound, is effective against some varieties of termites but should be used for internal work only.

Creosote, Penta and Borax are usually applied by spraying, dipping or brushing.

Vacuum Pressure Treatment

Copper/Chrome/Arsenic salts (CCA) are used extensively as wood preservatives in the timber industry. Pressure impregnation of these substances is carried out on seasoned or partly seasoned timber.

The timber to be treated is placed in large vacuum cylinders where the preservative is forced into the timber under pressure until the required up-take of preservative solution is achieved.

The preservatives become fixed in the timber and remain permanently effective providing reliable protection against all types of biological degrade. They do not provide any significant protection against weathering.

Wood Destroying Insects

- The Powder Post Beetle (Lyctus) is probably the most common wood destroying insect in Australia. It attacks the sapwood of several species of hardwood usually during the first year after the timber is milled.
- The Furniture Beetle (Anobium) attacks mainly the sapwood of soft timbers. It seems to have a preference for quite old wood such as antique furniture.
- The Pin Hole Borer (Ambrosia) attacks green timber of both softwoods and hardwoods.
- White ants or termites live in colonies. Some varieties build a mound above the ground while others live in galleries in timber. Still other varieties live below the ground. Detection of termites is difficult because they prefer poorly ventilated and dark areas. These insects destroy large quantities of timber annually in Australia.

Fungi

Fungi are low forms of plant life which live on wood using it for food. Fungi cause decay which is the partial disintegration of the wood substance. These tiny organisms need food, warmth, air and moisture to exist.

If any one or more of these elements are denied, fungi can be controlled. Decay of this type is usually called ‘wet rot’ or ‘dry rot’. Wet rot is caused by a fungus which requires very wet conditions to exist while dry rot requires some moisture, but much less than wet rot.

MANUFACTURED BOARDS

VENEER & PLYWOOD

Archaeologists have uncovered evidence that the practical use of adhesives and veneer was part of the craftsman's art 4,000 years ago. Veneer was used in the construction of ornamental cabinets and other articles in Egypt during the reign of the great Pharaohs and later in the early Greek and Roman civilisations.

There is an absence of evidence to show that veneering was practised during the middle ages, but the art was revived in Italy during the Renaissance in the 15th century. By the 17th century veneering was practised throughout Europe.

The development of furniture styles and the utilisation of a greater range of fancy timbers further popularised the use of veneer in the furniture industry. The introduction of machines during the Industrial Revolution of the 19th century included the use of large circular saws for cutting veneer.

Circular saws are very wasteful of material when cutting thin veneers and are rarely used in the commercial production of veneer today. Large lathe-like machines and guillotine-like slicers are used to produce most of the veneer in the modern timber industry.

Veneer Cutting Methods

Rotary cutting or 'peeling' is the method used to produce most of the veneer used today. The selected log is suspended in a large lathe and rotated. A blade, which is the full length of the log, is advanced towards the centre of the log cutting or peeling the veneer in a continuous sheet which is uniform in thickness.

Veneer is produced in thicknesses ranging from 1mm to 6mm. The thickness is regulated by adjusting the rate at which the blade is advanced into the rotating log.

Slicing is the method used when special grain effects are required for face veneers. A guillotine type operation utilises a blade which is the full length of the wood stock. This blade slices vertically through the stock and produces veneers by parallel cuts.

Special grain effects and figure variations can be achieved by using wood stock from a fork of a tree, at or near a knot or near the butt. These variations in veneer pattern result from variations in the tree's own cell formation or from differences in the colours of heartwood and sapwood. Sliced veneer sheets are numbered and stacked as they are cut. Numbering the sheets assists in matching the figure patterns in the production of plywood and veneered particleboard.

Sawing is rarely used in the production of veneer in Australia. Veneer saws are very large in diameter and have very small finely set teeth. These saws are specially designed for the purpose of cutting thin veneers with a minimum of waste sawdust. Sawing is used to produce veneer when the wood stock is too hard, too brittle or has too 'wild' a grain to use the conventional methods of rotary cutting and slicing.

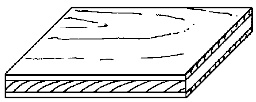
Drying Veneer

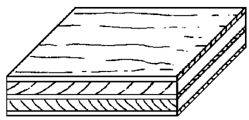
When veneers are cut the woodstock is either steamed or soaked with hot water. The high moisture content of the cut veneer must be stabilised before the veneer sheets are glued and pressed in the production of plywood or veneered particle board. The sheets of veneer are dried in air drying racks or by passing them through a drying kiln.

Plywood Production

The manufacture of plywood usually involves the bonding of three or more veneers (or plies) together so that the grain direction is at right angles in alternate layers. Although two-ply is sometimes made specially for bending, the majority of plywood sheets have an odd number of layers, varying from 3 to 21.

The illustrations on the right show plywood made with three layers and five layers.


Three Ply

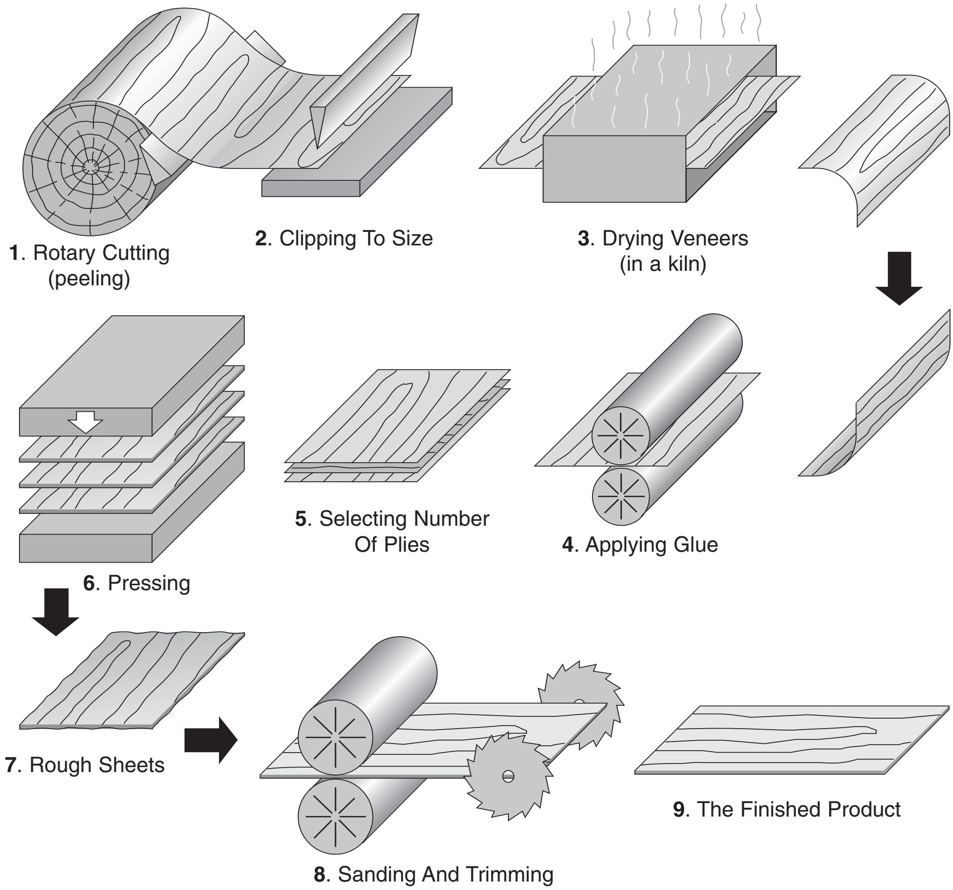

Five Ply

To improve strength and stability of the plywood sheet, the odd numbered veneers are usually placed with the grain direction running along the length of the sheet. The even numbered or cross bonded layers often differ in thickness from the others and have the grain running across the sheet.

Plywood sheets may be bonded with different types of glue depending on the use to which the material will be put. Interior grade plywood is bonded with glue that is not moisture resistant while exterior and marine grade plywood is bonded with water resistant adhesive. 'Water-proof' plywood is usually identifiable by the black glue lines visible on the edges of the sheets. Manufacturers usually use the dark coloured phenolic formaldehyde for exterior grades of plywood.

Process Diagram

The flow chart which follows illustrates the stages of manufacture of plywood.



Plywood Production Process

Advantages of Plywood over Solid Timber

- Cross bonding alternate veneers produces a very strong material. This strength is evenly distributed over the whole sheet. A piece of solid timber of equal thickness would be strong in the length but may be easily split in the width or with the grain.
- The effect of shrinkage is minimised.
- Much larger sizes are available.
- Economical use of scarce or expensive timbers can be achieved. Similar visual effects are produced by using either a veneered sheet or solid timber.
- Panels with matching figure (grain pattern) can be obtained.

- Thin sheets of plywood can be readily bent over framework or laminated to produce curved surfaces.
- Plywood does not split like some varieties of solid timber.

Disadvantages of Plywood

- In cabinet construction edges require sealing or covering with solid timber or veneer edge strips.
- Thin face veneers are easily sanded through with belt sanders or orbital sanders.
- Cross bonding of plywood sheets tends to make this material a little harder to work than solid timber.

Uses for Plywood Sheets

Since the introduction of particle board the usage of plywood in Australian industry has decreased. However, there are still applications for plywood in all branches of construction work for wall sheeting, partitions, doors, formwork for concrete projects, beams and trusses.

In boat building plywood is used for frames, decks, planking and hull sheeting. The furniture industry uses plywood sheets of varying thickness for applications such as carcass construction, doors, panels, shelves, cupboard backs and drawer bottoms.

PARTICLEBOARD

The introduction of particleboard in the 1960s revolutionised the cabinet making and joinery industries. Panels which previously had to be framed and sheeted with plywood or hardboard could now be simply cut from a sheet of particleboard.

Production

The production process of particleboard utilises the thinnings and trimmings from pine plantations as well as whole trees which are cultivated specifically for the production of particleboard and other manufactured boards.

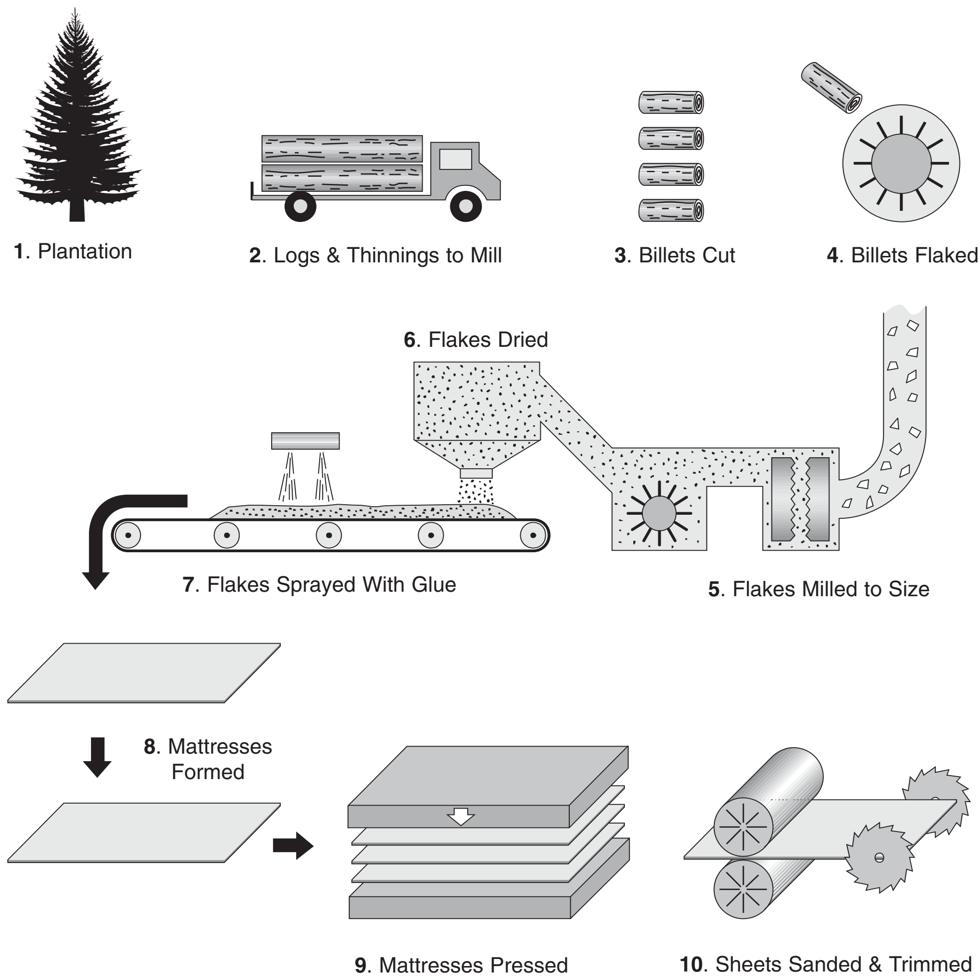
The various stages in the production of particleboard are listed below.

- Debarked thinnings and wood billets are treated with chemicals to prevent the growth of mould and are then cut and milled into coarse and fine flakes.
- These flakes are then dried and sprayed with urea formaldehyde glue before being formed into a mattress with coarse flakes sandwiched between outer layers of fine flakes.

- A number of these mattresses are then pressed between electrically heated platens forming strong, grainless sheets which are chemically treated to prevent attack by termites and borers. Some production lines use presses or platens heated by steam or hot water.
- Particleboard sheets are sanded true to accurate thickness and cut to the required sizes on a multiple saw arrangement. Sheets are available in a large range of sizes up to 4800 x 1830 and in thickness from 4mm to 33mm.

Process Diagram

The flow chart below illustrates the main stages of the particleboard manufacturing process.



Particleboard Production Process

Advantages

- Particleboard is available in very large sheets.
- Particleboard is very stable compared with solid timber. In normal atmospheric conditions very little swelling and shrinkage takes place.
- This stability enables particleboard to be used in a wide range of interior applications particularly as a base for covering with plastic laminate or veneer.
- Sheets have no grain direction which means that strength and rigidity are evenly distributed through the sheet.
- Particleboard can be quite easily worked with normal hand and machine tools.
- Sheets can be readily finished with paint or other liquid surface finishes.
- Sheets are available with plain, veneered and melamine surfaces.
- Particleboard does not require the support of framing in carcass construction.
- When compared with plywood or coreboard, particleboard is cheaper.
- Particleboard resists attack by termites and borers because it is chemically treated in the production process.

Disadvantages

- The edges of particleboard are very porous because of the board's structure. Exposed edges must therefore be covered with edge strips of solid timber, veneer, plastic laminate or iron-on plastic strips.
- Particleboard is much more absorbent than solid timber. If a piece of particleboard is left out in the rain and weather it will absorb water and swell or expand until it disintegrates.
- The flaky structure of particleboard causes edges to break away if nails or screws are inserted too close to the edges.
- Particleboard does not hold nails and screws as well as solid timber, particularly in the edges.

Working Techniques

- Particleboard can be worked with all normal hand and power woodworking tools which must be kept sharp for best results.
- If a hand saw or portable power saw is being used to cut sheets care must be taken to support the sheet properly to prevent movement and breakage towards the end of the cut.

- Glue should be applied to both surfaces when fabricating with particleboard. Edges may require two coats of glue because of the porous structure. The first coat is often absorbed completely leaving insufficient glue to make the bond.
- Particleboard screws which have full length thread should be used in preference to ordinary wood screws. The drill size should be small enough to allow the full depth of thread to be cut by the screw. Care must be taken not to over tighten the screw as particleboard fibres may tear away and joint strength will be reduced.
- Nails and screws should be kept a reasonable distance from corners when fixing into the edges of particleboard. Entry too close to a corner may result in separation of the layers of flakes.

Uses

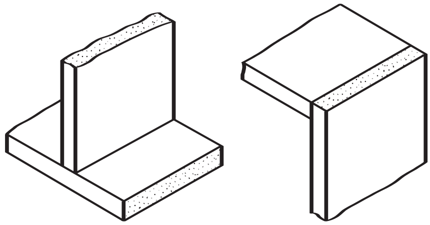
Particleboard is used in cabinet construction and building fitouts for almost any purpose where a panel is required; for example, doors, shelving and tops. Plain sheets can be used where a painted surface is required, while fancy veneered sheets can be used for a polished natural wood finish.

Particleboard sheets are also available with melamine surfaces, either plain white or with a pattern such as wood grain. These sheets are used in kitchen cupboards and other cabinet work.

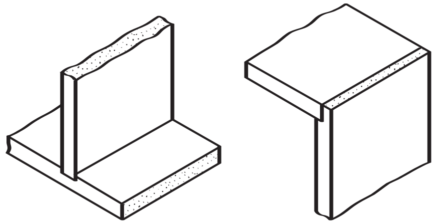
Particleboard flooring is used extensively in the building industry. These sheets are manufactured specially for this purpose. They are darker in colour than standard particleboard sheets. The dark colour is caused by the use of water resistant glue such as phenolic formaldehyde in manufacture. Standard particleboard produced using urea formaldehyde to bond the flakes together will disintegrate when exposed to lengthy periods of dampness because the glue is affected by moisture.

Carcase Joints

The diagrams illustrate simple butt and housing joints used with particleboard. These joints would be glued and clamped or glued and fixed with nails or screws.



Butt Joints



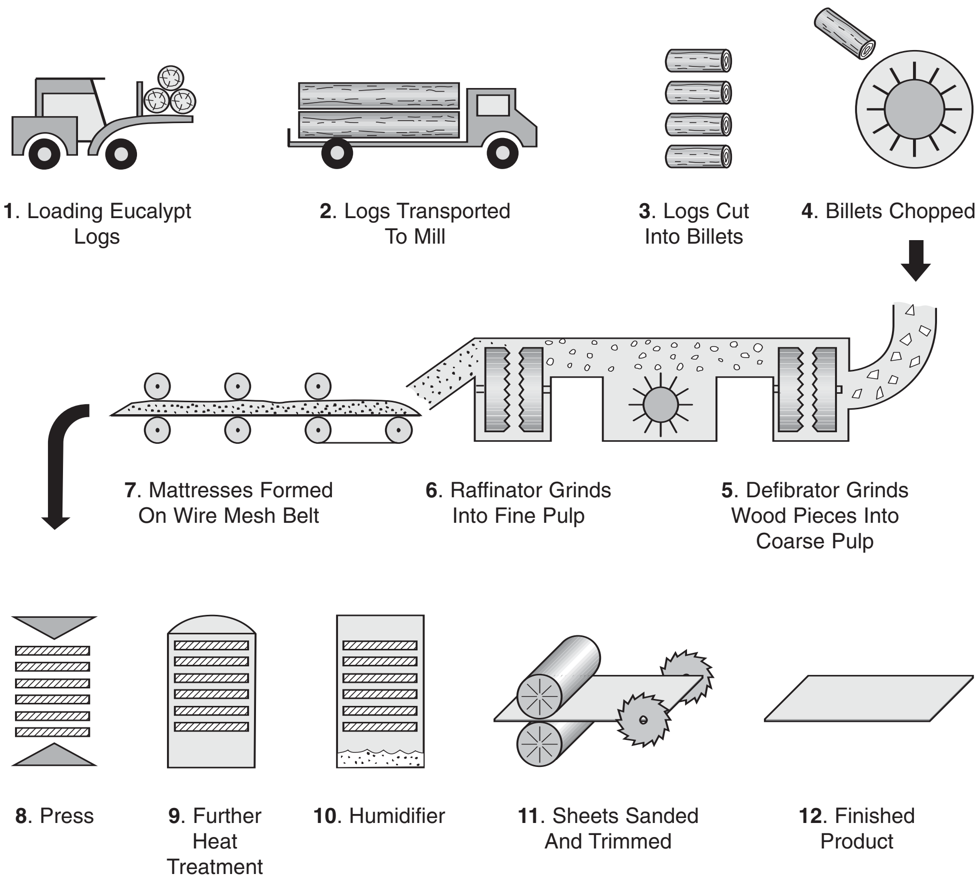
Housing Joints

HARDBOARD

Australian hardboard is manufactured under various trade names such as Masonite, which takes its name from an American, WH Mason who first began experimenting with compressed building boards in 1924.

Process Diagram

The flow chart which follows illustrates the main stages of the manufacturing process for hardboard.



Hardboard Production Process

Production

Hardboard is manufactured from hardwood chips, mainly eucalypt, pulped with water and then spread as a ‘mattress’ on a moving wire mesh screen. The mattresses are compressed at a high pressure in large hydraulic presses. The pulp mattresses are heated to about 240°C as they are pressed to form tough, dense, grainless sheets.

After pressing, the sheets are treated in humidifying ovens to stabilise the moisture content at 5% to 8%. Sheets are then sanded and trimmed to the exact sizes required. The process diagram on the previous page further explains the production process.

Advantages

- Hardboard sheets are available in a large range of sizes from 1220mm x 915mm to 5490mm x 1370mm. Available thicknesses range from 3mm to 9.5mm.
- Hardboard has no grain direction, thus providing equally distributed strength in the full length and full width of a sheet.
- It can be nailed or screwed close to the edge of a sheet.
- A range of painted, textured and patterned finishes are available.
- Hardboard can be formed into curved surfaces.
- All conventional hand and power tools can be used to work hardboard sheets.
- Tempered sheets offer increased moisture resistance and hardness and are suitable for exterior work.

Disadvantages

- Hardboard sheets require a supporting frame in construction work.
- Standard hardboard is more absorbent than timber.
- Extremes in atmospheric conditions such as humidity, dryness and heat will adversely affect hardboard causing swelling and shrinkage.
- Standard hardboard has less impact strength than an equal thickness of plywood. It will puncture or break much more easily.

Working Techniques

Most standard sheets require wetting on the back and stacking flat for about 24 hours before use to stabilise the moisture content. The procedure helps to prevent buckling of the sheets after they are fixed in position.

Some pre-primed (painted) types do not require wetting before they are nailed to the supporting frame. Care should be taken to read and follow the fixing instructions which are usually printed clearly on the sheet.

A sharp, fine-toothed hand saw should be used to cut sheets of hardboard which should be well supported to prevent movement which may cause breakage when cutting.

When sheets are fixed with edges butted together the edges should be vee-jointed or covered with a cover strip.

Carcass construction requires a supporting frame or corner members on which sheet edges can be fixed.

Uses of Hardboard

Traditionally, the most common use for hardboard has been for internal wall sheeting in the housing construction industry, i.e. for walls and ceilings.

The furniture industry utilises hardboard for cupboard backs, drawer bottoms and other purposes where a thin rigid sheet is required.

Some standard internal panel doors are sheeted with hardboard.

Hardboard sheets are also produced for special purposes, for example, pegboard and slotboard may be used for display boards and tool racks and standard hardboard is produced in special sizes to use as underlay for floor coverings.

MEDIUM DENSITY FIBREBOARD

Medium density fibreboard or MDF, is manufactured using basically the same process as for particleboard. The main difference is that in manufacturing MDF, the wood chips are pulped to separate the fibres which interlock to create the sheet strength. This fine fibrous texture is fairly uniform throughout the sheet.

MDF is available in plain sanded sheets, or with a range of veneered and melamine coated surfaces. Edge treatment requirements are basically the same as for particleboard.

Characteristics

- Designed for interior use, being resistant to light wear and abrasion.
- Has uniform density from surface to core.
- Edges can be accurately and neatly machined and finished.
- Easily worked and has good nail and screw holding qualities.

SOFTBOARD

In 1939, bagasse, the fibrous residue from sugar cane which remains after crushing, was compressed with an adhesive to form a soft sheet which was sold under the trade name ‘Caneite’. Modern softboard is manufactured from tops and trimmings of Radiata Pine trees.

Debarked wood is chipped, softened under steam, thickened using chemicals and adhesive and formed into a continuous wet sheet on a production line. The continuous sheet is pressed to remove the water, cut to the length required and then passed through a humidifying chamber to adjust the moisture content. Sheets are then trimmed and finished.

Advantages

- Has excellent thermal and sound insulation properties.
- Available with a pre-painted finish.
- Easy to saw.

Disadvantages

- Easily damaged, particularly on corners and edges.
- Little impact resistance in sheet surface.
- Nails tend to pull through the sheet.
- Very absorbent; affected by changing weather conditions.

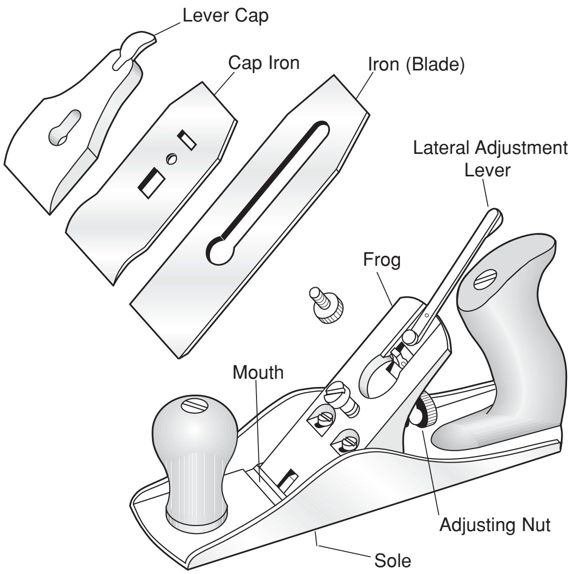
TOOLS & MACHINES

HAND TOOLS & EQUIPMENT

Planes

Planes are used to smooth the faces and edges of timber and to reduce pieces of timber to the sizes and shapes required.

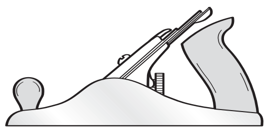
The illustration on the right shows the main parts of a typical plane. The plane iron (or blade) is screwed to the cap iron and then held in place on the frog with the lever cap.



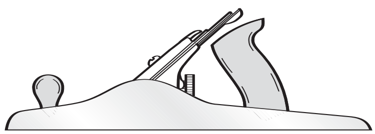
Parts Of The Plane

The depth of cut is adjusted by turning the adjustment nut clockwise to increase the depth and anti-clockwise to decrease the depth of cut.

The lateral adjustment lever is used to adjust the cutting iron so that the edge is parallel to the sole of the plane.

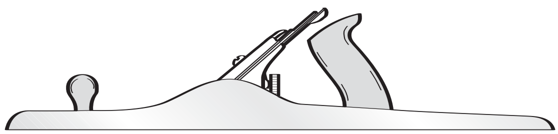

Smoothing Plane

The smoothing plane is mainly used for fine finishing work.


Jack Plane

The jack plane is a general purpose plane which can be used to remove waste quickly or for finishing work.

The try plane is used for straightening long edges.

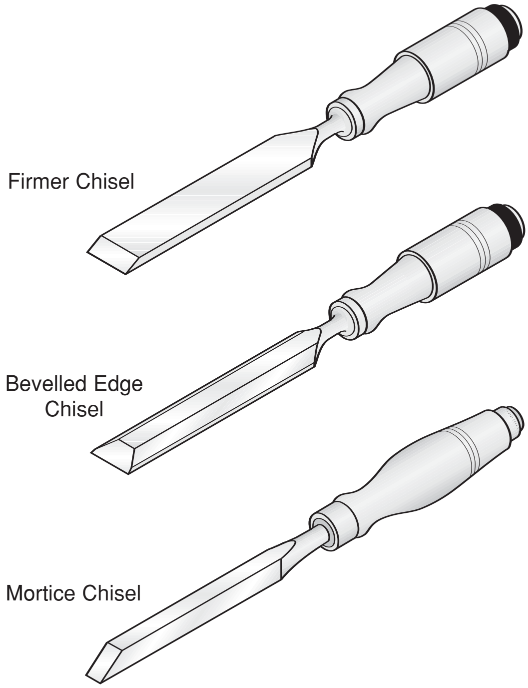

Try Plane

Chisels

The firmer chisel is a general purpose cutting tool used mainly for the heavier applications of bench work.

The bevel edge chisel is usually used for fine work such as paring and cutting dovetails where the bevelled edge allows the chisel to fit the shape of the joint.

The mortice chisel is much thicker and stronger than other chisels so it can be used as a lever in cutting mortices. Wide mortice chisels are often used for very heavy work.

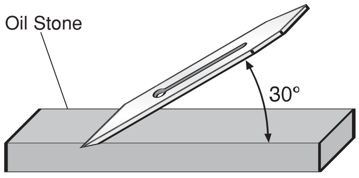


Sharpening Methods

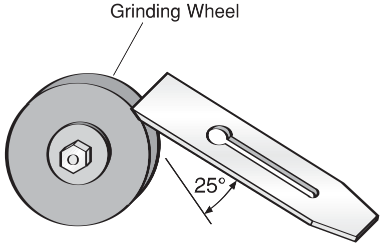
The diagrams which follow illustrate the methods of sharpening plane irons and chisels. When a cutting edge becomes dull it can usually be sharpened by rubbing on an oil stone to produce a fine bevel at 30° to the face of the blade.

A burr will be formed on the cutting edge. This burr must be removed by rubbing on the oil stone with the face of the blade flat on the face of the stone.

When the plane iron or chisel can no longer be effectively sharpened on an oil stone or if it has become gapped, it must be ground on a grinding wheel to an angle of 25° and then sharpened on an oil stone at 30°.



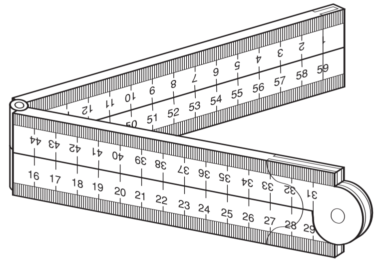
Sharpening Angle



Grinding Angle

Measuring And Marking Tools

Folding rules are used for making accurate measurements and are available in two sizes, 600mm and 1m. Never leave a folding rule open on the bench as it can be easily broken. Measurement should always be made with the rule on edge to avoid parallax errors.

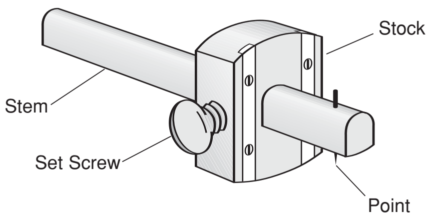


600mm Folding Rule

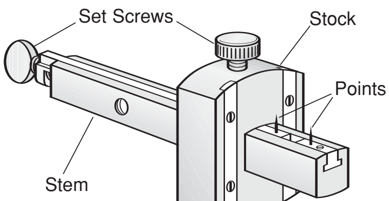
Steel rules are available in 300mm and 1m lengths. They are also used for making accurate measurements and are handy straightedges.

300mm Steel Rule

The marking gauge is used for marking lines parallel to the faces and edges of dressed or sawn timber. The stock is held firmly against the face side or face edge of the timber and the point scribes a line as the gauge is pushed forward.

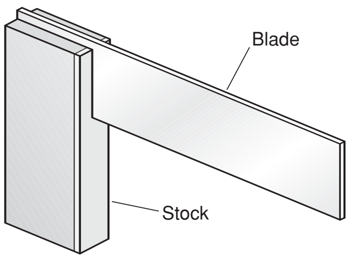


Marking Gauge



Mortice Gauge

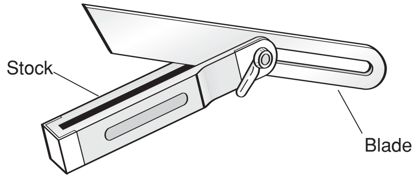
The mortice gauge is similar in construction and usage to the marking gauge except that it has two points. These two points scribe parallel lines as required when marking out a mortice. One point is fixed and the other is adjusted by loosening off the stock set screw and turning the set screw at the end of the stem, then tightening the stock set screw. The distance between the points is set to the width of the mortice chisel to be used.



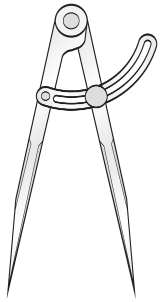
Try Square

The try square is used for drawing lines at right angles to the faces and edges of straight pieces of timber and testing edges and corners for squareness. When using the try square always hold the stock against the face side or face edge.

The sliding bevel is a marking tool which is used for drawing lines at acute or obtuse angles to the face side or face edges of pieces of timber. It is also used for testing the accuracy of angle cuts.



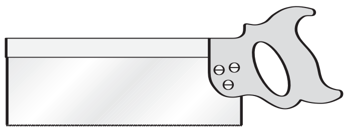
Sliding Bevel

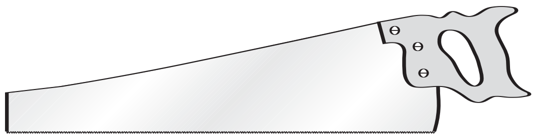

Wing Dividers

Wing dividers or compasses are used for scribing circles and arcs in marking out operations and for transferring measurements and stepping off equal distances on a setout. Wing dividers can also be used as a parallel gauge when scribing an irregular joint.

Saws

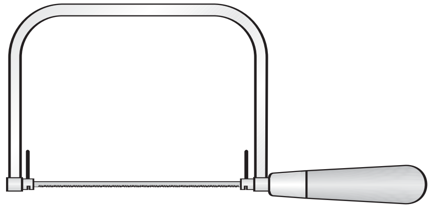
The tenon saw is a versatile tool used for both cross cutting and rip cutting in the whole range of fine bench work. It features a rigid back which stiffens the saw blade and helps to keep the cut straight.


Tenon Saw


Hand Saw

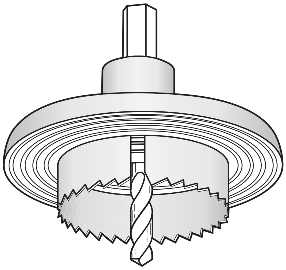
Hand saws are used for cutting both softwoods and hardwoods and are available in a range of sizes. Small hand saws with fine teeth are called panel saws and are used for accurate cross cutting of small sections and light panels. Large saws with teeth specially shaped for cutting with the grain are called rip saws.

Coping saws are used for fine cutting of curves and intricate shapes. The blade of a coping saw is usually placed in the frame with the teeth facing backward to cut on the backward stroke. This keeps the blade tight on the cutting stroke. Cutting on the forward stroke springs the frame and slackens the blade which can cause it to break.


Coping Saw

Keyhole saws are used when an internal cut is required. A hole is bored in the sheet or board to allow the saw to enter and start the cut. A portable jigsaw could also be used to perform this work.

Keyhole Saw



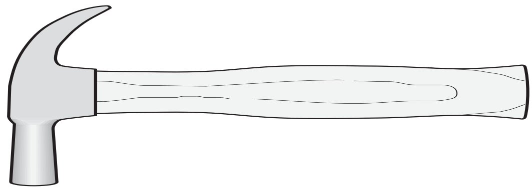
Hole Saw

The hole saw features a cylindrical saw blade and pilot drill. Interchangeable blades of different diameters are available. The hole saw cuts a perfectly round hole and is generally suitable for boards or sheets which are thinner than the width of the blade. Thicker material can sometimes be cut from both sides. Hole saws can be used in a portable drill but are most accurate when used in a drill press.

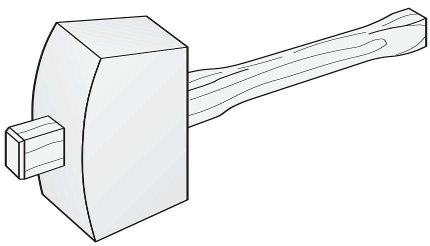
The teeth of a saw are 'set' so that the saw cut is wider than the thickness of the saw blade to prevent jamming. Every second tooth is bent outward and the alternate teeth are bent in the opposite direction. Tenon saws and hand saws are set with a special tool called a *sawset*.

Other Tools

Claw hammers are general purpose hammers which feature a specially shaped claw which is used mainly for pulling nails. The size of a hammer is given by the weight of the head. The type illustrated is a standard claw hammer with a replaceable wooden handle. Other types have steel or reinforced fibreglass handles. A hammer should never be used on a chisel in the workshop.



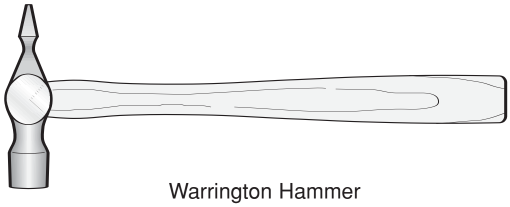
Claw Hammer



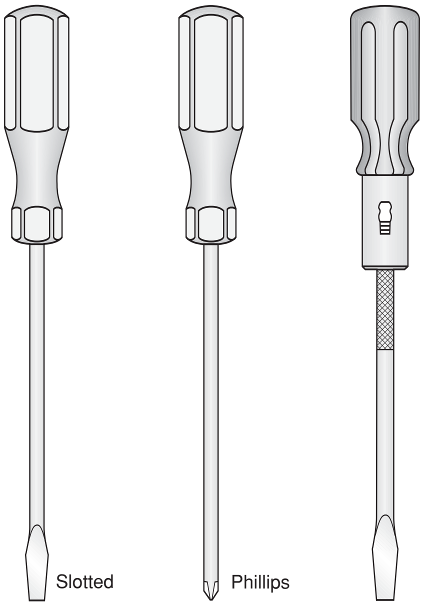
Mallet

The wooden mallet is used in conjunction with chisels to remove the waste material in most woodwork jointing operations. The mallet is preferred to a hammer because it is less likely to damage the handle of the chisel.

The warrington hammer is similar to the cross pein hammer used in metalwork but is generally smaller in size and weight. It is usually used for fine nailing work.



Warrington Hammer



General Purpose Screwdrivers

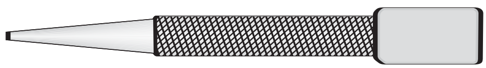
Ratchet Screwdriver

Screw drivers are used for turning screws when inserting or removing them from the work. The illustrations on the left show general purpose screwdrivers for both slotted and Phillips head screws.

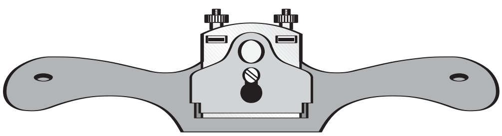
The ratchet screwdriver shown is also available for Phillips head screws. These screwdrivers have a mechanism that enables the screw to be driven or withdrawn in a continuous, alternating motion without altering the grip on the handle.

Care must always be taken to select a screwdriver that fits snugly into the slot of the screw.

The nail punch is used in conjunction with a hammer to punch nail heads just below the surface of the timber in preparation for stopping (filling).



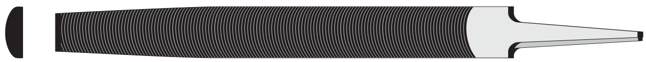
Nail Punch



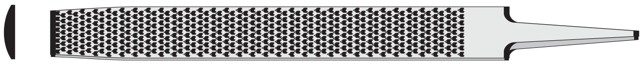
Spokeshave

The spokeshave is used to smooth round edges. It has a blade and cap iron similar to a plane and works on the same principle. Spokeshaves with a round sole are used on concave edges.

The half round file is often used in shaping operations such as freeform work and smoothing curved edges. The flat face of the file is used on flat or convex surfaces and the rounded side is used to shape concave surfaces. Half round files used in woodworking are sometimes called *cabinet files*.



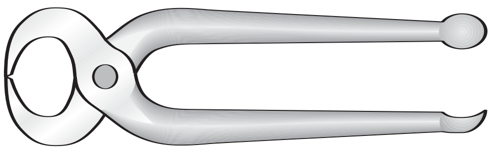
Half Round File



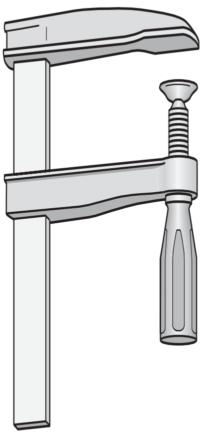
Rasp

A rasp is similar to a file. It has coarse teeth and is used for rough shaping wood. The main difference between a file and a rasp is the way the teeth are formed. The teeth of the rasp are punched into its surface, whereas the teeth on a file are cut into its surface.

Pincers are generally used for pulling small nails which bend when being driven in with a hammer. Pincers are sometimes used for cutting thin wire or small nails.



Pincers



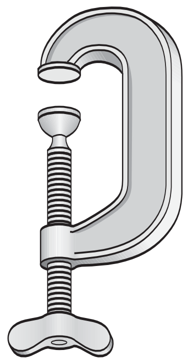
Quick Action Clamp

The quick action clamp illustrated on the left is a general purpose clamp used for holding parts together when fixing or gluing. These clamps are often called *quick release* clamps.

The G clamp shown on the right has similar uses to the quick action type.

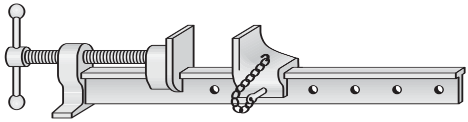
Its main disadvantage is that it is slow to operate compared to the quick release clamp.

Its main advantage is that a more positive pressure is possible with the screw type.

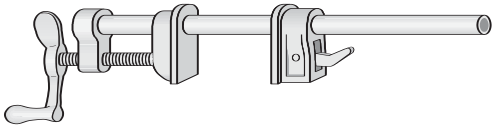


G Clamp

The sash cramp (or tee bar cramp) is used for holding large jobs such as frames and carcases when gluing. Considerable pressure can be applied to the job using one or more sash cramps.



Sash Cramp



Pipe Cramp

The pipe cramp is a general purpose gluing clamp. Their main advantage is that the length is limited only by the length of interchangeable pipe available.

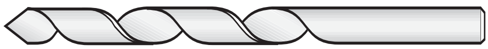
Twist drills are capable of cutting a variety of materials. A *high speed* drill will cut most metals including mild steel, as well as wood.

Twist Drill (drill bit)

Dowel bits are designed to cut a clean, reasonably flat bottom hole in softwood.

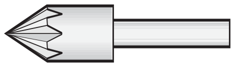
Dowel Bit

Single flute drills cut wood faster than twist drills which have two flutes.



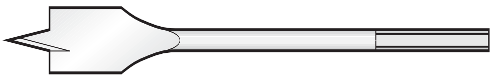
Single Flute Wood Bit

Countersink bits are used to enable countersunk screws to be sunk flush with the surface of the work.



Countersink Bit

Spade bits rely on high speed to cut efficiently. They are used for rough drilling in both softwood and hardwood.



Spade Bit

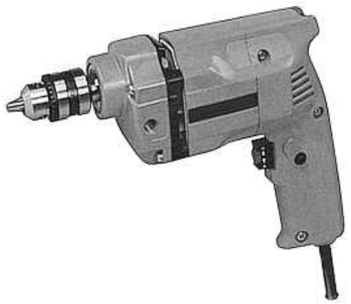
Auger bits are used for drilling deep holes and have a draw thread to assist entry. They should be used at very slow speed. Softwood auger bits have spurs on the tip to provide a clean cut.

Auger Bit (hardwood)

Auger Bit (softwood)

PORTABLE POWER TOOLS

Drills



Basic Drill

Portable drills are available in a wide range of types and sizes with a number of different features including dual and variable speeds, forward and reverse, torque settings and impact or hammer function.

The drill bit is held in a chuck which is connected by a shaft and gear arrangement to an electric motor. Most portable electric drills are equipped with a switch lock. Generally, students are advised to use the switch lock only when the drill is fixed in a drill stand.

Basic drills are light and compact, usually featuring variable speed and reverse. Chuck size is usually 6.5mm or 10mm.

Cordless drills feature a rechargeable battery and are usually equipped with a 10mm or 13mm chuck. Other features may include dual or variable speeds, multiple torque settings, forward and reverse. These features combine to make most cordless drills suitable for both drilling and screwdriving operations.

Cordless Drill

Impact Drill

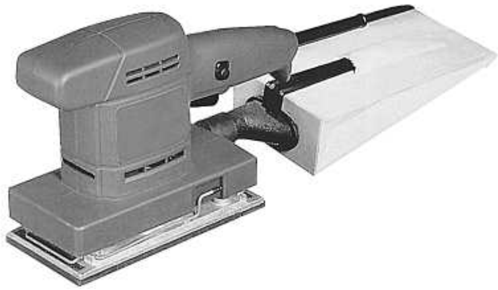
Impact drills often have extra features such as a two speed gearbox, variable speed reversible, usually with a 13mm geared chuck. The model illustrated on the left also has an adjustable depth guide fitted.

The impact or hammer mode is engaged by pressing the button provided and is used for applications such as drilling into masonry or brickwork.

Sanders

Orbital sanders are generally used for fine finishing work. The flat pad to which the abrasive paper is attached moves in a small orbit or circular motion at a very high speed.

The orbital action is caused by an eccentric attachment fitted between the pad and the drive shaft from the motor. The model illustrated on the right has a dust collection bag fitted.



Orbital Sander

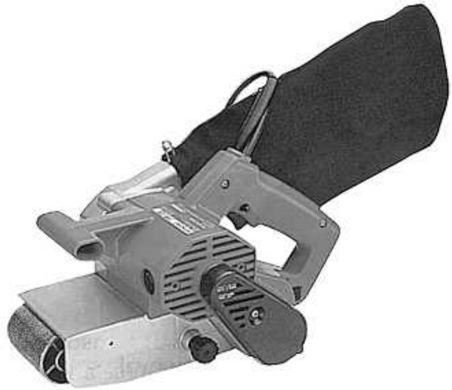
Random orbital sanders are often called eccentric sanders because they combine the circular motion of a disc sander with the eccentric motion of an orbital sander.

The combination of the circular motion and the orbital motion provides a fast but smooth sanding action which is suitable for fine finishing work.

Random Orbital Sander

Belt sanders are used mainly for rough sanding work as they tend to cut much more quickly than other types of portable sanders. A belt of abrasive material rotates around two drums which act like pulleys.

One of these drums is driven by an electric motor and the other runs free. Portable belt sanders feature an adjustment which is used to align the drums so that the belt runs true.



Belt Sander

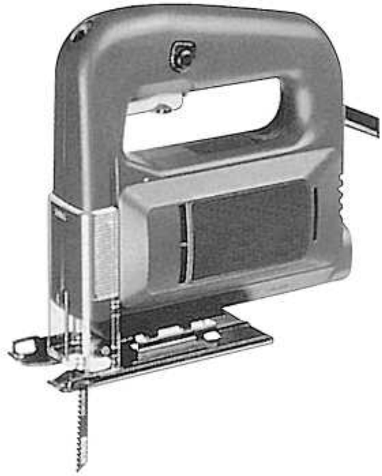
Jigsaw

The jigsaw is a versatile power tool which can be used for a variety of cutting operations on wood and most sheet materials.

It can be used for straight cutting but is most useful for cutting shapes which involve tight curves.

The model illustrated on the right features an adjustable foot plate which can be rotated up to 45° for bevel cuts. The foot plate should always rest wholly on the workpiece while cutting.

When cutting out internal shapes, a hole should be drilled through the material first, to allow entry of the jigsaw blade.



Jigsaw

Safety Precautions

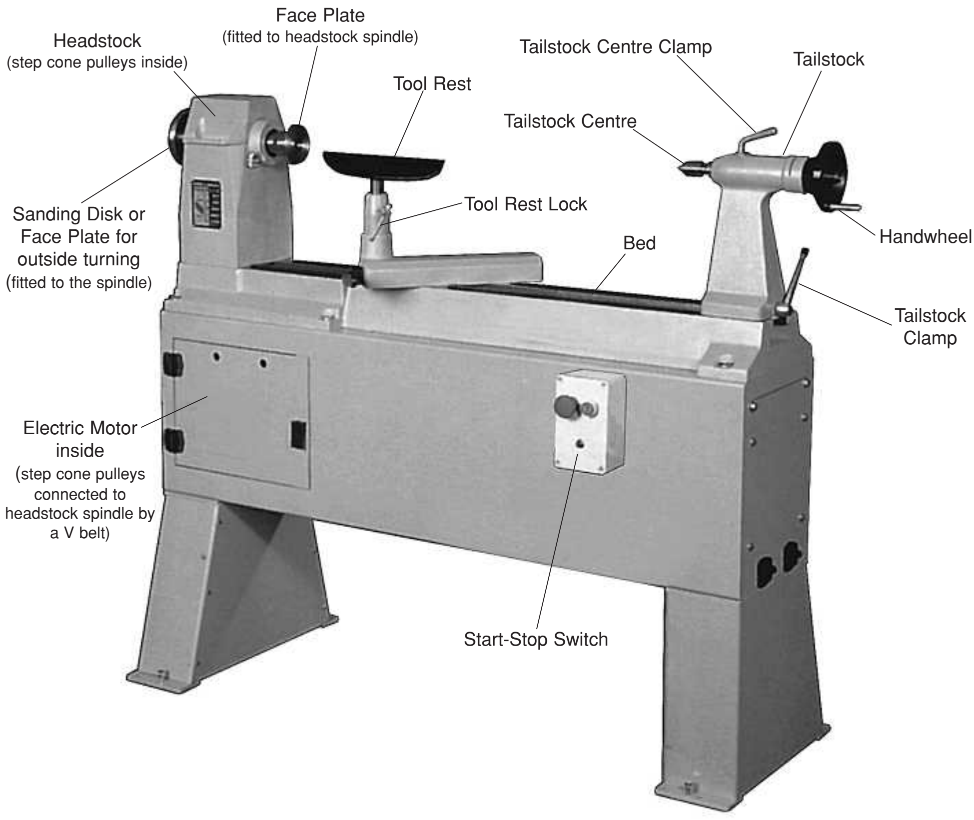
- Obtain permission from the teacher before using any portable power tool.
- Receive instructions in the safe and proper use of a power tool before commencing to use it.
- Fasten loose clothing, tie apron at the back, remove tie or tuck in safely between shirt buttons.
- Wear shoes which provide adequate protection for the feet.
- Do not wear rings, watches, bracelets or necklaces.
- Wear appropriate eye protection.
- Long hair must be constrained with a suitable cap or net.
- Hearing protection must be worn where noise levels are hazardous.
- Wear an appropriate dust mask if the operation of the tool produces airborne particles which could be a respiratory hazard.
- Never operate power tools in wet or damp conditions.
- Keep fingers and hands clear of moving parts, blades, sanding discs, etc.

- Keep the power cord clear of moving parts.
- Never use defective equipment. Report it to your teacher.
- Ensure that material being worked on is well supported or held securely where necessary.
- Ensure that off-cuts cannot fall onto the feet.
- Switch off and remove the plug from the power outlet before making adjustments or changing blades, sanding discs, etc.
- Do not switch off the power tool when it is under load, except in an emergency.
- Allow the power tool to reach operating speed before using it on the workpiece.
- Do not use the switch lock unless the power tool is set up as a stationary bench machine.
- Remove chuck keys immediately after use.
- Do not use blunt or damaged blades.
- Avoid blocking or covering the motor ventilation slots while using the power tool.
- Switch off at the power outlet and remove the plug when the power tool is not in use.
- On completion of the job, clean down the power tool and return it to its storage position.
- Never connect a portable power tool to a damaged power outlet.
- Do not strain power cords or extension leads, especially by lifting or dragging tools by the cords, or by pulling on the cord to remove the plug from the power outlet.
- Do not walk on flexible cords.
- Avoid dropping tools or materials on flexible cords.
- Position power cords with care to avoid trip hazards and to prevent damage to the cord or extension lead.
- Keep power cords clear of oil, grease, machines and sources of heat.
- Where possible, work near a power outlet to avoid using an extension lead.

THE WOOD LATHE

The wood lathe is one of the oldest machines used for shaping articles from wood. Archaeological evidence shows that the early Egyptians, about 1400 BC, had developed a machine which operated in a manner similar to the modern wood lathe.

The material being machined is held in the lathe while it is rotated at a suitable speed. Cutting tools are fed into the rotating wood and waste material is removed providing the operator with the means of creating the desired shape.



Wood Lathe

The photograph above illustrates a typical wood lathe and its component parts. The headstock spindle is driven by a vee belt connected to an electric motor. The motor may be directly below the headstock as in this example or fitted to the left side of the headstock. Step cone pulleys provide a range of turning speeds suitable for all turning operations.

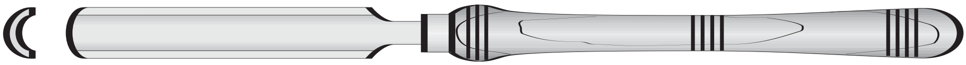
Turning speed should be varied according to the diameter of the material being used. Generally, the RPM should be reduced for larger diameter work.

Lathe Tools

Wood turning tools can be divided into two groups; scraping tools and cutting tools. For most normal turning operations the gouge, skew chisel and parting chisel could be described as cutting tools and the round nose, square nose and spear point as scraping tools.

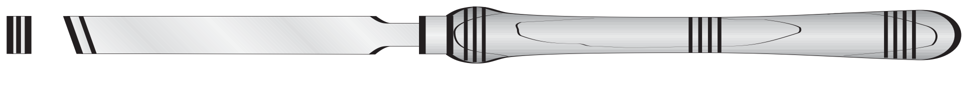
However, most tools are quite versatile, e.g. a round nose tool may be used as a cutting tool when turning the inside of a wooden bowl. The round nose tool is less likely to 'dig in' than the gouge in this type of wood turning. The illustrations below show a typical set of wood turning tools.

The gouge is used for quick removal of waste and for most rough turning operations.



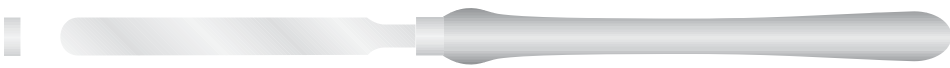
Gouge

The skew chisel is used for cutting and finishing straight and convex surfaces.



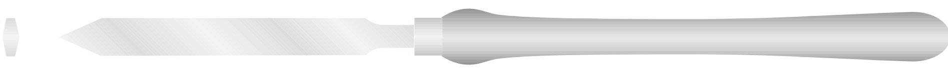
Skew Chisel

The round nose chisel can be used as a scraping tool for finishing shapes and for cutting grooves and concave surfaces.



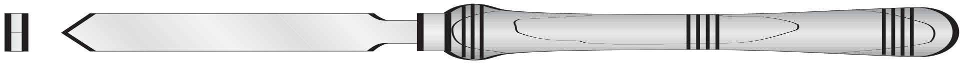
Round Nose Chisel

The parting chisel is used mostly for cutting square grooves and shoulders. Because its sides are relieved it can be fed into the work with little side friction.



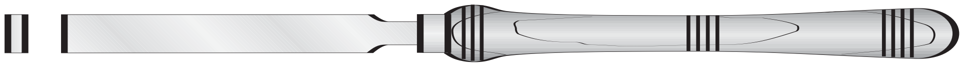
Parting Chisel

The spear point chisel can be used to advantage in scraping beads and shapes where a square nosed chisel would be difficult to operate because of the shape of the cutting edge in relation to the shape of the surface being turned.



Spear Point Chisel

The square nose chisel is usually used for finishing square grooves and shoulders.

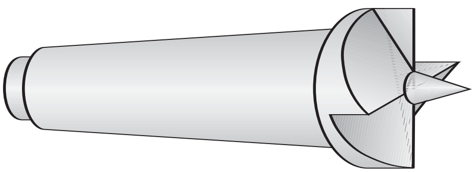


Square Nose Chisel

Centres

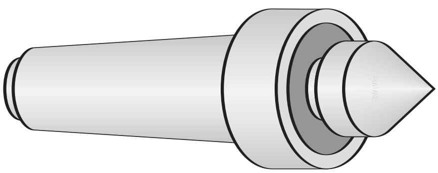
The wood stock for all spindle turning operations is held between the headstock and the tailstock of the lathe by means of centres. These centres are tapered and fit the tapers in the headstock and tailstock perfectly providing a non-slip friction fit.

The spur centre is fitted into the headstock spindle. The spurs are tapped into the end of the wood stock to grip the work, enabling the lathe spindle to rotate the job.

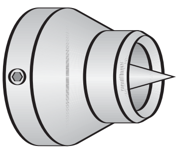


Spur Centre

The live centre or revolving cone centre is fitted into the tailstock to support the end of the job. Its greatest advantage over other types of tailstock centres is that lubrication is not required because the cone centre rotates with the work.



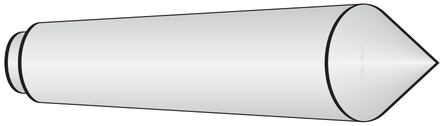
Live Centre
(Revolving Cone Centre)



Cup Centre Adaptor

A cup centre adaptor which can be fitted over the cone centre is also shown in the illustration.

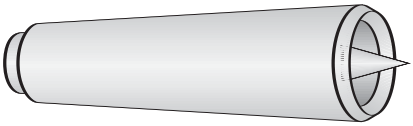
The plain centre is used in the tailstock to support the wood stock in a similar manner to the live centre except that it does not rotate with the work.



Plain Centre

Tailstock centres which do not rotate are often called dead centres.

The wood stock rotates on the conical surface of the plain centre causing friction and heat which must be minimised by lubricating with a suitable grease.



Cup Centre

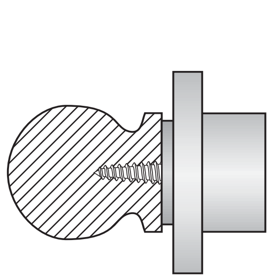
The cup centre is also a dead centre which can be fitted in the tailstock to support the work during spindle turning operations.

This type of centre provides extra bearing surface on the cup face and usually requires less adjustment than the plain centre during turning operations. The cup centre must also be properly lubricated because it remains stationary while the woodstock rotates causing friction and heat.

Face Plates

The illustrations which follow show three common methods of attaching material to the headstock of the wood lathe for turning articles such as bowls, lamp bases and knobs which cannot be successfully turned between centres.

The screw point face plate is suitable for turning small articles only, such as cupboard knobs and screw hole buttons.



Screw Point Face Plate

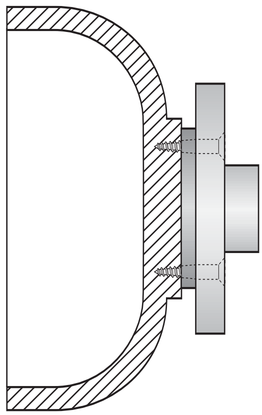
This type of face plate features a large fixed screw as illustrated on the right. The wood stock is centred with a small pilot hole then threaded onto the screw.

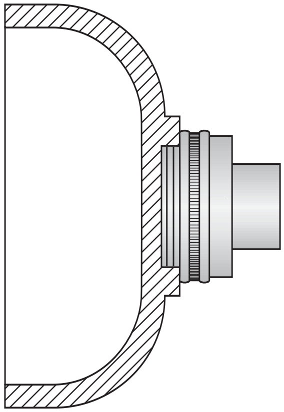
For safety reasons, larger articles should never be turned using a screw point face plate. The extra pressure exerted may cause the wood fibres to fracture around the screw with the danger of the job flying off the lathe.

The standard face plate is suitable for larger articles such as bowls. The wood stock is attached to the face plate with screws, usually three or four depending on the design of the face plate.

Care must be taken to use the correct length screws to ensure that the lathe tool does not come into contact with the screws when the centre is being turned out.

It is also very important that the surface of the wood stock fitted to the face plate is perfectly flat, otherwise movement may cause the screws to become loose.


Standard Face Plate


Face Plate Chuck

The face plate chuck or bowl turning chuck enables quick mounting and demounting of the wood stock.

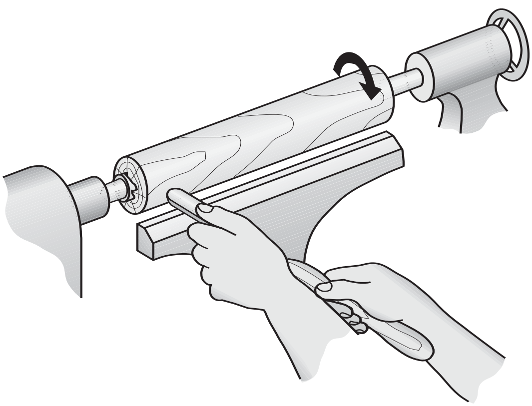
The type illustrated on the left locks into the back of the wood stock. The chuck is expanded to fit tightly into a recess which is first drilled with a special cutter.

Other types of face plate chucks are available, such as the multi-grip chuck. This versatile chuck can grip the wood stock by expansion but also converts to contraction mode so it can grip the wood stock externally like a conventional chuck.

Spindle Turning

The illustration on the right shows a typical spindle turning operation with the wood stock mounted between centres and rotating toward the operator.

The following procedure should be used to mount the wood stock in preparation for spindle turning.



- Mark the diagonals of the square ends of the wood stock.
- Punch both centre points to help locate the lathe centres.
- Saw cut the diagonals of one end about 3mm deep.
- Seat the spur centre in this end by tapping it in with a soft hammer or mallet and replace the spur centre in the headstock.
- Plane off the corners of the wood stock if necessary.
- Mount the wood stock making sure that the spur centre seats properly and move the tailstock up until the tailstock centre locates correctly. If a plain centre is being used it should be lubricated first.
- Wind the tailstock centre in until a good bearing surface is achieved.
- Rotate the wood stock by hand adjusting the tailstock centre to allow free rotation without sideways movement.
- Position the tool rest parallel to the wood stock and as close as possible. Rotate the wood stock by hand to ensure that it clears the tool rest.

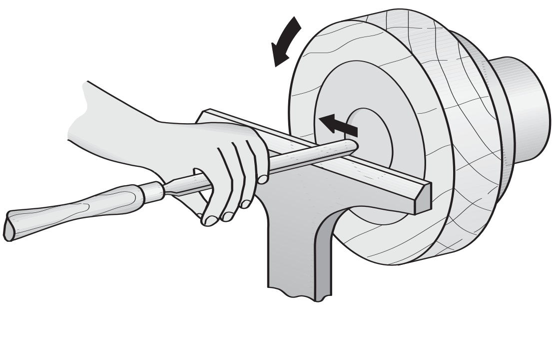
For cutting operations the height of the tool rest should be adjusted so that the cutting edge of the tool is slightly above centre and for scraping operations the cutting edge of the tool should be on centre.

Face Plate Turning

The position of the tool rest is very important in face plate turning. The illustrations which follow show the two basic positions. Other positions may be necessary depending on the shape of the article being turned. The illustration below shows the tool rest position when the face of the wood stock is being turned.

The tool rest should be as close as possible to the work and just below centre so the cutting edge of the tool is on centre.

When turning the face of the job the movement of the tool should be from the centre toward the operator as shown by the arrow in the illustration.

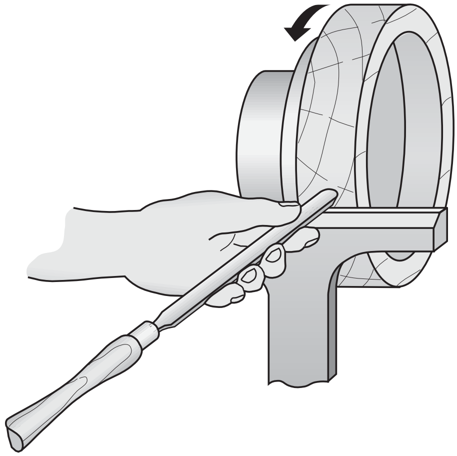


Turning the face of the job

The illustration on the right shows the tool rest position when the edge of the job is being turned.

The tool rest should be positioned as close as possible to the work and its height adjusted so the cutting edge of the tool is slightly above centre.

Positioning the cutting edge just above centre helps to prevent 'digging in' when turning the edge of large diameter work.



Turning the edge of the job

Safety

Students should use the wood lathe only when:

- Permission is granted by the teacher.
- Adequate instruction in the safe and proper use of the machine has been received.

Personal Safety

- Wear a face shield to protect the eyes and face.
- Hair that is long enough to present a safety hazard should be adequately restrained.
- Loose clothing which could be caught in moving parts of the wood lathe should be removed or fastened.
- Do not wear rings, watches, bracelets or other adornments which may come into contact with moving parts of the lathe.
- When you are operating the wood lathe, make sure you are the only student in the designated work area.

Operating Safety

- Inspect the timber to be used for loose knots, cracks and other defects. Do not attempt to turn material that is not perfectly sound.

- Ensure that wood stock is correctly and securely mounted in the lathe. If not sure, ask your teacher to check it.
- Tool rest must be as close as possible to the work.
- Never leave tools on the bed of the lathe while operating.
- Do not leave the machine area while the lathe is running.
- Stop the lathe before making adjustments or measurements.
- Tool rest should be removed when sanding.
- Hold the cutting tool firmly with both hands.
- Keep fingers clear of all moving parts.
- Hold the tool firmly on the tool rest.
- Check tailstock centre adjustments regularly.

THE BUFFING MACHINE

The photograph below illustrates a typical buffing machine used for polishing mainly plastic materials in school workshops. The machine spindle is fitted with tapered screws to which the polishing buffs or mops are attached.

The right hand tapered screw has a right hand thread and the left hand tapered screw has a left hand thread. When the machine is running the spindle is rotating towards the operator.

Buffing Machine

The direction of the rotation causes the mop to actually tighten on the screws by centrifugal force. If the left hand tapered screw had a right hand thread the left hand mop would tend to loosen and perhaps come right off the spindle when the machine was switched on.

The mops are usually dressed with a very fine abrasive before use. Several types are available, the most common being in the form of a wax which is impregnated with the fine abrasive grit. This abrasive should be applied sparingly with the machine running.

Mops are generally made from calico or other similar material layered to a thickness of 25mm or more.

Operation and Safety

- Ensure that loose clothing is secured. Remove watches and any other adornments which might come into contact with moving parts.
- Protect hair and eyes.
- Make sure that only operators are inside the designated work area.
- Keep hands clear of moving parts.
- The point of contact between the work piece and the mop should be kept below centre.
- Apply a light pressure and work from the centre of the work piece toward the lower end. Working towards the upper end may cause the mop to grip the top corner and pull the work piece from the operator's hands.

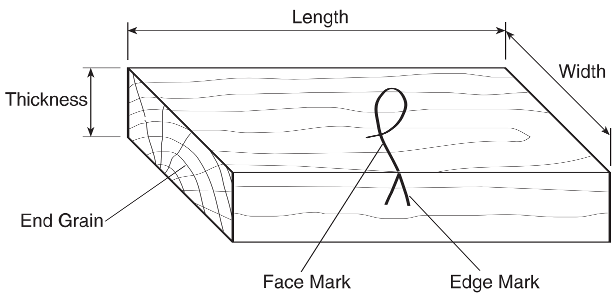
WOODWORK TERMS & JOINTS

SOME WOODWORK TERMS

The drawing below illustrates a piece of dressed timber and some of the commonly used woodwork terms which are listed below.

Length: The dimension which is measured in the direction of the wood fibres. The length is usually the longest dimension of the board.

Width: Usually the largest dimension of the cross section of a board.



Dimensions and Identification Marks

Thickness: Usually the smaller dimension of the cross section of a piece of timber.

End Grain: The pattern formed in the cross section of a piece of timber by the growth rings and medullary rays.

Face Mark and Edge Mark: These are identification marks placed on the chosen face side and face edge of a piece of timber.

All marking tools are used from the face side and/or face edge when setting out.

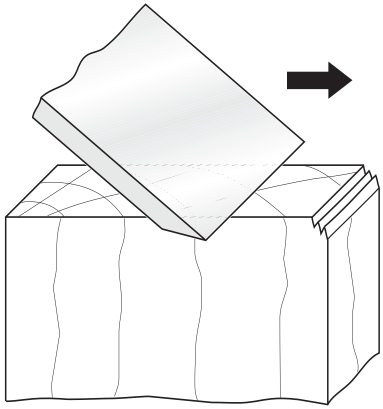
With the Grain/Across the Grain: The term 'with the grain' refers to the direction of the fibres in the wood structure.

For example, a saw cut in the direction of the fibres is with the grain. This cut is usually called a rip cut.

A cross cut is one that is made across the direction of the wood fibres. Planing across the grain also refers to cutting across the direction of the wood fibres.

The illustration on the right shows the likely effect of planing across the grain in the end of a piece of timber.

Planing from both ends towards the centre can prevent the corner from breaking out.

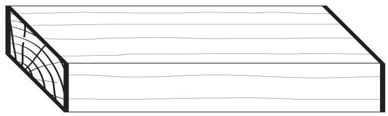


Likely effect of planing end grain in one direction

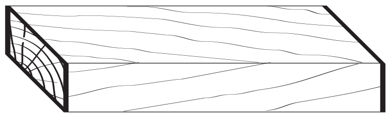
Straight Grain/Cross Grain: A piece of timber with straight grain has been milled or sawn parallel to the wood fibres.

Cross grain occurs when the board has been sawn from the log at a slight angle to the wood fibres.

The illustrations below show the direction of wood fibres in pieces of timber with straight grain and cross grain.



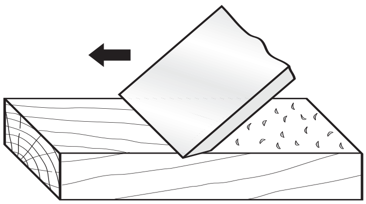
Straight Grain



Cross Grain

Against the Grain: This term usually refers to planing a cross grained board by cutting against the lie of the wood fibres. The fibres tend to lift and break away instead of cutting cleanly.

Planing against the grain of a piece of timber will usually result in a rough surface. This can generally be avoided by examining the workpiece and determining the lie of the wood fibres before commencing to plane the surface.



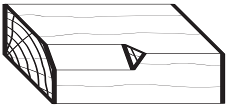
Planing against the grain

The drawing on the left illustrates planing against the grain.

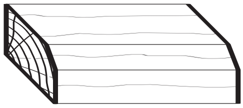
When planing with the grain of a cross grained board the plane iron cuts the ends of the wood fibres cleanly leaving a smooth surface.

Edge Treatment

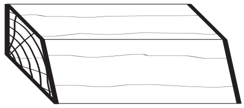
The following illustrations show some of the ways that edges can be shaped in woodworking for either decorative or structural purposes.



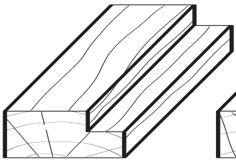
Stopped Chamfer



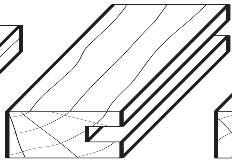
Chamfer



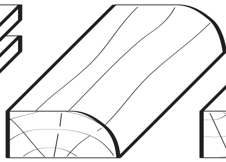
Bevel



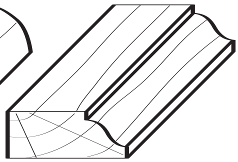
Rebate



Groove



Bull Nose



Mould

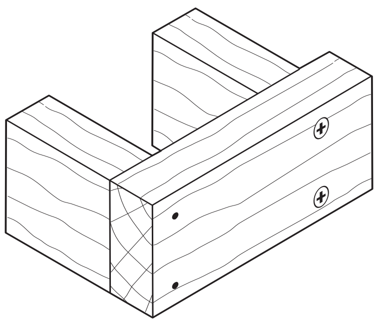
WOODWORK JOINTS

It is important for the woodworker to be able to construct a range of joints and to understand their advantages and disadvantages so the most appropriate joints can be incorporated in projects that are being designed.

Butt Joints

Butt joints are constructed very simply with one piece of timber cut perfectly square, then glued, butted against the other piece and fastened with nails or screws.

The illustration on the right shows a butt joint fastened with screws and a corner or end butt joint fastened with nails. Nailing close to the end of a piece of timber may require pre-drilling if the timber has a tendency to split.



Butt Joints

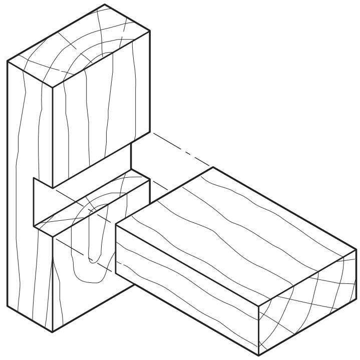
Butt joints generally don't need to be clamped because the screws or nails hold the joint together while the glue dries.

Housing Joints

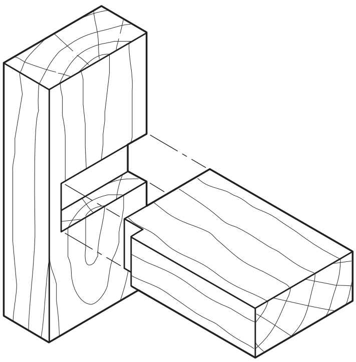
Housing joints provide more strength than butt joints and are often used where load bearing is an important design factor in the project under construction.

For example, a shelf in a cupboard that is to be used to store heavy objects may be housed into the sides of a cupboard so it can carry more weight.

Through housings, as illustrated on the right, are used in situations where it doesn't matter if the joint is visible on the edge.



Through Housing



Stopped Housing

Stopped housings are generally used in a design where the appearance of the edge is important.

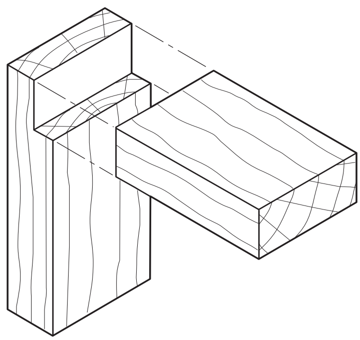
The illustration on the left shows a stopped housing joint that would be used in timber framing.

From the face edge the assembled joint would have the appearance of a butt joint. In other words, the housing is not visible.

Rebate housings are often called rebate and butt joints or sometimes end housing joints.

Rebate housings are stronger than butt joints because they have two contact surfaces. When the joint is assembled both contact surfaces are glued.

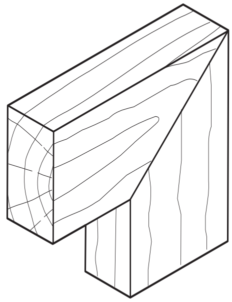
If necessary, the joint can be nailed two ways. Nails at right angles to each other hold the joint together in both directions.



Rebate Housing

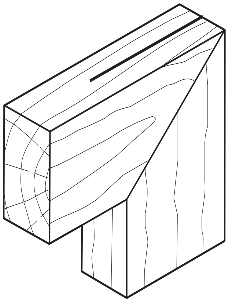
Mitred Joints

A true mitre is constructed by cutting both of the members to 45° and butt jointing these surfaces as illustrated on the right. However, the term 'mitre' is often applied to joints where angles other than 45° are used.



Mitre

Mitres are used to join the corners of picture frames and mouldings such as architraves around window and door openings as well as decorative mouldings on furniture.



Feathered Mitre

Special corner clamps can be used to hold a mitred framing joint when nailing.

The illustration on the left shows a feathered mitre which is reinforced by a thin piece of wood glued into a saw cut.

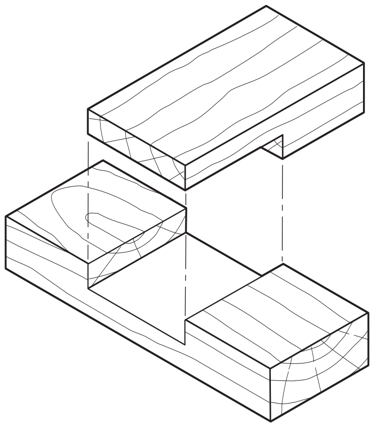
Halving Joints

Halvings are simple joints in which half the thickness of the material is removed from each member, so that when the joint goes together the faces are flush.

When marking out halving joints it is very important to use face and edge marks. All gauging should be done from the face side.

For example, a slight error in setting the marking gauge to the centre of the thickness of the material will still result in a flush joint if both pieces are gauged from the face side.

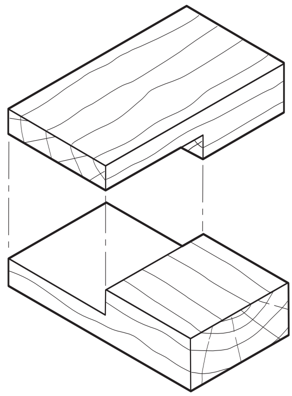
All marking out should be accurate with lines squared from the face edge. Care must also be taken to saw on the waste side of the line. Waste material is removed using a firmer chisel and a mallet.



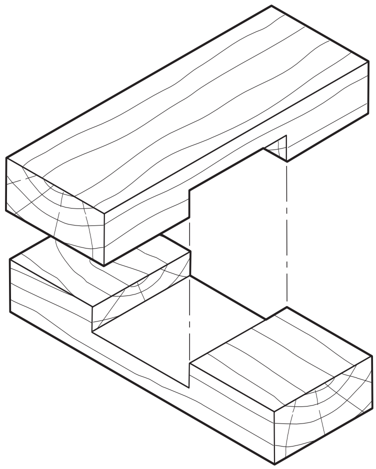
T Halving

T halving joints, as illustrated above, can be used in framing where mid-rails are required. These joints are sometimes called half checks.

Corner halvings are often called end half checks. These joints are generally used in the corner of a frame. The illustration on the right shows a typical corner halving.



Corner Halving



Cross Halving

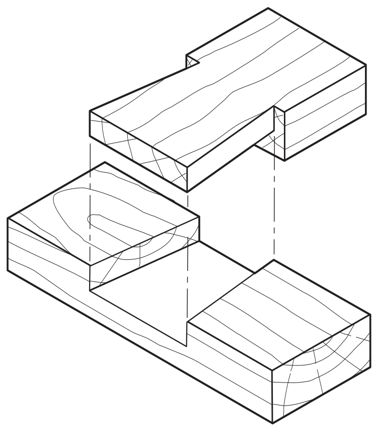
Cross halving joints are used where members of a frame or other structure intersect each other. These joints are sometimes called cross half checks.

The illustration on the left above shows a cross halving joint with checks cut on the flat. Another cross halving could be constructed with the checks cut on the edge.

Dovetail halvings are used in preference to other halvings when a T joint is in tension in one direction.

The dovetail shape, when properly fitted prevents the joint from being pulled apart in the direction of the member on which the dovetail is cut.

The illustration on the right shows a typical dovetail halving joint.

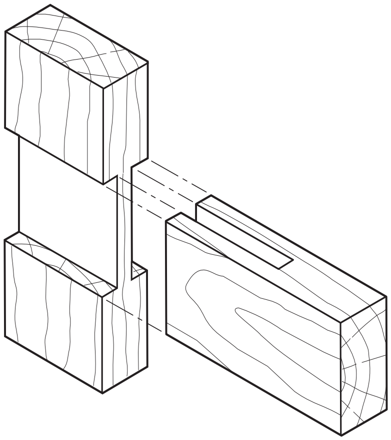


Dovetail Halving

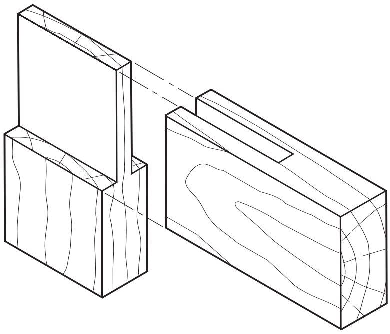
Bridle Joints

Bridle joints are framing joints that are constructed by dividing the thickness of the material into three. One third is removed from the centre of one member and from the outsides of the other member. In practice a mortice gauge would be used to mark out the joint if it was to be cut by hand.

The gauge would be set to the thickness of the mortice chisel to be used during construction. The illustrations below show a T bridle joint and a corner bridle joint.



T Bridle



Corner Bridle

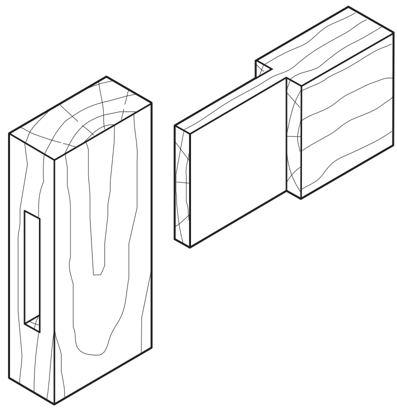
Mortice And Tenon Joints

Mortice and tenon joints are probably the most common of the framing joints used in the construction of furniture and wooden joinery such as doors and windows.

These joints are similar in construction to the bridle joint in that the thickness of the material is divided into three.

In practice, mortice and tenon joints that are to be cut by hand are marked out using a mortice gauge set to the thickness of the mortice chisel that will be used.

Through mortice and tenon joints, as illustrated on the right, are used in framing for joining intermediate rails to a stile.



Through Mortice And Tenon

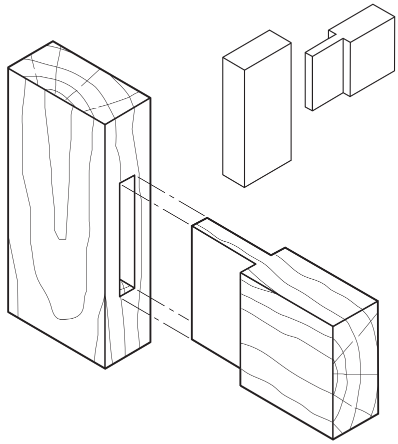
The through mortice and tenon joint is generally used only when it is not an important design factor that the joint is visible on the edge of the frame.

A stub mortice and tenon joint would be used where it is important that the end of the tenon is not visible in the finished job.

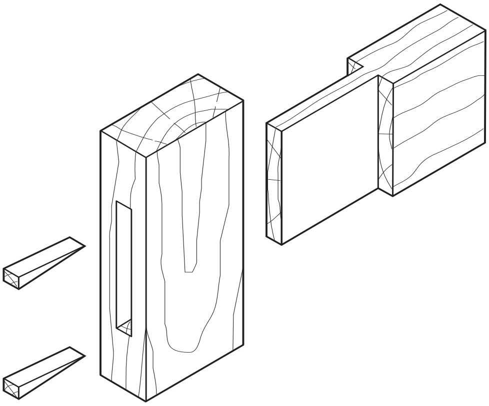
Stub mortice and tenon joints have a mortice depth of about two thirds to three quarters of the timber width.

The illustrations on the right show that the joint is not visible on the edge of the frame.

Stub mortice and tenon joints should always be used where this is an important design factor.



Stub Mortice And Tenon



Wedged Mortice And Tenon

Wedged mortice and tenon joints are used where extra strength is required to resist forces that act to pull the joint apart.

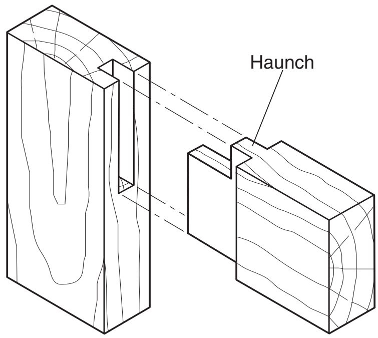
Wedged mortice and tenon joints, as illustrated on the left, are generally used in the construction of wooden doors and windows.

Another advantage of wedged joints is that the cramps can be removed after the wedges have been glued and tapped in. The wedges will hold the joint together firmly until the glue dries.

Haunched mortice and tenon joints are used on the corner of a frame or the top of a chair or table leg.

The mortice is kept a suitable distance in from the end and the tenon is cut to form a haunch as illustrated on the right.

A haunch can be used with both stub and through tenons. A tapered haunch that is not visible on the edge also provides another design option.



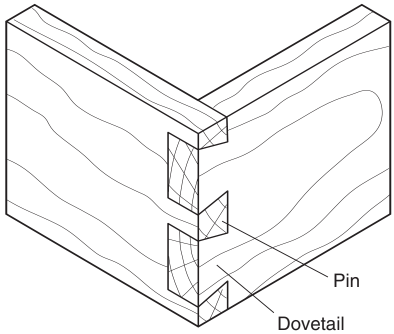
Stub Haunched Mortice And Tenon

Dovetail Joints

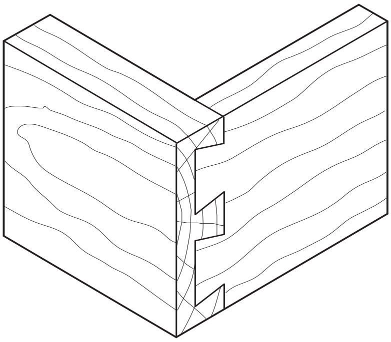
Dovetail joints are generally used to construct box-like projects because the nature of the joint allows wide boards to be firmly joined at the corners without using nails or screws.

The through dovetail or box dovetail, as illustrated on the right, is used where both pieces to be joined are the same thickness and it is not considered to be detrimental to the design if the joint is visible on both faces of the corner.

Through dovetails that are visible in the finished job are sometimes used as a feature in the design of a box-like project.



Through or Box Dovetail



Lapped Dovetail

The lapped dovetail is generally used in applications where the joint is not to be visible from one direction.

Traditionally, lapped dovetails have been used to join the sides to the front in drawer construction.

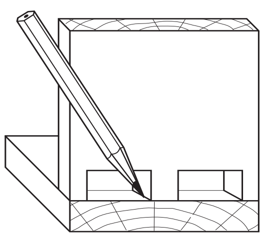
Lapped dovetails are often called drawer dovetails.

Dovetails and pins together comprise a dovetail joint as shown in the illustration at the top of the page. The dovetails are cut on one piece of timber and the pins on the other. Pins are smaller than the dovetails with the outer pins being smaller than the inner ones.

A sliding bevel is generally used to mark out the dovetail angle. This angle is often referred to as the pitch of the dovetail.

A satisfactory pitch for most dovetail joints is an angle of one in six.

The illustration on the right shows the method most commonly used for marking out a dovetail joint.



Scribing Dovetails

The pins are marked and cut out, then the dovetails are scribed from the pins. This method is more convenient than cutting the dovetails first because there is more room to work in the dovetail sockets than the pin sockets.

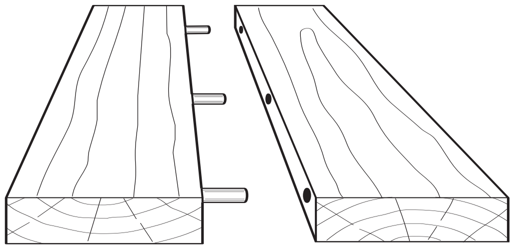
Widening Methods

Widening is a term often used to describe any method of joining two or more boards such as for a table top. There are numerous methods of widening, the most basic of which is the dowel method shown below.

The dowel method is similar to the dowelled butt joint used in framing. Several dowels may be used depending on the length of the boards being joined (or jointed).

When two or more boards are to be joined, care must be taken to alternate the direction of the growth rings irrespective of the type of joint being used.

The illustration on the right shows two boards correctly positioned for jointing.



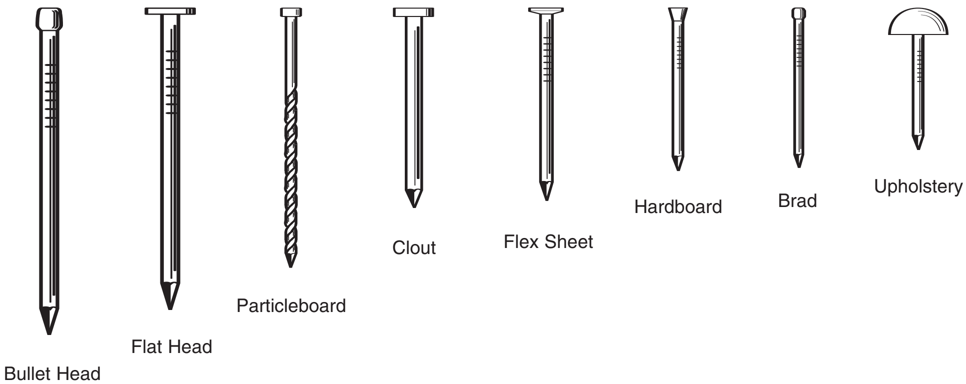
Dowel Jointing

Wide boards tend to cup away from the heart when subjected to changes in atmospheric conditions. Alternating the growth rings will compensate for this movement and the wide jointed board will remain reasonably straight.

FIXING & FINISHING

NAILS

The diagrams below illustrate a selection of the most common nails used in the woodworking trades today. However, there are numerous other special purpose nails such as underlay nails, plasterboard nails, process nails and collated nails of various types which are used in portable nailers.



Nails

Bullet head nails are the ordinary general purpose nails used for fixing timber framing, mouldings, flooring and general cabinet work. Galvanised nails are available for external use.

Flat-head nails are used for fastening thin boards such as case timber, where the nail head does not have to be punched and filled for appearance and where the larger flat head might prevent the nail from pulling through. Small flat head nails are often sold as wallboard nails.

Particleboard nails have been designed specially for nailing particle board. The twisted thread provides more grip in the flaky structure of particle board than bullet head nails.

Clouts are heavy duty flat head nails, usually galvanised for external use such as fixing sheets of flat galvanised iron.

Flex sheet nails are generally used for fixing fibre cement sheets to framework. The head helps to prevent the nail from pulling through the fibrous sheet.

Hardboard nails are used for fixing high density compressed boards such as masonite to framing. The tapered head is designed for ease of entry into the hard surface of the sheet.

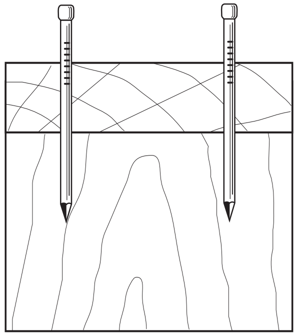
Brads or panel pins are like small bullet head nails and are used for very fine nailing, generally where the head of the nail is to be punched and filled or where it can be concealed in a random groove or other panel feature.

Upholstery nails are available in a range of colours and are used for visible fastening of leather and fabrics to the wooden frames of covered furniture.

Nailing Methods

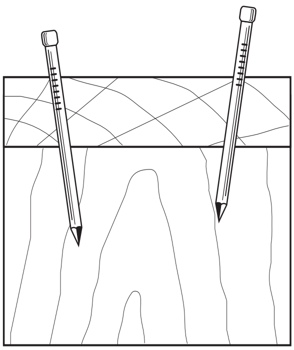
The diagrams which follow illustrate the *nail positions* for three commonly used methods of nailing timber.

Parallel nailing can be used satisfactorily in timber which grips the nails very well, such as hardwood. This nailing method which is illustrated on the right, may not provide sufficient joint strength if used in very soft timber.



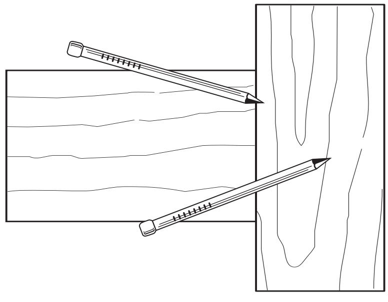
Parallel Nailing

Dovetail nailing or splay nailing shown on the left provides greater strength in the nailed joint than parallel nailing because nails which are not parallel to each other are more difficult to withdraw.



Dovetail Nailing

Skew nailing illustrated on the right is used where timber thickness or inaccessibility prevents other methods from being used.



Skew Nailing

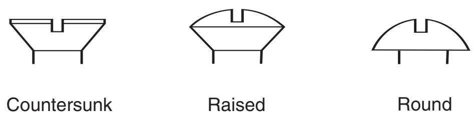
SCREWS

There are many screw types on the market today, from traditional wood screws to a large range of screws manufactured for specific uses.

The diagrams which follow illustrate some of the most common types of screws used in the woodworking trades and building industry.

Head Types

The choice of head type will usually be determined by the application for which the screw is to be used.



Screw Head Types

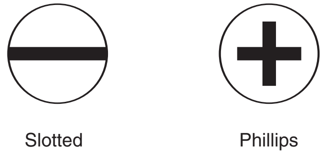
Countersunk head screws are used where the head of the screw is to be flush with the surface of the material being fixed. A countersinking bit is generally used to form the tapered hole (countersink) that the head fits into.

Raised head screws are often used for decorative purposes such as fittings and handles and for fixing sheets in conjunction with a cup washer.

Round head screws are generally used where the material being fixed is too thin to be countersunk.

Slot Types

The type of slot in the screw head will determine the type of driver to be used. A correctly fitting driver tip should be selected to prevent damage to the screw slot.



Driver Slots

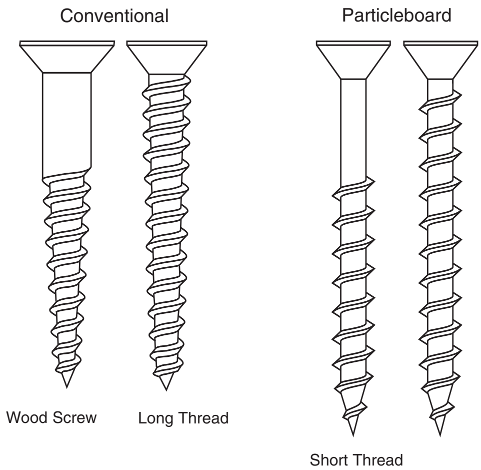
The illustrations on the right show the two most common types.

Slotted screw heads are the traditional type used on conventional wood screws as well as other types of screws.

Phillips head screws with their cross shaped slot are probably the most common type of screw used today. The driver tip selected should fit snugly into the slot without rotational movement or play.

Thread Types

The illustrations on the right show the common types of threads on screws which are used for general woodworking applications.



Screw Thread Types

Conventional wood screws are used for fixing to solid timber. A clearance hole is required for the unthreaded shank of the screw to prevent binding in the material being fastened (as shown below).

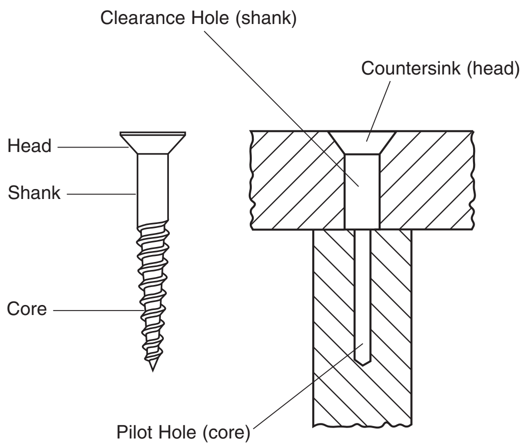
Long thread screws are also used for fixing to solid timber and are fully threaded for additional holding power.

Particleboard screws feature a full length thread which provides extra grip in the flaky structure of particleboard and other manufactured boards such as medium density fibreboard (MDF). A clearance hole (as shown below) may also be required.

Short thread particleboard screws generally do not require a clearance hole for the unthreaded part of the screw.

Drilling Screw Holes

The illustration on the right shows the parts of a wood screw and the screw holes that are generally required to be drilled in the material.



Screw Holes

A pilot hole the diameter of the screw's core is drilled in the base material to allow the screw to cut its own thread.

A clearance hole slightly larger than the shank of the screw is drilled through the material being fastened to prevent binding.

ADHESIVES

Bonding of two porous substances was once attributed solely to the keying of adhesive around the fibres and into the crevices of the materials. Scientific studies now suggest that this might account for only a small part of the joint strength and that molecular attraction is primarily responsible for adhesion.

There are many types of adhesives available today but many are not suitable for use in the school workshop. Some types require strictly controlled temperature or special apparatus for application or curing while other special purpose adhesives may have a very limited shelf life.

It is necessary to know the characteristics of adhesives so that the most suitable type can be chosen for a particular job. The adhesives listed below are some of the more common products used in industry today.

Polyvinyl Acetate

Polyvinyl Acetate (PVA) is a white, ready to use glue produced by reacting acetylene with acetic acid. PVA is not water resistant but does resist fungi and bacteria, has excellent gap filling qualities, is non-staining and not flammable.

It is a good general purpose glue but will not bond a non-porous surface to any other, for example metal to wood. PVA has unlimited shelf life in sealed plastic containers and a cramping (pressing) time of up to four hours depending on air temperature and humidity.

Contact Glue

Contact glue is a synthetic rubber based adhesive. It is mostly used to bond plastic laminate to manufactured boards, for example in kitchen bench tops. It can also be used to bond flexible rubber and some plastic materials to wood and to each other.

Adhesive is applied to both surfaces and allowed to become touch dry before bringing the surfaces together. Bonding takes place immediately on contact. Strength increases as the glue cures over several days. No cramping is necessary and shelf life is approximately one year.

Formaldehyde Adhesives

These adhesives are thermo-setting resins which are hardened by the addition of a catalyst. The setting action is one of chemical change and while the process may be accelerated by heat, the plastic glue cannot be softened by heat once it has set.

Urea Formaldehyde is an adhesive used widely in industry and is available in powder and liquid forms. Where exceptionally long open working times are required, resin may be applied to one surface and hardener to the other so that setting does not take place until the parts are brought together.

Urea formaldehyde is generally used in the manufacture of sheet materials such as plywood, standard particleboard and medium density fibreboard.

Phenol Formaldehyde is a dark coloured adhesive used mainly in the manufacture of marine plywood and other building materials where moisture resistance is very important.

Melamine Formaldehyde is a waterproof, heat resistant, non-staining adhesive, prepared for use by mixing the powdered resin with water and then adding the liquid hardener. Separate application of the resin and hardener is possible, making melamine formaldehyde ideally suited to caravan construction and boat building.

Resorcinol Formaldehyde is supplied as a dark coloured liquid usually with a powdered hardener. It is generally accepted as the best adhesive for the construction of boats and aircraft where bonding of wood materials is necessary and wherever an extremely durable glue is required.

Resorcinol formaldehyde has outstanding resistance to moisture, cold, heat, solvents, mould or fungi. Its only disadvantage is that the dark colour stains timber.

Epoxy Resin Adhesives

These adhesives are also of the two part type with resin and hardener. Epoxy resin glues are waterproof and very strong. They will bond wood to wood, metal to metal, rubber to metal, glass to glass, glass to metal and thermo setting plastics to each other.

Normal setting time for most epoxy resin adhesives is about 8 hours but this can be reduced by heating. There are also quick setting varieties on the market that will begin to set in a few minutes.

ABRASIVES

Abrasive paper used for smoothing timber and other wood products, consists of abrasive materials in the form of grit, bonded to a paper backing. Sheet abrasive materials are often loosely referred to as ‘sandpaper’, hence the term ‘sanding’ which is the action of rubbing a surface with abrasive paper.

Sheet Abrasives

Glass paper is a traditional abrasive paper that has been used in woodworking for centuries. It is made from crushed glass, quartz or flint which is glued to stiff brown paper. It is not waterproof and is generally used for light hand sanding.

Garnet paper is similar to glass paper except that the abrasive material is made from garnet, a semi-precious stone which is reddish-brown in colour.

Garnet is of medium hardness and toughness and because it has a tendency to fracture, forms new cutting edges as it is being used. Garnet paper is available in rolls usually 100mm and 150mm in width.

Silicon carbide is manufactured from coke and sand fused together in a furnace and then ground to a fine grit. It is a shiny black synthetic abrasive which is brittle and fractures into sharp wedge-shaped slivers.

It is very hard and is generally bonded to waterproof sheets with a waterproof adhesive. Silicon carbide sheets are usually called ‘wet and dry’ abrasive paper.

Aluminium oxide is manufactured from bauxite, iron filings and coke fused together in a furnace and then ground. It is usually a grey-brown colour, extremely tough and resistant to normal wear.

This abrasive is particularly suited to heavy duty machine sanding. Most abrasive discs used on portable power sanders are made from aluminium oxide.

Grading Abrasive Materials

After crushing, abrasive materials are sieved through accurately woven silk screens. The size of the mesh is determined by the number of openings per given area and this in turn determines the grade of the abrasive.

For example, a sieve which has 80x80 holes per given area would be graded as 80 grit. Grades can be generally described as very coarse, coarse, medium, fine and very fine. Abrasive grit can range from 20 (coarsest) to 1200 (finest).

The most common grades used for bench work and general woodworking applications are listed below:

- medium (60 to 80)
- Fine (100 to 180).

Applications

Glass paper and garnet paper are used mainly in woodworking applications for the preparation of surfaces to be finished with paint, varnish or other materials. Both abrasive papers are suitable for hand sanding but garnet paper is preferable for use on an orbital sander because it is more durable than glasspaper.

Silicon carbide and aluminium oxide are usually bonded to waterproof paper or fabrics in the manufacture of a range of abrasive sheet materials. These abrasives are suitable for use on a variety of surfaces such as wood, plastics, metal, and paint.

Water is used with wet-and-dry abrasive paper to prevent waste material in the form of dust from clogging the grit. The water washes the waste away enabling the abrasive grit to contact the surface being sanded.

Aluminium oxide is suitable for heavy duty machine sanding such as sanding discs, belt sanders and in floor sanding machines.

Aluminium oxide and silicon carbide are both used in the manufacture of abrasive wheels (emery wheels). Abrasive wheels are generally used for tool sharpening and general metal grinding.

WOOD FINISHING

The two basic stages of wood finishing are surface preparation and the application of finishing materials.

Surface Preparation

Surface preparation is a very important part of wood finishing. The method used will depend on the type of wood or wood product that is to be finished and the type of finish required.

Sanding

Refer to the previous section for information on abrasive papers. Usually garnet paper or glasspaper will be used for hand sanding in the wood shop. Abrasive papers should be used in conjunction with a sanding block when hand sanding flat surfaces.

Larger surfaces can be sanded with an orbital sander or a random orbital sander before being finished by hand sanding. Refer to the section on Portable Power Tools for more information about these sanders.

When hand sanding, care must be taken to always sand with the grain, particularly when clear finishing materials are to be used. Scratches in the wood surface caused by sanding across the grain show through a clear finish and spoil the appearance of the finished product.

Most hand sanding operations in the wood shop require the use of a medium grade abrasive paper to remove blemishes from the surface, followed by a fine grade paper to remove any scratches made by the coarser grit on the medium grade paper.

Stoppings

Stoppings, more commonly called 'putty' should be used to fill all nail holes and cracks, so that a uniform finish can be obtained. Some of the common types of stoppings are listed below.

- Wood putty – ready to use plastic compounds available in a range of natural wood colours and plain for painted surfaces.
- Wax stoppings – synthetic wax sticks available in a range of natural timber colours.
- Powder Mixes – usually plastic or plaster based compounds which are mixed with water to form a thick paste and are generally suitable for interior use only. A powder mix preparation is often called water putty.
- Linseed oil putty – generally used for external applications under oil based paints. The oil content tends to discolour timber and prevents penetration of stain.

Application of Finishing Materials

Common finishing materials are stain, wood grain fillers, clear finishes and paint.

Stains

Items of furniture and other articles are often made from cheap timber and stained to look like more expensive varieties. Stain, if required, is applied after the surface is sanded to colour the wood before the application of a clear finish.

Wood stains are available in a number of natural timber colours and other decorative colours. Stains are manufactured with either a water base or a spirit base.

Clear Finishes

The most popular clear varnishes used today are one part polyurethane plastics, usually available in gloss, satin and matt finishes.

The first coat should be thin and evenly brushed, rolled or sprayed over the surface to be finished. This coat causes the wood cells on the outer surface to swell and also sets the loose fibres on the surface, usually resulting in a rough or gritty surface when the coat is dry.

A light sand with a very fine abrasive paper will provide a smooth surface in preparation for the second coat. If a third coat is required the surface should be lightly sanded first.

Wood Grain Fillers

Wood grain fillers are sometimes used to fill the pores of open grained timber to provide a smoother base for application of the clear finishing material. Ready to use wood grain fillers are available in a range of popular timber colours.

Grain filler is usually applied by rubbing it into the grain with a hessian pad after firstly applying a thin coat of clear sealer to the timber and allowing it to dry. Any excess is wiped off with a clean cloth, leaving the filler in the pores.

Wood grain filler should be allowed to dry thoroughly before applying a coat of clear finishing material. For timber that is to be stained, the filler should be applied after the stain.

Paint

Paint can be classified as water based or oil based in either exterior or interior quality.

Oil based paints are thinned and brushes cleaned with mineral turpentine.

Water based paints are thinned, when necessary, with a little water and brushes wash out easily in cold water.

New timber requires a first coat of special paint called primer, then an undercoat followed by the finish coat. Some plastic paints (usually water based) do not require an undercoat.

PLASTICS

HISTORY, PROPERTIES & CLASSIFICATION

A Brief History

The word *plastic* is derived from the Greek word *plastikos* which means being in a physical state suitable for moulding, forming or shaping.

The history of plastics began around 1870 but for about 60 years up to the 1930s very little progress was made in the development of plastic materials which are so common today.

Researchers in Europe and the United States of America found that plastic materials could be made from a variety of naturally occurring materials. For example:

- Cellulose nitrate (commonly called celluloid) was originally produced from a vegetable product called cellulose. This plastic material was first used as a substitute for ivory in the production of billiard balls and other articles.
- Some plastic buttons, buckles, knitting needles etc, were first produced from casein plastics which were derived from animal protein usually in the form of milk.
- Phenol formaldehyde (originally called bakelite) was made from materials extracted from coal tar and wood alcohol as a substitute for another natural material, shellac.

Rapid advancement in the plastics industry occurred during the years between 1930 and 1950 when many of the plastics used today were developed. These materials are completely synthetic polymers (long string molecules) derived from chemicals, not natural substances as in the early days of the plastics industry. During this phase of the development of the plastics industry coal was the most important source of raw materials.

Crude oil began to replace coal as the source of base chemicals in the early 1950s. Massive expansion of the petrochemical industry provided relatively cheaper raw materials for the production of plastics. As a result the price of finished plastic products began to fall. This in turn encouraged an increase in consumption. The continuation of this trend over recent years has seen plastics consumption per head of population in many countries double every few years.

Today, plastics are used extensively in the home. Kitchen bench and table tops, carpets and other floor coverings, upholstery, furniture, foam cushions and mattresses, telephones, electrical appliances, kitchen utensils, toys, garden hoses, paint, wall paper and light fittings are just a few of the domestic applications of these extremely versatile materials.

Plastics have revolutionised the packaging of food and other products with the introduction of plastic films, bags and containers. In the transport industry cars, trucks, ships and aircraft all use plastic components in their manufacture.

In the building industry plastics are being used extensively as decorative finishes on building boards, plumbing applications such as pipes and gutters, wall cladding and a wide variety of fittings and components.

Plastics appear to be used in just about everything that is manufactured today. In fact many of the most significant technological advances of recent years may not have been possible without plastics. Space vehicles and artificial body organs and joints are notable examples.

Traditional materials such as wood, stone, metals, animal fibres and vegetable fibres have been used since earliest times but plastics are an entirely new family of materials created by industrial chemists.

There are many different types of plastics in common use today. Each has its own chemical composition and its own characteristics and properties. Chemical engineering of plastics can create materials requiring certain properties by developing an appropriate chemical composition.

General Properties

Even though different types of plastics have their own unique characteristics, there are underlying general properties which apply to most plastics. Some of these are listed below.

- Plastics do not rot or corrode.
- Most plastics are good insulators of heat and electricity.
- They are easy to shape and mould.
- Plastics are relatively light in weight.
- Most plastics can be produced in a variety of colours.
- Most plastics will burn readily while giving off toxic fumes.

Basic Classification

A convenient method of classifying plastic materials is to observe their reaction to heat. Two basic groups are described below.

Thermoplastics

Thermoplastics is the term applied to the group of plastic materials that will soften readily with the application of heat and will harden again once the temperature is reduced to normal.

This process can be repeated indefinitely providing the temperature is kept below the level at which the material will burn or degrade.

Common thermoplastics used in school workshop subjects are Acrylic and PVC. Information about these materials is provided in later sections of this text. Other common thermoplastics are Polypropylene, Polyethylene and ABS.

Thermosetting Plastics

Thermosetting plastics or thermosets become solids under the application of heat and pressure and will retain that form. Re-heating will not change the properties of thermosetting plastics unless the temperature is high enough to burn the material.

An irreversible chemical change occurs during the processing of thermosets. This change can be likened to the setting of concrete.

The formaldehyde family of plastics are all thermosets along with thermosetting resins which require the addition of a catalyst to effect the chemical change which causes the material to set.

ACRYLIC

Acrylic is an abbreviation of the chemical name polymethyl-methacrylate. This material is probably the most common plastic used in school workshops because it is easy to work with hand and machine tools, is readily available in a variety of colours and can be easily moulded.

Acrylic can be heat-formed, hot-air welded, solvent welded, cemented, turned, drilled, tapped, polished and, if necessary, painted. Some common uses for cast acrylic are light fittings, tail-light assemblies, advertising signs, instrument housings, tap knobs, etc.

Working Temperatures

Cast acrylic, being a thermoplastic, changes from its rigid state to a rubber-like material when heated to suitable temperatures. In this soft, pliable state it can be formed by bending, stretching or compressing to almost any shape. If held in the required shape while cooling, cast acrylic will retain its new form and revert to its rigid state.

This change from rigid to pliable occurs gradually as the temperature is increased. At approximately 85°C some acrylic shapings may exhibit a tendency to demould or begin to straighten out.

The material does not actually become pliable until the temperature reaches about 120°C but for best results should be heated to somewhere between 150°C and 160°C to allow a reasonable amount of working time before heat is lost and the flexibility is reduced.

In most school workshop applications the cast acrylic sheet is heated using an oven or strip heater and then transferred to a jig or mould for shaping. It is very important that, during this process, the acrylic sheet is at uniform temperature suitable for moulding.

If shaping is attempted below 120°C, the acrylic sheet is likely to split during moulding or, because of the excessive pressure required to shape the material, it will be highly stressed and will have a lower demoulding temperature, lower impact strength and less resistance to crazing.

Cast acrylic sheet should not be heated to a constant material temperature above that which is recommended because it will begin to degrade at around 170°C. Degrading is evident when small bubbles or blisters begin to form in the material.

Shrinkage

When acrylic sheet is heated to shaping temperature for the first time it tends to shrink slightly (about 2% or 3%) in the length and width with a corresponding increase in the thickness of the sheet. This slight dimensional change is permanent but is not repeated with further heating.

Cooling

Shaped acrylic articles should be held firmly in the jig or mould until the material temperature has lowered to about 60°C. Acrylic is a poor conductor of heat and cools slowly. Forced cooling should not be used because this tends to cause uneven stresses in the material. Differences in the cooling rates of the two surfaces of acrylic sheet can result in severe distortion and warping of the article.

Plastic Memory

Cast acrylic sheet is said to possess a plastic memory which allows the same piece of material to be reshaped if the first attempt is not satisfactory.

A moulded acrylic shape will demould and revert back to its original flat state when it is reheated. It could be said the material ‘remembers’ that it was originally a flat sheet.

Bonding

A variety of adhesives for plastic materials are readily available in hardware stores. However, not all plastic adhesives are suitable for acrylic. Very few are general purpose adhesives that will bond a number of different plastics.

Some of the urethane adhesives used for model building are suitable for acrylic, as well as the special purpose acrylic cements and general purpose plastic glues. Some of these preparations rely mainly on the principle of adhesive bonding.

Adhesive Bonding

Adhesive bonding means that the adjacent surfaces are not fixed to each other but fixed to a film or glue between the surfaces.

Cohesive Bonding

Cohesive bonding or solvent welding is the method used most commonly in school workshops for projects which require visual appeal.

Cohesive bonding is achieved by introducing a solvent to the joint line and allowing the solvent to dissolve the surface (freeing the molecules) of both pieces to be joined.

A light pressure is applied, the solvent evaporates and the molecular bond is strengthened.

Solvents that will successfully bond acrylics are listed below:

- chloroform
- ethylene dichloride
- methylene chloride.

OTHER PLASTICS

There are many different types of plastics used in industry today. Some of the most common ones are listed below.

Polyvinyl Chloride

Most thermoplastics are hard and rigid when cold. Polyvinyl chloride (PVC) however, can be made permanently flexible at all temperatures. This is achieved in manufacture by the addition of oil-like substances called plasticisers. The greater the amount of plasticisers used the more flexible the finished product.

PVC is used to produce gutters and downpipes, insulation for electrical wiring, pipes, house cladding, mouldings and sheets. Very thin layers of PVC are laminated to paper or other materials to make washable vinyl wallpapers and upholstery material.

This versatile material is also used to make soles for shoes, vinyl tiles and vinyl floor coverings. PVC sheet and pipe are often used for school workshop projects and can be worked using the same techniques, tools and equipment as for acrylic.

Polyethylene

Polyethylene (or polythene) is one of the lightest plastic materials except for the foams. It is identifiable by its smooth, waxy surface. It is tough, waterproof and a good electrical insulator. These properties make polythene suitable for a large variety of uses.

Most plastic bags and sheets are made from polythene. Its toughness is used to effect in the production of squeeze bottles. A high density variety of polythene is sometimes used to produce articles such as buckets and rubbish bins.

Polypropylene

Polypropylene is very similar to high density polyethylene and is often used in the manufacture of tableware and kitchenware, crates (for bottles), ice cream containers, bodies of power tools, battery cases, etc.

Acrylomitrile Butadiene Styrene

ABS is classed as an engineering plastic. It is tough and resistant to most chemicals and is used in the manufacture of automobile grilles, headlight and tail-light housings, telephones, chrome plated fittings, cosmetic containers, etc.

Cellulose Acetate

Cellulose acetate is tough, strong in thin sections, reasonably flexible and very easy to work and mould. It can be easily coloured during manufacture and is often used to produce articles such as steering wheels, tool handles, toothbrushes and ball point pens.

Nylon

Polyamide resins are thermoplastic materials generally known as nylons. The combination of strength, stiffness, abrasion resistance, chemical resistance and electrical insulation put this material in the engineering plastics category. Nylon is used in a wide range of applications such as thrust washers, bushes, pump valves, impellors, zippers, small gear wheels, hinges and catches.

Polystyrene

Polystyrene is produced from ethylene gas and benzine. It is generally chemical resistant, quite tough and water resistant. Several different types of polystyrene are in common use and their applications range from car grilles, telephones, TV cabinets, chrome plated fittings to packaging for dairy products.

Polystyrene foam is produced from polystyrene beads which are about 3mm to 5mm in diameter. A special hydrocarbon is introduced to the beads which expand up to 50 times their original size when heated in the first stage of production. The expansion is caused by the release of a gas when heat is applied.

In the second stage of the process the expanded beads are loaded into a mould where they are again heated. The expanded beads soften and further expand in the mould. The softened polystyrene segments fuse together under heat and the pressure generated by the release and expansion of pentane gas. The resultant material is a very lightweight plastic foam.

Some common applications of this material are in packaging, insulation in refrigerators and cool boxes, bottle packs, surfboards, fishing floats, acoustic tiles and sheets which can be cut to any required shape.

Polyvinyl Acetate

Polyvinyl acetate (PVA) is a very versatile material with a wide variety of applications. The white glue generally used for woodworking is a PVA adhesive. Polyvinyl acetate in its original form is a colourless solid plastic material available in granules or powder form. It is also procurable in solutions and paste form.

Polyurethane

Polyurethane is a very versatile plastic material. The spongy foam used in cushions, mattresses, dashboard padding etc, is generally produced from polyurethane.

In a more solid form, polyurethane is used to manufacture soles and heels in the footware industry.

Polyurethane is also used in liquid form to produce a clear finish for furniture and other wood products.

Polyester Resin

Polyester resin is a thermosetting plastic used extensively in fibre reinforced plastic applications such as fibre glass furniture, boats, car bodies, etc. The liquid resin is mixed in exact proportions with a catalyst (hardener) and a chemical reaction takes place, generating some heat as the material sets.

Polyester resin exhibits a balance of good mechanical, electrical and chemical properties, ease of handling, low cost and dimensional stability when set.

Epoxy Resins

Epoxy resins also cure with the aid of a catalyst and have similar applications to polyester resins. They are also thermosetting plastics, usually yellowish in colour with similar properties to polyesters except that epoxys are more resistant to chemical solvents.

Formaldehyde Resins

Formaldehyde resins are thermosetting plastic materials available in a number of distinct types which exhibit a wide range of properties. Three types are listed below.

Urea Formaldehyde

Articles produced from urea formaldehyde (UF) are very hard, have very good electrical resistance and are available in many colours as the material lends itself well to colouring in the production process.

Urea formaldehyde is often used in the production of articles such as picnic ware, electrical goods, toys, switches, power points and bathroom fittings. In liquid form UF is used in a versatile adhesive with wide application in industry. Common applications are the production of standard plywood and particle board. (Refer to those sections of this text).

Melamine Formaldehyde

Melamine formaldehyde (MF) resins are tougher than UF resins and usually exhibit a better surface finish. Other properties are similar to UF. This material is used to produce household appliances, kitchenware, handles, etc.

One of the most extensive applications of melamine formaldehyde is in the production of laminated plastics used on table and bench tops and for surfacing manufactured boards used for cupboard doors and furniture construction.

Phenol Formaldehyde

Originally products made from phenol formaldehyde (PF) were very dark brown in colour. Early plastic light switches and power points were a dark brown colour and were generally manufactured from phenol formaldehyde.

Modern production methods enable this material to be coloured using a full range of decorative colours. PF cures to a hard and rigid state. It is water resistant, chemical resistant and is a very good electrical insulator.

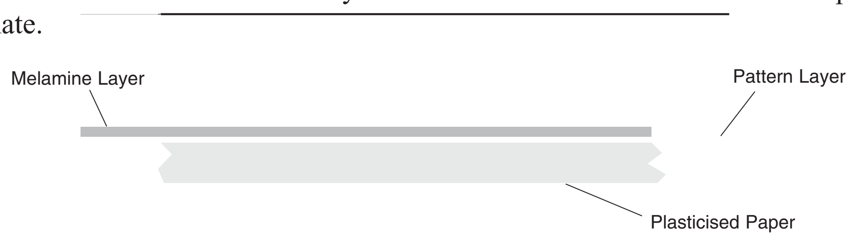
This material has a wide range of applications especially in electrical components, switches, knobs, handles, etc. Phenol formaldehyde adhesive is used in the production of special particleboard which is used for flooring in the building industry.

LAMINATED PLASTICS

Plastic laminates are marketed under a variety of trade names; the most common probably being Laminex®. Laminates are built up with several layers (or laminations) of plasticised paper topped with a layer of melamine forming a hard, clear, heat and acid resistant covering for the pattern layer.

Generally available in 1.3mm and 0.8mm thicknesses, plastic laminates offer a variety of plain colours and decorative patterns, some with a wood grain effect in gloss, satin and textured finishes.

The illustration below shows the layers or laminations which form a sheet of plastic laminate.



Laminated Plastic

Working Techniques

Cutting & Scoring

Cutting with a fine-toothed saw, such as a hacksaw, tenon saw or panel saw should be done with the face of the material upwards to avoid chipping. The hard nature of the material dulls the saw teeth quite quickly.

An alternative method is to score the face deeply with a sharp blade used against a straightedge, then bend the sheet upwards while pressing down firmly on the straightedge.

The laminate will snap cleanly along the score. Special cutters tipped with tungsten steel are available for this purpose.

Gluing

Contact adhesives are most suitable for use with ordinary workshop equipment although other glues such as urea formaldehyde are used for industrial applications.

Contact adhesive is readily available in both liquid and gel forms which can be applied with a spreader, brush or roller. Brush and roller applications are suitable for some of the thinner liquid types of contact glue but the spreader or scraper is the most common type of applicator and is usually supplied by the manufacturer with cans of contact glue.

Contact adhesive is flammable and toxic and should not be used near naked flames or in confined spaces. Glue should be spread on both surfaces making sure there is adequate coverage around the edges.

When the glue is touch dry (usually takes 10 to 20 minutes) the surfaces can be brought together. Contact adhesives give instant bonding and repositioning the laminate is not usually possible.

Edge Finishing

Edge finishing can be carried out within a few minutes after bonding with contact glue. Plastic laminates are quite hard and will quickly damage cutting edges. Tungsten tipped plane irons and router cutters are most suitable for edge finishing of plastic laminates while files and abrasive paper can be used for fine finishing work.

When filing edges of plastic laminate care must be taken to work from the face towards the back so that it does not lift or chip.

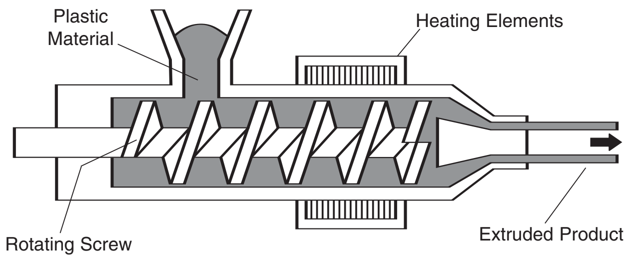
MANUFACTURING PROCESSES

The most common industrial processes for converting plastic materials into products are listed below. Extrusion, blow moulding and injection moulding are probably the most widely used in industry.

These three processes are most often used for thermoplastic materials and all depend on the characteristic that thermoplastics melt or soften with the application of heat and can be held in this state until formed under pressure. When the material cools the moulded shape is retained.

Extrusion

Plastic material, either in granule or powder form, is fed into a barrel-shaped heating chamber which contains a rotating screw. The diagram below illustrates how the screw pushes the molten plastic toward the end of the heated barrel.



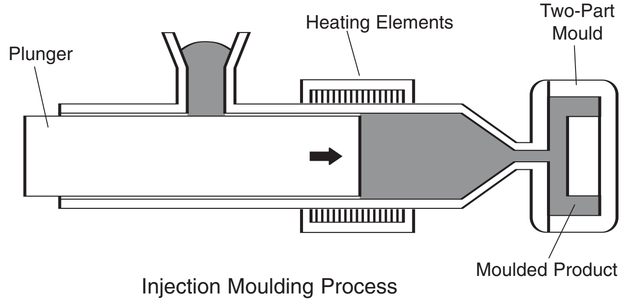
Extrusion Process

The screw provides the pressure required to force the molten plastic through a die or aperture which gives the product its shape. This production process is used in the manufacture of pipe, tube, rod, sheet or mouldings and other complex profiles. After cooling the extrusion is either coiled or cut into lengths.

Injection Moulding

The injection moulding process uses plastic material in granule form which is melted in a barrel-shaped heating chamber as shown in the diagram below. At regular intervals a plunger is forced forward to inject a measured quantity of the molten plastic into a two-part mould the shape of the article that is being manufactured.

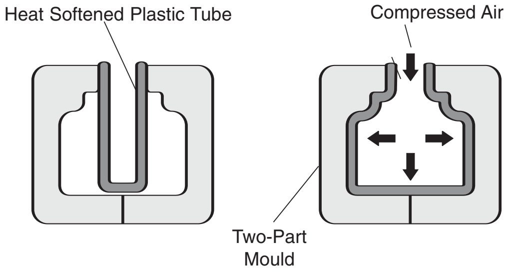
The molten plastic cools and solidifies quickly in the mould. The two parts of the mould are separated and the finished product is ejected. Modern injection moulding machines are automated and fast.



Injection Moulding Process

Blow Moulding

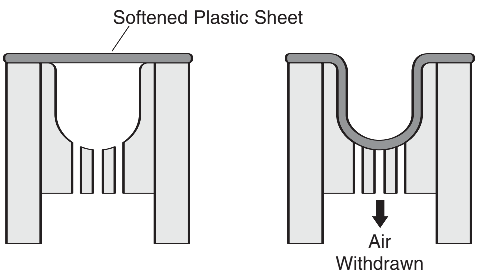
In the industrial blow moulding process an extrusion machine is used to melt the plastic powder or granules and extrude it through a die to form a tube. Short lengths of the almost molten tube are automatically cut and clamped inside a two-part mould and blown outwards with compressed air into the shape of the mould as shown in the adjacent diagrams. The blow moulding process is used to produce articles ranging in size from small bottles to lawn mower grass catchers and large drums. Softened sheet materials are sometimes used in this process.



Blow Moulding Process

Vacuum Forming

The vacuum forming process utilises thermoplastic sheet materials which are softened under a heating element and draped over a mould from which the air is then withdrawn. As the vacuum is applied the softened plastic sheet is drawn into the shape of the mould as illustrated in the diagrams on the left.

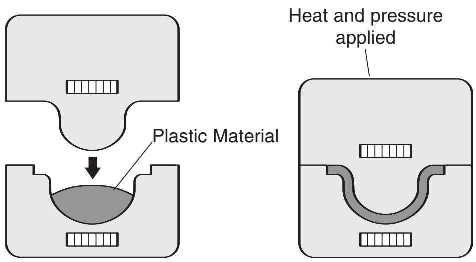


Vacuum Forming Process

Compression Moulding

In the compression moulding process thermosetting plastics are the most common materials used. A weighed amount of the material, usually in powder form, is deposited automatically in the mould and subjected to heat and pressure as illustrated in the diagrams on the right. In this process the plastic material melts and then undergoes a chemical change which causes it to harden or set.

Compression moulding is a much slower process than injection moulding.



Compression Moulding Process

Calendering

Melted plastic materials are squeezed between sets of rollers to form a continuous sheet or film in the calendering process. Calendering is a much faster process than extrusion for the production of sheet or film.

Casting

There are several different forms of the casting process for liquid plastic material. Plastic material may be cast on to paper or cloth in a thin layer such as in the production of upholstery vinyl. Another type of casting requires the plastic to be poured into a mould and allowed to set hard by chemical reaction.

HEATING METHODS

In school workshops thermoplastic sheet is heat softened and usually bent or shaped in a jig or mould. The choice of heating methods will depend on the nature of the project.

For some projects the whole sheet must be softened so that it can be formed into a complex shape. Other projects may require a simple bend in which only a narrow strip of the material needs to be heat softened.

The illustrations which follow show a typical oven and strip heater used for softening thermoplastic materials.

The Oven

The oven would normally be used when the whole piece of material needs to be softened.

The oven should be set to 160°C and preheated before the material is placed on the oven shelf for heating.

A piece of sheet aluminium should be placed on the wire shelf to prevent marking of the plastic.

Stainless Steel Oven

If there is considerable heat loss caused by regular opening of the oven door a higher setting could be used but care must be taken not to let the material degrade. Degrading temperature is about 170°C.

The Strip Heater

The strip heater is generally used where straight bends are required.

Most strip heaters are equipped with adjustable guides linked across pivot pins.

The distance between the guides determines the width of the strip of plastic material being heat softened.

Strip Heater

A sharp bend may require only a narrow strip of the material to be heat softened.

Safety

- Always wear cotton gloves when handling hot materials.
- Keep hands, combustible materials and metal objects clear of heating elements at all times.
- Ensure that electrical cords are well clear of heating elements.
- Never attempt to remove anything that may fall in the vicinity of the strip heater element or the oven element. Switch off and report to the teacher.

WELDING PLASTICS

Most thermoplastics can be welded using a simple process which involves heat softening or plasticising the materials, then bonding them together with the application of pressure and a filler rod.

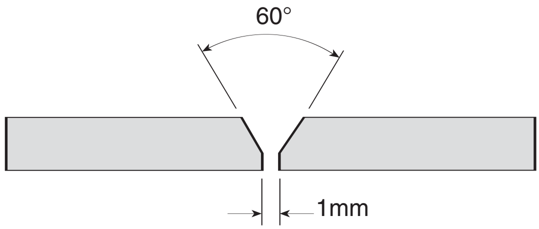
Heat Gun

The heat is applied to the weld area using a heat gun which blows hot air. The heat gun is fitted with a small nozzle which allows the heated air to be directed to the weld area. The photographs on the right show typical heat guns that are suitable for basic plastic welding.

Heat Gun
(nozzle removed)

Welding PVC Sheet

The illustration on the right shows how 3mm polyvinyl chloride sheet is prepared for a typical welded butt joint.

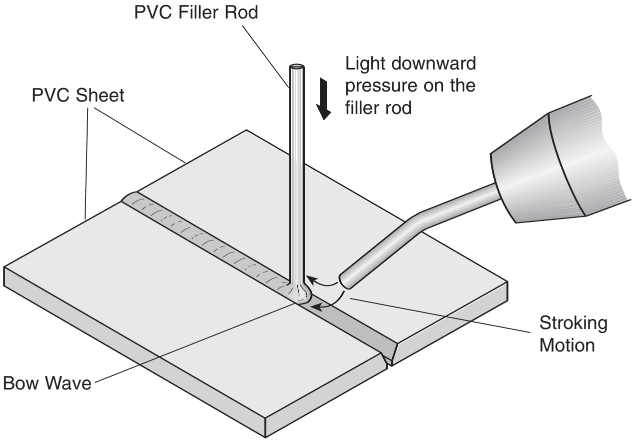


Butt Joint Preparation

The edges of the sheet are bevelled to an included angle of 60°. Thicker sheets would be bevelled for welding on both sides.

Before welding commences the parts are clamped in position about 1mm apart.

Hot air is then directed along the V formed by the parts and at the same time to the base of the PVC filler rod. The nozzle of the heat gun should be no closer than 6mm to the work.



Welding PVC Sheet - Butt Joint

The jet of hot air should be directed in a gentle stroking motion, up and down not side to side.

This action fuses the rod to the parent material and also pre-heats the next part of the joint to be welded.

The filler rod is held in a vertical position and downward pressure is applied as shown in the illustration on the left.

The downward pressure causes a ‘bow wave’ to form at the leading edge of the filler rod as it is being fed into the joint and the point of contact moves along the weld line.

Note that the filler rod should be held only at right angles to the weld line and only downward pressure should be applied. If the rod is held in a backward sloping position, too much pressure may be applied and the material will tend to fold into the gap between the sheets.

Safety

- Check the heat gun and power cord for signs of damage. Report any faults to the teacher.
- When not in use, place the heat gun on the rest (if supplied) away from the edge of the bench.
- Ensure that the nozzle is never directed toward flammable materials, the power cord or parts of the body.
- Never operate the heat gun in damp conditions or in the vicinity of flammable vapours.
- When switching on the heat gun, hold it firmly to counter any sudden twisting movement due to torque.
- Do not leave the vicinity of the welding area while the gun is turned on.
- To close down a heat gun that is equipped with a cooling setting, switch off the heating element and then allow the fan to run for sufficient time to cool down the element and the heat shield before disconnecting from the power outlet.
- Return the heat gun to its storage place only after it has cooled down.

DESIGN & PLANNING

INTRODUCTION

No matter what article is to be made, a certain amount of preparatory work must take place before construction can commence. This could involve developing a design from a completely new idea, or modifying an existing design to suit the circumstances, or even using an existing design without changing it in any way.

Whatever the design entails, each part of the article's construction should be carefully planned so that the article can be completed exactly according to the original design.

Design and manufacture depend on each other. For example, there is no point in designing something that you cannot make in your workshop because you don't have a special machine or piece of equipment that would be necessary to complete the article according to the design.

It must be possible for you to construct the article with the tools, equipment, materials and skills that are available to you. On the other hand the design itself must be an accurate link between the original idea and the article that is finally produced.

Careful planning will be necessary through all stages of the project to ensure that the finished article satisfies all requirements of the design.

A DESIGN CASE STUDY

The following is recommended as a general approach to the design and manufacture of any practical project you may wish to undertake. The following sequential steps form a logical procedure that can be applied to most design problems:

- Situation
- Brief
- Investigation
- Solution
- Realisation
- Evaluation

Situation

What is the particular design problem?

Make sure you understand exactly what is required.

For example, if you were asked to design a bedside table and you had no idea what a bedside table was, would you proceed to make a kitchen table instead? Of course you wouldn't. You would make it your business to find out what a bedside table was and then proceed from there.

Brief

What are the needs related to the design problem?

Using the previous example of the bedside table, consider the following:

Should the table be built so that articles placed on it can be easily reached by a person lying in bed, or should it be made so the person has to sit up or even get out of bed to see or reach these articles? Should this piece of furniture be capable of storing things? If so, what?

These are only a few of the things a designer might have to consider while writing a brief for the design project. Can you think of any others?

Investigation

What are the required specifications of the project?

After determining the needs of the project and writing the brief, it becomes necessary to decide the best way to meet these requirements. Some aspects to consider in the case of the bedside table might be:

- Overall sizes should suit the space available and other determined needs.
- Assuming storage is required, would it be best to include doors or drawers or both?
- Finish: The type of finish required often determines the choice of materials, e.g. natural timber finish or plastic laminate.
- Form: Form is the shape of the article. The simplest shape often makes the best design. Ideas for the shape of the article can be found by observing similar articles made from other materials or the same material.

- Proportion: When the basic shape of the article is decided, the next consideration is the proportions of its parts. Using the example of the bedside table again, you may have decided that the height should be 600mm with one drawer and four turned legs.

  Should the legs be 100mm high and the drawer 500mm deep? If not, which proportions would satisfy storage requirements and also be pleasing to the eye?

- Decoration: Is a simple, well proportioned design most suited to the situation, or is some form of decoration required to enhance the appearance of the article?

- Harmony: Will the article blend with the surroundings? If the existing bedroom furniture has a plain painted finish, would it be best to make the bedside table to match or would it be preferable to have a complete contrast such as a highly polished natural timber finish?

  Obviously you would consider the appearance of the whole room and most likely decide to match the furniture.

- Availability of materials: Before you finalise your design you should make sure all the materials in the sizes you require are readily available.

- Cost: The total cost of materials to be used should be considered carefully while the materials are being chosen for the project. For example, you may have to decide if a more expensive material is worth the extra cost in terms of function and appearance.

- After deciding on such things as shape, size, storage, finish and materials, you should think about the actual construction of the project.

  Does your design combine materials in such a way that joints will have maximum strength? Have you got the right tools to do the job? Have you got enough room in your workshop? Have you got the technical skills required to make the article to the design you are considering?

Solution

After having considered the situation and investigated it thoroughly, you should be in a position to bring all your ideas together and formulate your design.

Generally, it is desirable to draw sketches or make technical drawings that show all necessary construction details.

If you have a working knowledge of graphical techniques you should be able to make accurate pictorial drawings or orthographic drawings that show two or three different views.

Realisation

Realisation is the actual construction of the project from raw materials through to the finished product, working from the design drawings and any other specifications that have been noted during the design process.

Efficient realisation depends not only on having the practical skills to do the work, but also on systematic planning of construction procedures. For example, you might consider doing all the marking out at once or all the cutting at once to save time.

This, however may not always be possible. For example, the location of one part might require the prior completion or part completion of another part before it can be worked on.

If your work is planned thoroughly you may detect problems before they occur and possibly work out ways to overcome them.

Evaluation

When your project is complete it should be tested and evaluated. Try to determine if it really does the job that was originally intended or if it could be improved in some way.

Using the bedside table example again, the following could be used as a simple evaluation procedure.

Place the table in position beside the bed and test its height, storage capacity and appearance by answering the following questions:

Can a person lying on the bed reach the drawer easily or switch off an alarm clock that might be placed on the table?

If not, what is wrong with the design? Is it too high or is it too low?

Does the drawer hold the articles it was designed to store?

Does the table match the rest of the bedroom furniture?

This type of evaluation should discover any faults in the basic design. In addition, you will probably need to get a suitably qualified person to evaluate your construction techniques and the quality of finish.

At this stage it may be necessary to make some modifications to the project to correct design faults.

Notes

Notes

Notes

METALS

CLASSIFICATION

For the purpose of description, metals can be divided or classified into alloys and pure metals.

A **pure metal** contains no impurities or additives.

An **alloy** is a mixture of two or more metals.

Most metals in common use today are not in their pure form because:

- Technical problems involved with purification increase production costs, often unnecessarily.

- The properties or characteristics of metal can be changed by the addition of trace elements and other metals. For example, aluminium in its pure form is extremely soft and requires the addition of other metals to form an alloy which is more serviceable in industry.

Metals can be further classified into two groups; ferrous metals and non-ferrous metals.

Ferrous metals are those which contain iron. Some common ferrous metals are mild steel, cast iron, tool steel and stainless steel.

Non-ferrous metals are those which have no iron content such as aluminium, gold, copper and zinc.

PROPERTIES

Malleability

This is a characteristic which allows a metal to be rolled or hammered into thin sheets. Gold in its pure form is the most malleable of all metals. It can be hammered out thinner than the thinnest paper.

Ductility

Ductility refers to the ability of metal to accept mechanical deformation without fracturing or cracking particularly when being stretched as in the wire making process.

Brittleness

This is the tendency of a metal to break under low stress with little deformation.

Hardness

Hardness is the ability of a metal to withstand scratching or abrasion.

Toughness

Toughness is similar to a combination of strength and ductility. It is sometimes described as a condition between brittleness and softness which allows a metal to be bent or stretched without failure.

Tensile Strength

The tenacity or tensile strength of a metal is the maximum pulling stress that the metal can withstand before breaking. A test piece is placed in a special machine and stretched until it breaks. The stress required to break the metal piece can be measured and stated as the tensile strength of the metal.

HEAT TREATMENT

Sometimes it becomes necessary to change the physical properties of some metals. In many cases this can be achieved with the application of heat.

Annealing

Annealing becomes necessary when a metal 'work hardens', for example, a piece of copper that is being worked into a dome shape using a bossing mallet and dishing mould or block. The more the copper is beaten the harder it becomes.

In this example hardening occurs because of changes in the crystalline structure of the metal due to beating with the bossing mallet. If the metal becomes too hard to work before the desired shape is achieved it should be softened by a process called annealing.

Heat is used in the annealing process which varies for different metals. Copper can be annealed by heating to a dull red then quenching in water. This process realigns the crystalline structure of the metal which becomes much softer and easier to work.

A big project may need to be annealed several times before completion. Aluminium can be annealed by heating to approximately 260°C and then allowing it to cool in the air at room temperature.

Hardening And Tempering

Hardening and Tempering of tool steels are sometimes necessary to make them more serviceable in machining operations.

Hardening is carried out by heating the tool steel to cherry red and quenching it quickly in oil or water. This leaves the metal harder but quite brittle.

Tempering reduces brittleness by increasing the toughness of the metal with only a slight reduction in hardness. Tempering involves reheating the brittle metal to a lower temperature and allowing it to cool more slowly.

The temperature for tempering will vary depending on the desired properties. The changing colours of oxides on the steel are often used as indicators of temperature.

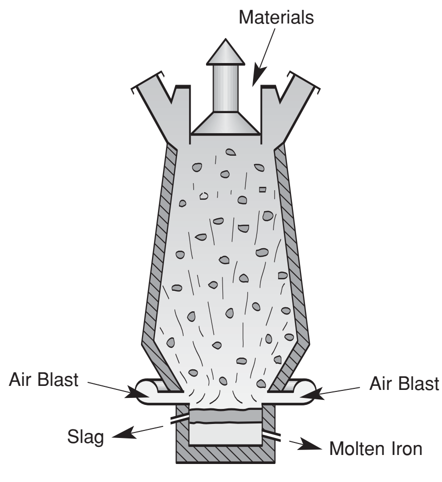
IRON

Iron is smelted from iron ore (haematite). Large deposits of iron can be found in various parts of Australia. Two important iron ore producing areas are the Pilbara region of Western Australia and the Middlebank Ranges in South Australia.

The ore is usually mined by the open cut method and conveyed or transported to a crushing plant where the large ore boulders are broken down to an average particle size of 100mm.

The Iron Making Process

The illustration on the right shows a typical blast furnace used in the production of iron. The blast furnace is charged with the raw materials listed on the following page.



Blast Furnace

Iron Ore: Crushed to an average particle size of 100mm.

Coke: Provides the fuel for the smelting operation. Coke is produced by heating coal in the absence of air.

Limestone: Acts as a flux in the blast furnace by helping the molten iron to flow.

Iron Ore Sinter: Fine particles of iron ore fused with crushed coke, crushed limestone and blast furnace flue dust. The addition of sinter utilises the residue from previous smelting operations.

Air is forced into the bottom of the blast furnace creating a fierce combustion which provides the very high temperatures necessary to smelt the metal iron from iron ore. The iron forms into liquid drops near the bottom of the blast furnace where the temperature is over 1900°C.

The waste material (called slag) floats to the top of the molten iron which is tapped from the furnace. The molten iron is either taken directly to the steel making furnace or cast into ingots called 'pigs' (hence the name pig-iron) for later use.

Cast Iron

Cast Iron is grey in colour, has a melting point of 1260°C and a high carbon content between 2% and 5%. The most common use of cast iron is in foundry work where it is melted down and poured into moulds to form castings which might include machine parts, flywheels, vices, framework for machinery, etc.

Cast iron is very brittle therefore it cannot be forged or worked in the same way as more malleable metals. Cast iron is very strong in compression but has a low tensile strength.

STEEL

Pig-iron contains many impurities such as carbon, silicon, manganese, phosphorus and sulphur.

The steel-making process involves:

- Removal of impurities to produce almost pure iron.
- Addition of the necessary alloying materials to produce the type or grade of steel specified.

The Bessemer Converter

The process for manufacturing large quantities of steel had its beginnings in the 1850s. Henry Bessemer experimented with the idea of purifying molten iron by blowing air through it. He developed a large pear shaped, brick lined vessel called the Bessemer Converter.

Air was forced into the bottom of the Converter to cause a violent combustion and burn out the impurities. Weighed amounts of ferro-alloys were then added to return the small amounts of carbon, silicon and manganese required.

The Open Hearth Furnace

The Open Hearth Furnace, which is still used in some countries to produce steel commercially, is a long rectangular brick enclosure which has a shallow hearth. Raw materials are charged into the furnace and heated to a suitable temperature.

An oxygen lance is then introduced through the top of the furnace to provide the 'blow' which causes the violent combustion necessary to burn out the impurities. Trace elements and alloying metals are added after the molten metal is tapped from the hearth furnace.

Basic Oxygen Process

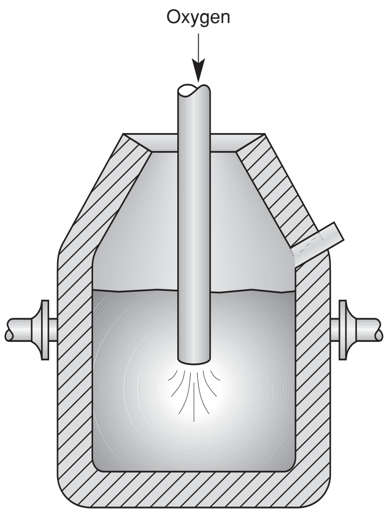
The Basic Oxygen Process was developed from the Bessemer process in Austria about 1950. Most of the world's supply of steel is now produced by this method.

A large pear shaped vessel similar to the one invented by Henry Bessemer is used in the Basic Oxygen Process.

Molten iron (and sometimes molten steel from scrap) is charged into the large vessel and a jet of pure oxygen is introduced from the top.

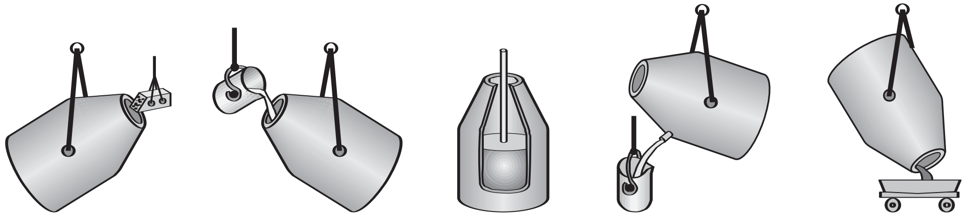
The use of oxygen instead of air eliminates the absorption of nitrogen in the molten metal which was a problem with the Bessemer process.

Trace elements and alloying materials are added as required according to the grade of steel being manufactured.



Basic Oxygen Furnace

The series of illustrations which follow show the principal stages of the Basic Oxygen Steelmaking Process.



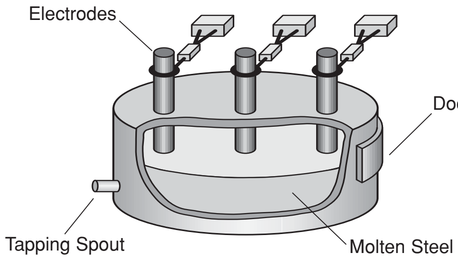
1.Charging Scrap | 2.Charging Molten Iron | 3.Oxygen Blow | 4.Tapping | 5.Slagging

The Electric Furnace

Electric furnaces are sometimes used to produce special grades of steel in relatively small quantities. Most electric furnaces have three carbon electrodes which protrude through the top of the furnace.

Each electrode carries a heavy current of electricity which produces the necessary heat by striking an arc to the ferrous material in the furnace.

The illustration on the right shows the three carbon electrodes and the basic construction of a typical electric furnace.



Electric Arc Furnace

Teeming

Teeming is the process of pouring molten steel from the Basic Oxygen furnace into a ladle from which it is then poured into ingot moulds. The molten metal is poured from the bottom of the ladle as an overhead crane moves it from mould to mould.

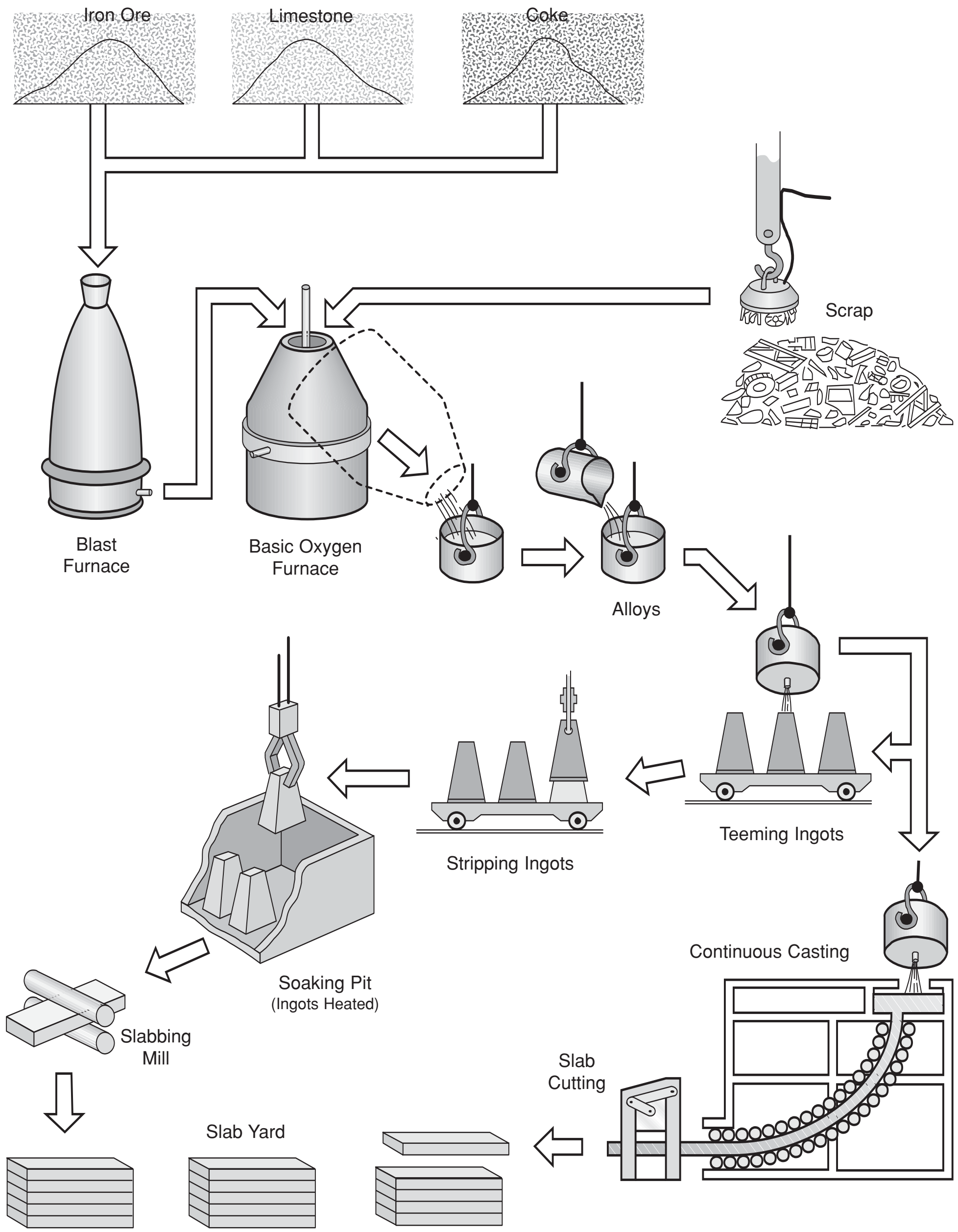
The ingot moulds are tapered to allow easy removal of the ingot after it has cooled and solidified. The removal of ingot moulds from the ingots by overhead crane is called stripping.

Continuous Casting

Molten steel from the furnace can be cast into any required shape straight from the ladle. For example, as shown in the process chart on the following page, slabs can be continuously cast and cut to length while hot and still soft. The method eliminates reprocessing of ingots which result from the teeming process.

Raw Materials to Slabs

The process chart below illustrates the steelmaking process from raw materials through to pig-iron and then steel slabs.



The Steel Making Process

Mild Steel

The ferrous metal which is most familiar to students is mild steel. It is used for most metal turning projects, filing, fitting and fabricating exercises in the school workshop. Mild steel is also used in the manufacture of sheet materials such as tinplate, galvabond and zincanneal.

Mild steel is a very versatile material with many uses and applications in industry. The carbon content is around 0.25% which tends to make the metal reasonably strong while remaining easily workable.

Mild steel will bend when cold. It forges and welds very well, but cannot be hardened and tempered successfully. As with most ferrous metals, mild steel is susceptible to rust.

SHEET STEEL PRODUCTS

Thin sheets of mild steel form the base of many of the common sheet metals used in industry today. The sheets are usually coated with another metal, plastic film or paint to prevent the surface from rusting.

Tinplate

Tinplate consists of a thin sheet of mild steel coated with a very fine layer of tin on both sides. Tinplate is usually produced by:

- Hot-dip tin coating of the sheet steel in a continuous line process in which steel strip is passed through a pot of molten tin.
- Electro-plating in a continuous line process where a very thin, smooth coating of high purity tin is applied by electrolysis.

Tinplate is very easy to work but dents easily. Tinplate should not be used in situations where exposure to moisture is prolonged. The tin coating on the steel tends to slow the rusting process but does not prevent it.

The main uses of tinplate are in food and drink packaging (cans) and in the production of some kitchen utensils (e.g. cake tins).

Sheet metals such as tinplate are said to have ‘grain’ but it should not be inferred that the ‘grain’ in metals is similar to the grain in wood. The term ‘grain’ refers to the crystalline structure of the metal. When sheet metal is rolled from a large slab the crystals align themselves with the direction in which the sheet was rolled.

If the sheet is then formed into a curve it bends forming a series of small flats or kinks. To prevent this happening the metal is rolled first one way and then the other several times to disturb the grain structure or 'break the grain'. The metal is then rolled out straight and shaped to the form desired.

Galvabond

Galvabond consists of a thin sheet of mild steel which is coated with the metal zinc. The zinc coating usually contains a small amount of aluminium to make it more pliable and less likely to flake off when the sheet is bent or shaped.

Because galvabond contains only a small quantity of aluminium it solders readily. Some other galvanised sheet products have a higher proportion of aluminium in the coating and do not solder readily.

Galvanised sheet products can be manufactured by either of the methods previously described for tinplate:

Hot-dip zinc coating (galvanising) of sheet steel is a continuous line process in which steel strip is heat treated to develop suitable forming properties and then coated with zinc as it passes through a vat of the molten metal. The galvanising (zinc coating) solidifies uniformly as the coated steel strip emerges from the vat of molten zinc.

Electro-galvanising of sheet steel is also a continuous line process where a thin coating of high purity zinc is applied by electrolysis.

The thin galvabond sheet used in school workshops is relatively easy to work by hand or machine. Overworking will, however, cause the galvanising to flake off the steel sheet. The zinc coating prevents rusting of the metal. Galvabond is used mainly in plumbing applications such as roofing, guttering, down pipes, tanks and air conditioning ducts.

Zincanneal

Zincanneal is made by heating sheets of galvanised iron (galvabond) in a furnace to a temperature of 340°C and re-rolling. This causes the zinc coating and the surface metal to alloy and prevents the coating from flaking if bent sharply.

Terneplate

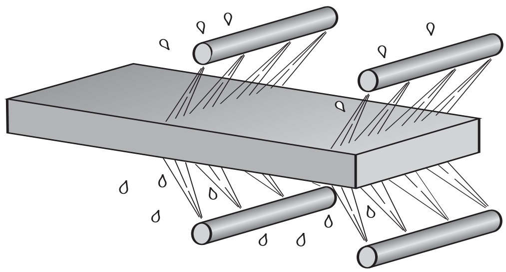
Terne coating sheet steel is the process of hot dipping sheet steel in terne metal which is an alloy of lead and tin. Because it resists corrosion and is very easily soldered, terne plate is used in the manufacture of TV chassis and fuel tanks.

SHEET STEEL MANUFACTURE

The series of illustrations which follow show the various stages of production of sheet steel and sheet steel products. The process begins with the raw material (steel) in the form of large slabs.

Slab Descaling

Slabs are reheated in a furnace to rolling temperature of around 1200°C. They have a uniform coating of surface oxide or scale which must be removed before rolling.

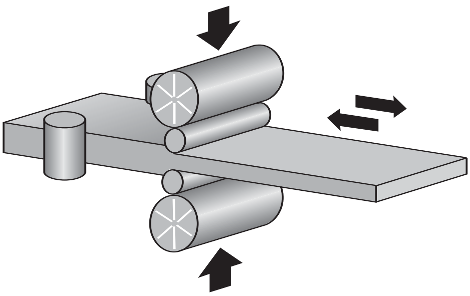


Slab Descaling

Water, jet sprayed under very high pressure loosens and removes the scale from the slab surface. The illustration above shows the slab descaling process. After descaling the slab moves to the roughing mill.

Reversing Roughing Mill

The descaled slab is roughed down by forward and reverse rolling either seven or nine times. Each rolling pass reduces the thickness and increases the length of the slab.



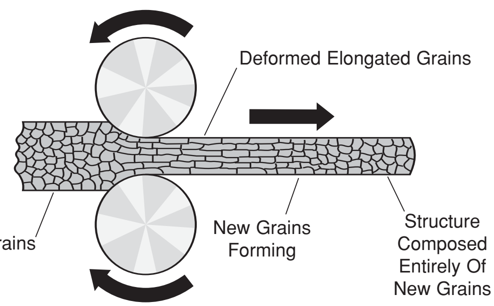
Reversing Roughing Mill

The width is kept constant by vertical rolls as shown in the illustration on the left.

The finished bar could be up to 120 metres long. The bar then moves to the Hot Finishing Mill.

Grain Structure

Grain structure deforms during the hot rolling process in the Reversing Roughing Mill. A new structure quickly forms in the hot steel.



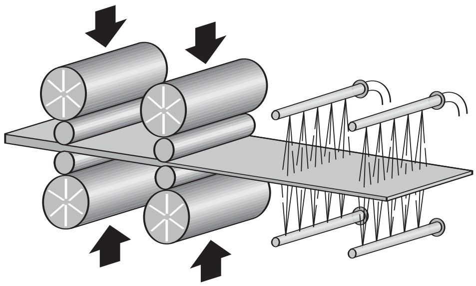
Grain Structure

Hot Finishing Mill

Hot finishing mills comprise a number of sets of rolls, one following the other. The hot bar passes through rolls reducing the section by as much as 50% on each stand.

The illustration on the right shows the lengthening strip. The emerging hot rolled strip can be up to 1200 metres in length.

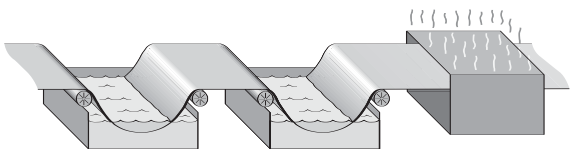
Normal rolling temperature is about 900°C but temperature is reduced to about 650°C by water sprays before the strip is coiled.



Hot Finishing Mill

Strip Descaling

When the hot rolled strip emerges from the hot finishing mill it has a surface coating of black iron oxide. The iron oxide scale must be removed before further processing can take place.



Continuous Pickle Line

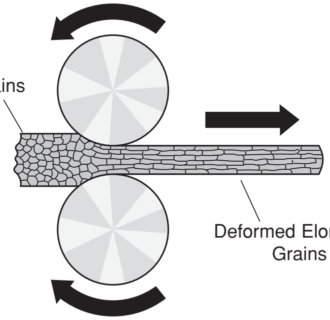
In the continuous pickle line illustrated on the left, strip is descaled in heated acid baths. It is then cleaned, side trimmed, oiled and re-coiled ready for the cold reduction mill.

Cold Reduction

Cold reduction mills comprise a number of stands of rolls in tandem. The leading end of clean pickled coil is slowly fed through each set of rolls and on to the re-coiler.

When tension has been established between each stand the mill accelerates and reduced strip exits at about 60-80km/h.

Grain structure is deformed during cold reduction and heat treatment is necessary to develop a new structure.



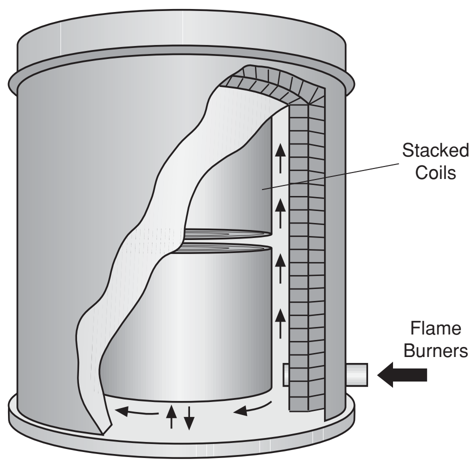
Cold Reduction Mill

Annealing

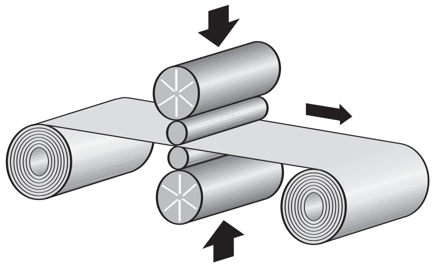
After the cold reduction process, steel grain structure is elongated making it hard and springy.

Annealing is a process of heat treatment where the grain structure is re-crystallised to make the steel ductile. The illustration on the right shows an annealing coil furnace which is gas fired.

Continuous strip annealing is an alternative method of heat treatment used, for example, on continuous galvanising lines.



Annealing Furnace



Temper Rollers

Skin Passing

After annealing, the coil moves to a set of rolls which reduces thickness slightly but improves surface texture and flatness.

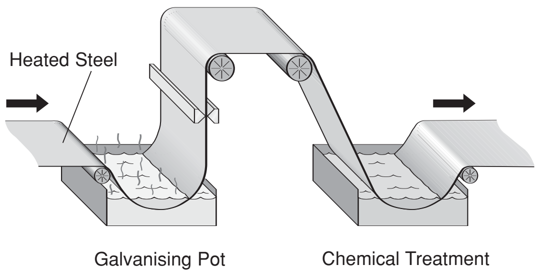
This process which is shown on the left, is called skin passing or temper rolling.

Continuous Hot-Dip Zinc Coating

Hot-dip zinc coating (galvanising) of sheet steel is a continuous line process in which steel strip is heat treated to develop suitable forming properties and then coated with zinc as it passes through a pot of the molten metal as shown below.

Thickness and finish of the zinc coating are precisely controlled to requirements. The zinc coating solidifies uniformly and rapidly as the coated strip emerges upward from the zinc pot.

The zinc coating is then chemically treated to preserve its surface appearance.



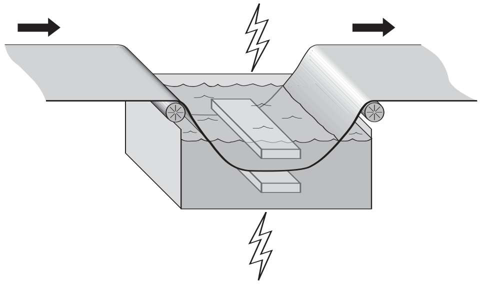
Galvanising Process

Electro-Galvanising Sheet Steel

Electro-galvanising is a continuous line process in which a very thin, smooth coating of high purity zinc is applied to the surface of the steel sheet by electrolysis.

Strip is chemically cleaned and treated before entering an electro-plating bath where the strip is made the cathode and passes between zinc anodes in the electrolyte solution.

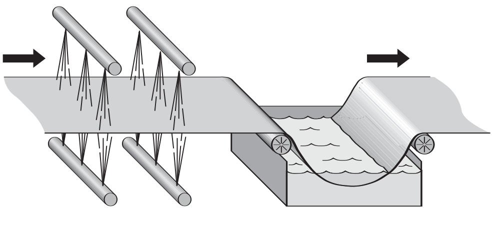
The thickness of the deposited zinc is controlled by a combination of line speed and electric current.



Electroplating Bath

Preparation For Organic Coatings

Organic coatings are decorative and functional paint or plastic films applied to pre-treated sheet steel strip. Many modern product fabrication methods are designed around steel pre-finished with formable organic coatings which can only be manufactured by strip processing under carefully controlled conditions.



In Line Treatment

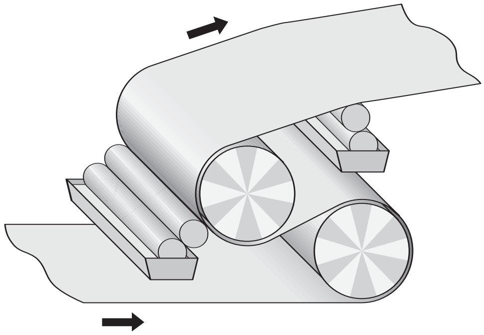
Before organic coatings can be applied in the line process, steel strip must first be thoroughly cleaned and chemically treated as shown on the left.

A similar pre-treatment is required for electro-galvanising as described previously.

Painted Finish

Coil painting is a continuous line process in which steel strip is thoroughly cleaned and chemically pre-treated prior to painting.

Primer and finish coats are roller coater applied to one side or to both sides of the steel simultaneously and then oven cured.



Paint Rollers

Very flexible paints can be tailored to withstand any forming operation required. Paint resins include silicone polyesters, vinyls and acrylics.

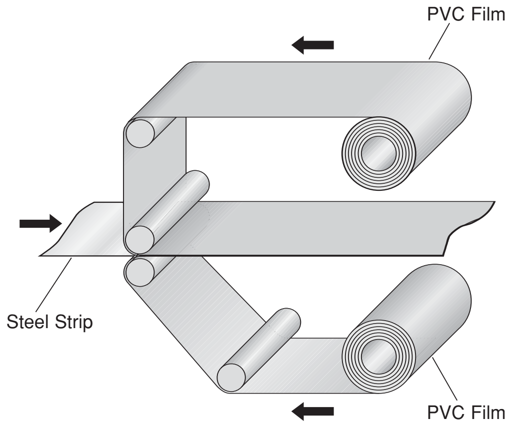
Some typical uses of pre-painted steel include roofs and walls, swimming pool surrounds, facades, awnings, freezers, refrigerators and other household appliances, highway signs and auto number plates.

PVC Film

PVC (polyvinyl chloride) films are adhesive bonded to line pre-treated steel strip under heat and pressure.

Decorative films such as wood grains or other patterns, embossed or plain, are applied to one side or both sides of the strip simultaneously.

Typical uses for film bonded sheet steel could include metal cabinets and display units.



Applying Film

COPPER

Properties And Uses

Copper is a reddish-brown metal that is ductile and malleable. It is a good conductor of heat and electricity and is highly resistant to corrosion. Copper is soft and easy to work with hand tools. It can be finished to a very high polish but tarnishes quite quickly.

Copper is used mainly for the production of electrical wire, water pipe and flat sheet which is used in a variety of plumbing applications and electrical appliances such as water heaters. Copper is used quite extensively in ornamental and art metal work.

Copper Alloys

Copper alloys readily with a number of other metals. Combining metals with different properties can produce an alloy with a set of characteristics or properties which are distinctly different from the original metals.

Some common copper alloys are:

- **brass**, which is an alloy of copper and zinc
- **bronze**, an alloy of copper and tin
- **nickel-silver** which combines copper, nickel and zinc
- **cupro-nickel** which is an alloy of copper and nickel.

Production Process

The production of copper involves a number of stages from mining through to refining. A brief description of the main stages of production follows.

Mining

Deposits of copper are usually found deep below the earth's surface. Sometimes it is found in the form of native copper but usually as ore in a vein system. Large amounts of rock are generally processed to yield relatively small amounts of copper.

The ore body itself rarely yields more than 5% copper and usually constitutes less than 2% of the material processed which includes rock, earth, etc.

Because there is such a small proportion of copper in the ore body some processing is usually conducted close to the mine site.

This local processing avoids high costs involved with the transportation of large quantities of material which would eventually yield a relatively small economic return.

For example, copper ore is mined and processed at Mt Isa. The processing plant at Mt Isa produces blister copper, which is in a rough form and contains some impurities.

The blister copper is transported to Townsville where it is refined for local and overseas markets.

Milling

Copper ore is crushed, screened to provide pieces about 12mm in diameter, mixed with water and ground finely in a rod mill or ball mill. These mills consist of very large tumblers which rotate causing the enclosed steel rods or balls to crush the ore.

The slurry is then treated with chemicals in a series of air agitated tanks. This is called *floatation* because copper mineral floats to the top as froth attached to the air bubbles.

This froth is called *copper concentrate* and usually contains about 25% copper.

Smelting

Smelting involves the removal of almost all the impurities in the copper concentrate. These impurities are usually sulphur, iron and silica.

Copper concentrate is filtered and then roasted which removes about half the sulphur in the form of sulphur dioxide.

The roasted product is called *copper calcines*. The copper calcines are smelted in a coal fired reverberatory furnace. As the calcines melt in the furnace they separate into two layers of molten material.

The upper layer is slag or waste material and the bottom layer is a *copper matte* which contains about 45% copper.

The copper matte is charged into a furnace similar to a Bessemer Converter where air is blown through the molten material.

Iron is oxidised and removed as slag (aided by the presence of silica) and the remaining sulphur is driven off.

The resultant product is *blister copper* which is about 99% pure but not in a usable form. The blister copper requires further refining.

Refining

Blister copper is usually refined by the process of *electrolysis*. The blister copper is cast into shapes which are suitable for use as anodes in the electrolytic process.

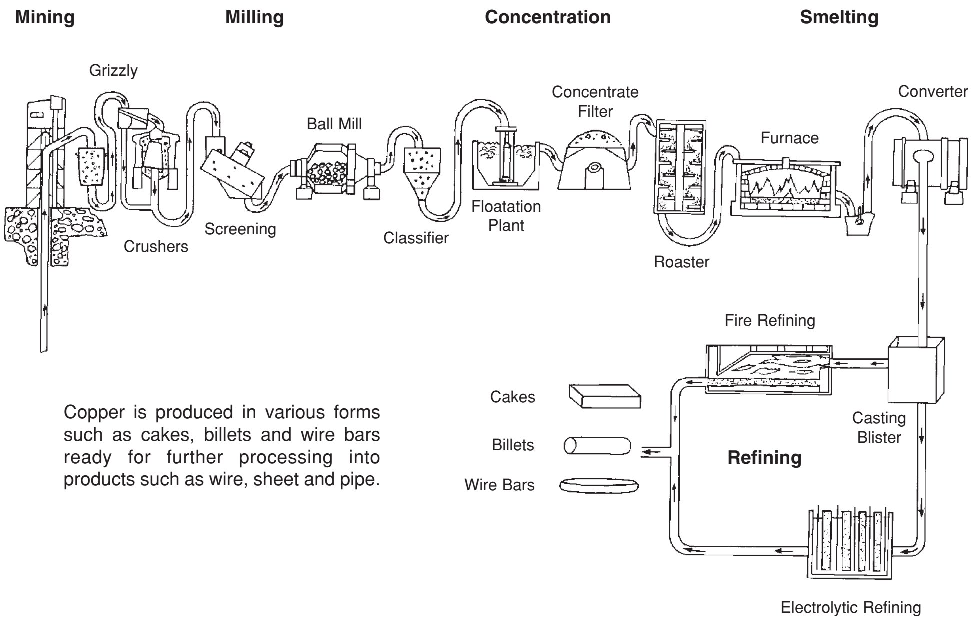
The blister copper anodes are placed in a large tank of dilute sulphuric acid and arranged in rows with thin sheets of pure copper arranged alternately as cathodes.

An electric current is passed through the anodes and cathodes via the electrolyte solution which causes the copper of the anodes to dissolve and to be deposited on the cathodes.

The cathodes are removed from the tank and the pure copper is melted and cast into billets or other shapes for further processing.

Process Chart

The process chart below provides additional information in graphic form about the production of copper.



Production Of Copper

Production Summary

Mining: Mining is carried out either underground or by the open cut method.

Milling: The grizzly sorts ore pieces, large pieces go to the crusher. After screening, ore pieces that are too large for the ball mill are returned to the crusher. The ball mill grinds the ore to a fine texture.

Concentration: In the flotation plant copper concentrate bubbles to the surface. Waste sinks to the bottom and water is removed in the filters.

Smelting: The roaster blows hot air through the concentrate. The furnace smelts the copper (copper matte) and the converter blows air through the molten material to burn out impurities.

Refining: Electrolysis is generally used. Fire refining is rarely used today.

ALUMINIUM

Properties

Aluminium is a greyish silvery coloured metal. It is very light compared to other structural metals and is corrosion resistant, non-magnetic, non-sparking, has high reflectivity and can be highly polished. Aluminium has good thermal and electrical conductivity and is easy to work with normal tools and metalworking machines.

Aluminium Alloys

Pure aluminium is very soft and requires the addition of other elements to form alloys which are much more serviceable in industry than the pure metal. The elements usually used to produce aluminium alloys are copper, zinc, manganese, magnesium and silicon.

The added elements usually do not constitute more than 10% of the final product. The tensile strength of alloys may be up to 600% greater than the tensile strength of pure aluminium.

Uses

Aluminium is used in the production of windows and doors, shop fronts and fittings, roofing, wall cladding, gutters and down-pipes, kitchen utensils, boats, aircraft, electrical wiring and in the automobile industry, to name just a few of the applications of this versatile metal.

Mining

Aluminium is produced from a reddish clay-like material known as bauxite which is generally mined using the open cut method.

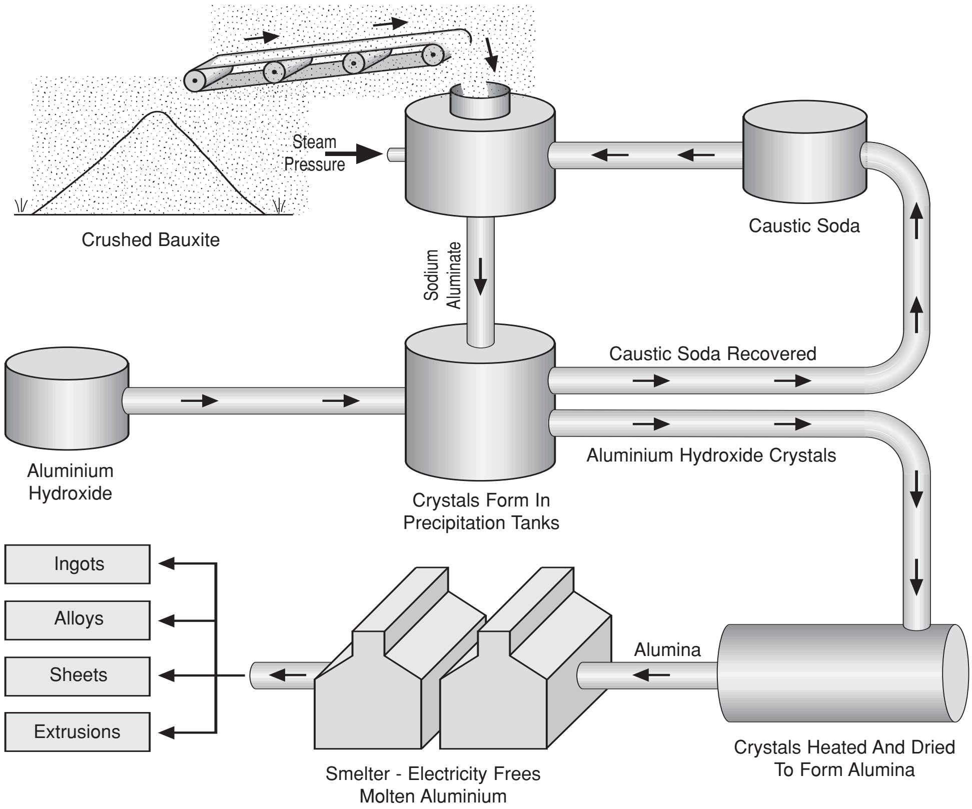
Open cut working simply consists of removing the overburden of small trees, scrub and soil with bulldozers (sometimes blasting is required) and scooping up the ore with front end loaders or drag lines and shovels.

The bauxite is then transported in very large trucks to the crushing plant where it is reduced to fairly small particles (screened through a 25mm x 25mm grid).

The crushed ore is then moved by conveyor belt to stockpiles, ready for transportation to the refinery.

Producing Aluminium

The process chart below shows the various stages of the production of aluminium from the raw material, bauxite.



Aluminium Production Process

Refining

In the refining process, approximately two tonnes of bauxite are required to produce one tonne of alumina which is a fine white powdery substance. In 1888 Carl Joseph Bayer developed a method of producing alumina from bauxite using caustic soda.

The Bayer Process is still generally used today and it involves mixing the bauxite and sodium hydroxide (caustic soda) under steam pressure. The aluminium oxide in the bauxite and the caustic soda react to form soluble sodium aluminate.

Impurities are filtered out and the sodium aluminate in solution is pumped into a tank where small quantities of aluminium hydroxide are added. Solid crystals of aluminium hydroxide precipitate out. These crystals are heated in long revolving drums where the water is driven off to leave alumina (aluminium oxide).

Smelting

The reduction of alumina to aluminium occurs through electrolysis. The commonly used commercial method is the Hall-Heroult electrolytic process.

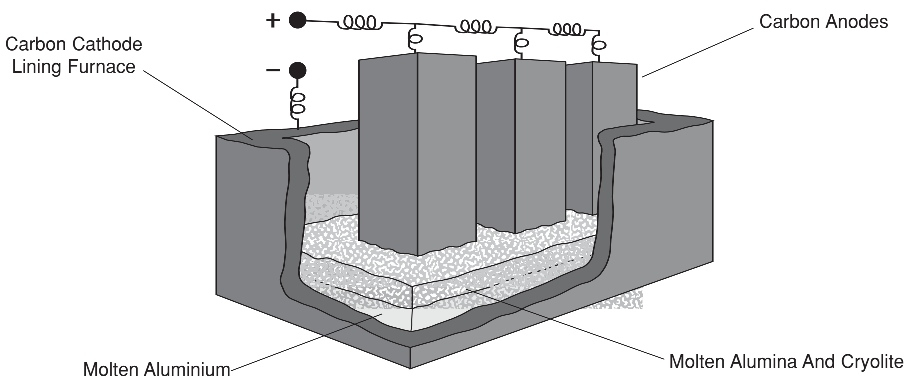
Very large amounts of electrical energy are needed to produce one tonne of aluminium from two tonnes of alumina. The availability of cheap electricity usually determines the location of the smelting plant.

Alumina is heated to a very high temperature in electric furnaces or ‘pots’. The furnaces are about 4 metres wide, 5 metres long and 1.2 metres high and arranged in rows (pot lines) which may contain up to 150 units.

Each steel cased furnace is lined with carbon, which acts as a cathode. Blocks of carbon (anodes) which carry the electric current are immersed in the furnace as shown in the illustration below.

Cryolite, in which alumina readily dissolves, is poured into the furnace and alumina added. During the electrolytic action the alumina decomposes and the pure aluminium sinks to the bottom of the furnace.

The molten aluminium is periodically tapped by suction tapping equipment and cast into ingots or placed in holding furnaces where other metals are added to form alloys of varying hardness.



Electric Furnace

TOOLS AND MACHINES

HAND TOOLS

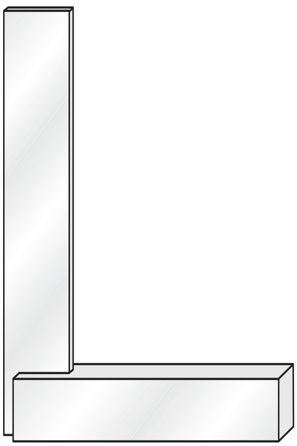
Some of the common metalwork tools used in school workshops are illustrated below. Typical uses are listed beside each illustration.

Measuring And Marking Tools

The steel rule is used for measuring, testing edges for straightness and as a straightedge for marking out.

Steel Rule

The engineers square illustrated on the left is used for drawing lines at right angles to straight edges and testing for squareness.



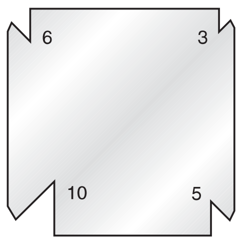
Engineers Square

Scribers are hardened tools which are used to mark lines on the surface of metal.

Scriber

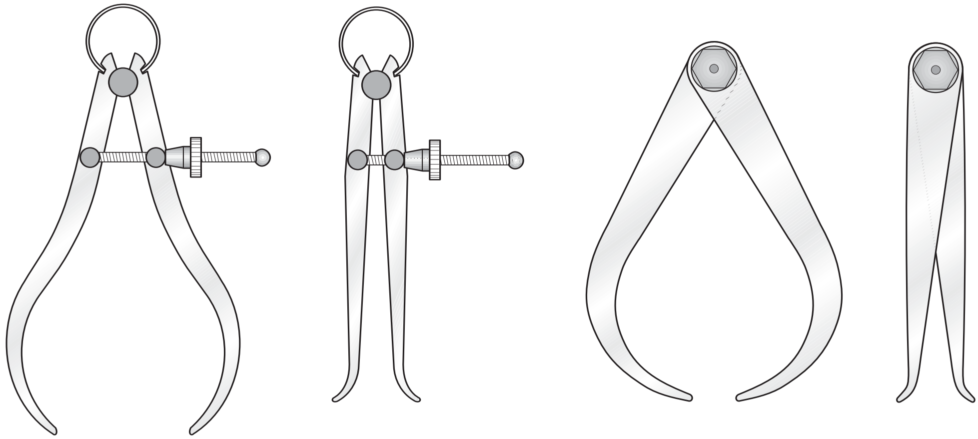
The scratch gauge is used to mark lines parallel to the edges of sheetmetal.

It is a simple tool, usually made from stainless steel sheet. Gauge sizes are made to standard allowances for seams and edges in sheetmetal working, for example 3mm, 6mm, 5mm and 10mm.



Scratch Gauge

SPRING CALIPERS FIRM JOINT CALIPERS



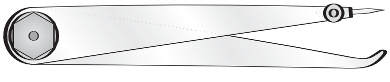
Outside Calipers · Inside Calipers · Outside Calipers · Inside Calipers

Inside calipers are used to measure or test inside diameters and to test edges for being parallel to each other.

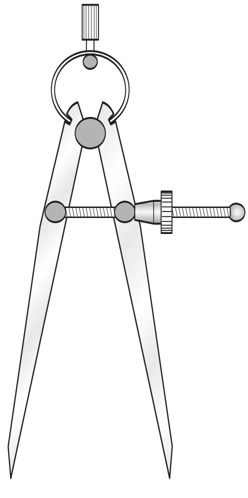
Outside calipers are generally used to test and measure outside diameters and sometimes to test straight edges which are a large distance apart, for being parallel to each other.

The illustrations above show the most common types of calipers used in the metal workshop. The spring calipers are set by means of an adjustment nut and screw. The firm joint calipers can be lightly bumped to make fine adjustments to the setting.

Jenny calipers are marking tools which are used for scribing lines parallel to the edges of the material. Jenny calipers are often called hermaphrodite calipers or odd-leg calipers. The illustration below shows a common type with adjustable point.



Jenny Calipers



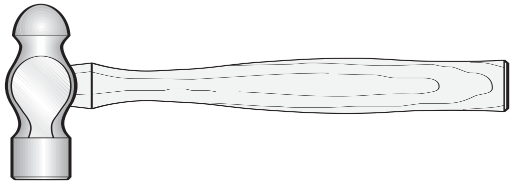
Spring Dividers

Spring dividers, as shown on the right, are used for scribing circles and arcs and sometimes for drawing lines parallel to the edges of sheet metal.

Percussion Tools

The engineers hammer or ball pein hammer is mostly used for heavy percussion work such as cutting metal with a cold chisel.

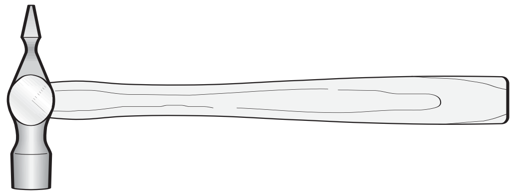
It is also used for solid rivetting and sometimes for beating a pattern into art metals.



Engineers Hammer

The cross pein hammer is a general purpose hammer used mainly for lighter work than the engineers hammer.

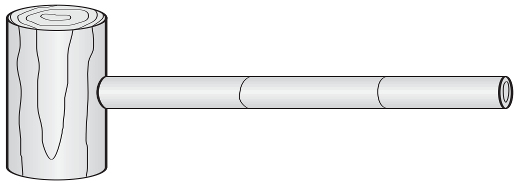
The cross pein can be used in corners that are difficult to work in with the face of the hammer.



Cross Pein Hammer

The tinman's mallet is used for bending and shaping metal usually on stakes or mandrels.

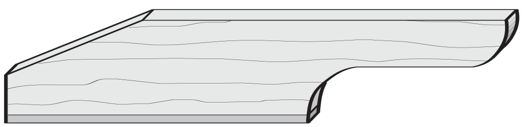
The mallet is generally used only when the work is too heavy for a dresser.



Tinman's Mallet

The dresser is generally made from wood and faced with a material such as red fibre or polyethylene.

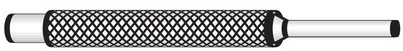
The dresser is used in sheet-metal working for turning edges and dressing corners.



Dresser

Punches And Chisels

The pin punch or solid punch is used to make a hole in soft sheet metal when joining with tinman's rivets and to drive metal pins.



Pin Punch

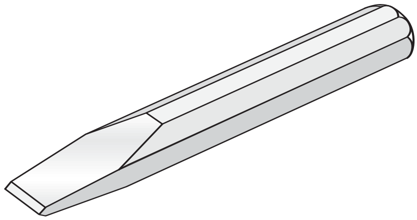
Centre punches are used to make an indentation in the surface of metal to enable a twist drill to enter accurately and sometimes for witness marking. The point angle of a centre punch is 90°.

Centre Punch

Prick Punch

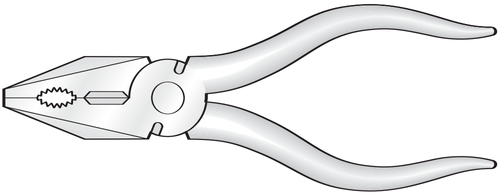
The prick punch is mainly used to accurately and permanently witness mark centres and lines with a small indentation (prick). The point angle of a prick punch is usually 60°.

The cold chisel is made from steel which is hardened and tempered so that it can be used to cut softer metals. The chisel shown on the right is a typical general purpose flat chisel. Other chisels are made for special purposes such as cutting keyways and grooves.



Cold Chisel

Pliers And Tinsnips



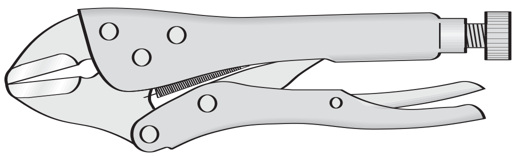
Combination Pliers

Combination pliers are general purpose workshop pliers used for bending and cutting wire, gripping small rods and holding thin materials when drilling.

Special purpose pliers such as snipe nose pliers and circlip pliers are also used in the workshop.

Lock-grip pliers or vice grips are used as a clamping device in a variety of workshop operations.

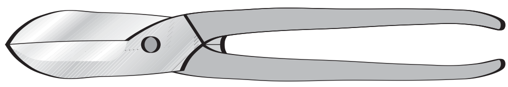
Holding two or more pieces of thin mild steel together while an aligned hole is drilled through them would be a typical example.



Lock-Grip Pliers

Straight tinsnips are used for straight cutting and large curved cuts in light gauge sheet metal.

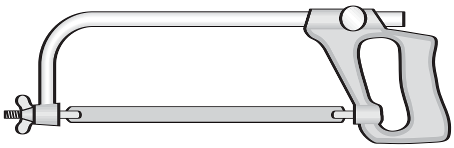
Bent snips or curved jewellers' snips are used for cutting tight curves in light gauge sheet metal.



Straight Tinsnips

Hacksaws And Blades

The hacksaw is used for cutting metal bar and rods as well as other materials such as plastics. Hacksaw frames are adjustable to take a number of different blade lengths.



Hacksaw

Hack saw blades are available in two varieties. One is soft with hardened teeth and the other is fully hardened. The hard blades wear better, but are brittle and more likely to break. Blades are also available in several lengths, the most common being 300mm.

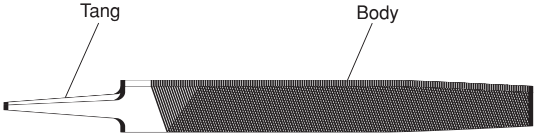
Hacksaw blades are manufactured with various numbers of teeth per 25mm to suit a range of uses. Common grades are 32, 24 and 18 teeth per 25mm. Generally, a fine blade is used for cutting thin tube, sheet metal and thin sections. Coarser blades are more efficient on solid or thick sections.

Files

Files are used in the workshop for a variety of purposes from rough waste removal to fine finishing of material surfaces. The illustration below shows the two main parts of a file.

The tang of the file is not hardened during manufacture. The tang can be quite sharp and may cause injury to the hand if the file is used without a properly fitted handle.

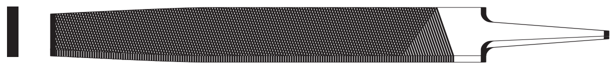
The body of a file is hard and brittle. This is where the teeth are located. During manufacture the teeth are cut into the body which is then hardened and tempered.



Files may be single cut or double cut. Single cut files have one series of parallel teeth cut at an angle to the centre line of the file. Double cut files have their teeth cut in opposite directions. The grade of a file refers to the coarseness of the cut. The three most common grades are Smooth, Second Cut and Bastard.

Some of the common files used in metalwork and plastics work are shown in the illustrations which follow.

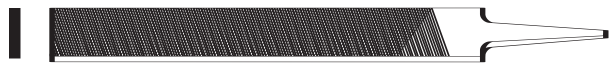
The flat file is a general purpose file that can be used on a wide range of materials.



Flat File

It has double cut teeth on the faces and single cut teeth on both edges. The body is tapered toward the point.

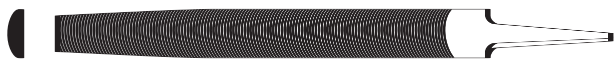
Hand files are also general purpose files that have double cut teeth on the faces.



Hand File

They are parallel files with single cut teeth on one edge only. The edge without teeth is called the *safe* edge.

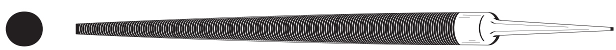
Half-round files have one flat face and a curved back.



Half Round File

Like the hand file the shape of the body tapers toward the point. Half round files are used to file round holes and concave curves.

Round files or rat-tail files are generally used for enlarging holes and filing concave surfaces.

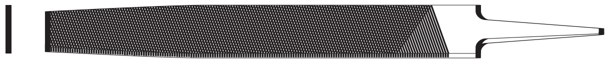


Round File

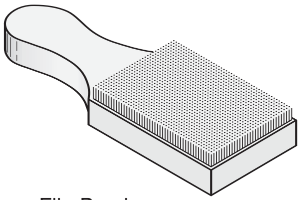
Triangular files are used for filing internal corners between the angles of 60° and 90°. Small triangular slim taper files are often called saw files. They are used for sharpening handsaws.

Triangular File

Warding files are used for filing narrow slots or notches and for working in confined spaces.



Warding File



File Brush

A file brush which has stiff wire bristles should be used to clean waste material out of the file teeth.

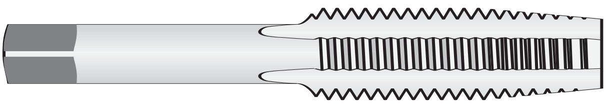
The file brush should be used only in the direction of the file teeth to avoid unnecessary wear of both the file teeth and the brush.

Thread Cutting Tools

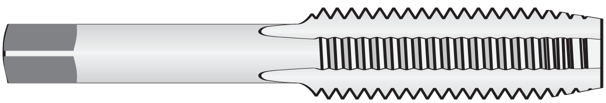
Taps are hardened tools used for cutting internal screw threads. The illustrations below show the three types of taps required to tap a blind hole. A blind hole is not drilled all the way through the material.

The taper tap is used to start the thread. The teeth are ground back to a long taper to make the cut easier to start.

The taper tap would also be used to thread a hole that goes all the way through thinner material.

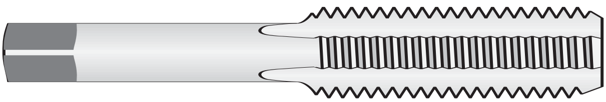


Taper Tap



Intermediate Tap

The intermediate tap is used after the thread has been started with the taper tap. As shown in the illustration, the intermediate tap has a shorter taper than the taper tap.

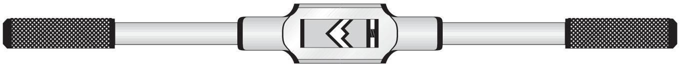


Bottoming or Plug Tap

The bottoming tap is commonly called a plug tap and is used to finish the thread in a blind hole.

A tap wrench is used to hold the tap and provide the rotational power which is necessary for the threading operation. A bar type tap wrench is illustrated below.

Tapping A Thread



Tap Wrench

A suitable cutting oil should always be used during tapping operations. When tapping a thread care must be taken to back off the cutting action every half turn or so. This reverse action breaks off the waste material.

Taps are very hard and therefore very brittle, hence they will break if too much pressure is applied particularly if the waste material is allowed to build up.

The tapping hole must be smaller than the outside diameter of the tap so the teeth of the tap can cut into the metal. For most metric threads the size of the tapping hole can be found using the following simple formula:

$$\text{Tapping Hole} = D - p$$

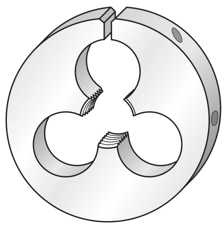
D is the outside diameter of the tap and *p* is the pitch. Pitch is the distance between threads.

Cutting An External Thread

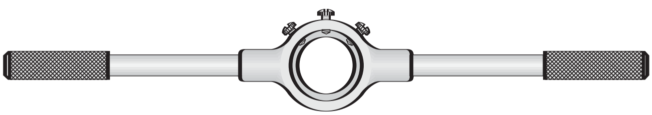
Button dies are hardened tools which have a threaded hole that cuts external screw threads on round bar.

Most button dies have the diameter and pitch of the thread stamped on them, for example 4.5mm x 0.60mm.

This means that the outside diameter of the thread is 4.5mm and the pitch of the thread is 0.60mm.



Button Die



Die Stock

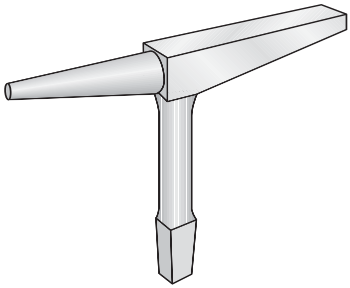
A die stock, often called a die holder, is used to hold the button die.

A small bevel should be filed on the end of the metal rod to be threaded. This will help the thread to start as the die stock is rotated. Cutting oil should be used and the cutting action backed off every half turn or so to break off the waste.

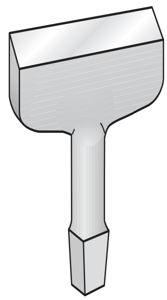
METALWORK STAKES

The illustrations which follow show some of the stakes and mandrels which are used for bending and shaping light gauge sheet metal. Metalwork stakes usually have a tapered shank which is fitted and sometimes bolted to a stake bench.

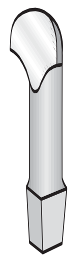
Stakes are usually manufactured from mild steel which is quite soft and easy to damage. Hammers should not be used to bend or shape sheet metal on these stakes. Some processes require the use of a mallet but generally a dresser is satisfactory for most soft sheet metals.



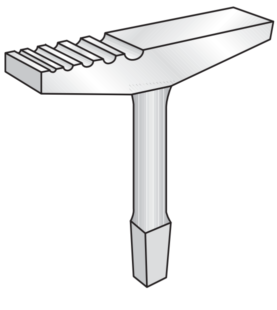
Bick Iron or Beak Iron



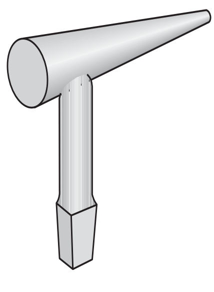
Hatchet Stake



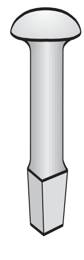
Half Moon Stake



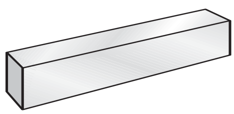
Creasing Iron



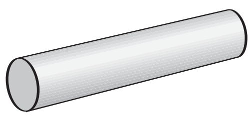
Funnel Stake



Dome Head Stake



Square Mandrel



Round Mandrel

PORTABLE POWER TOOLS

Drills

Portable drills are available in a wide range of types and sizes with a number of different features including dual and variable speeds, forward and reverse, torque settings and impact or hammer function.

The drill bit is held in a chuck which is connected by a shaft and gear arrangement to an electric motor. Most portable electric drills are equipped with a switch lock. Generally, students are advised to use the switch lock only when the drill is fixed in a drill stand.

Basic Drill

Basic drills are light and compact, usually featuring variable speed and reverse. Chuck size is usually 6.5mm or 10mm.

Cordless Drill

Cordless drills feature a rechargeable battery and are usually equipped with a 10mm or 13mm chuck. Other features may include dual or variable speeds, multiple torque settings, forward and reverse. These features combine to make most cordless drills suitable for both drilling and screwdriving operations.

Impact Drill

Impact drills are usually powerful multi-purpose drills which have extra features such as a two speed gearbox, variable speed reversible, usually with a 13mm geared chuck. The model illustrated on the right also has an adjustable depth guide fitted.

The impact or hammer mode is engaged by pressing the button provided. This feature is generally used for drilling into masonry or brickwork.

Drill Stand

Drill Stand

The drill stand shown on the right is designed to be bolted to a workbench and will take any portable drill with a collar diameter of 43mm.

The base plate is slotted so that a machine vice or workpiece can be bolted down or otherwise fixed in position for maximum accuracy in drilling operations.

The switch lock on the drill can be engaged when the tool is used in this way.

Angle Grinder

Angle grinders are mostly used for rapid removal of material. They are fitted with grinding discs or wheels that are available in a range of grades for finer or coarser work. The photograph below shows a typical small angle grinder suitable for general purpose use in the metal workshop.

Angle Grinder

The forward handles on these tools are interchangeable for both right and left hand operation.

Angle grinders are so named because the shaft which drives the abrasive disc is at an angle, usually 90°, to the motor shaft. This arrangement allows the operator to comfortably apply pressure to the flat of the abrasive disc during grinding operations.

Nibbler

Nibblers cut a slot in a continuous punching action. With each stroke a piece of material (slug) is removed as the nibbler is fed into the work.

Nibbler

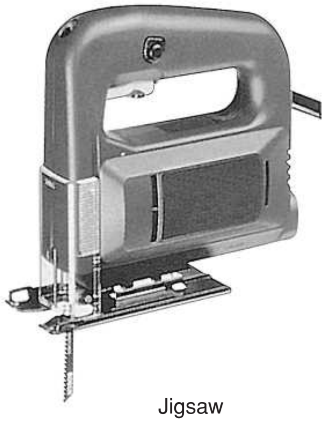
This cutting action makes the nibbler highly manoeuvrable. It is particularly suitable for cutting shapes with tight curves or corners.

Jigsaw

The jigsaw is a versatile tool which can be used for a variety of cutting operations on most sheet materials including metal.

It can be used for straight cutting but is most useful for cutting shapes which involve tight curves.

The jigsaw shown on the right has a variable speed feature which allows the operator to use the cutting speed most suited to the job by varying the pressure on the trigger switch.



Jigsaw

Safety Precautions

- Obtain permission from the teacher before using any portable power tool.
- Receive instructions in the safe and proper use of a power tool before commencing to use it.
- Fasten loose clothing, tie apron at the back, remove tie or tuck in safely between shirt buttons.
- Wear shoes which provide adequate protection for the feet.
- Do not wear rings, watches, bracelets or necklaces.
- Wear appropriate eye protection.
- Long hair must be constrained with a suitable cap or net.
- Hearing protection must be worn where noise levels are hazardous.
- Wear an appropriate dust mask if the operation of the tool produces airborne particles which could be a respiratory hazard.
- Never operate power tools in wet or damp conditions.
- Keep fingers and hands clear of moving parts, blades, sanding discs, etc.
- Keep the power cord clear of moving parts.
- Never use defective equipment. Report it to your teacher.

- Ensure that material being worked on is well supported or held securely where necessary.
- Ensure that off-cuts cannot fall onto the feet.
- Switch off and remove the plug from the power outlet before making adjustments or changing blades, grinding discs, etc.
- Do not switch off the power tool when it is under load, except in an emergency.
- Allow the power tool to reach operating speed before using it on the workpiece.
- Do not use the switch lock unless the power tool is set up as a stationary bench machine.
- Remove chuck keys immediately after use.
- Do not use blunt or damaged blades.
- Avoid blocking or covering the motor ventilation slots while using the power tool.
- Switch off at the power outlet and remove the plug when the power tool is not in use.
- On completion of the job, clean down the power tool and return it to its storage position.
- Never connect a portable power tool to a damaged power outlet.
- Do not strain power cords or extension leads, especially by lifting or dragging tools by the cords, or by pulling on the cord to remove the plug from the power outlet.
- Do not walk on flexible cords.
- Avoid dropping tools or materials on flexible cords.
- Position power cords with care to avoid trip hazards and to prevent damage to the cord or extension lead.
- Keep power cords clear of oil, grease, machines and sources of heat.
- Where possible, work near a power outlet to avoid using an extension lead.

THE METAL LATHE

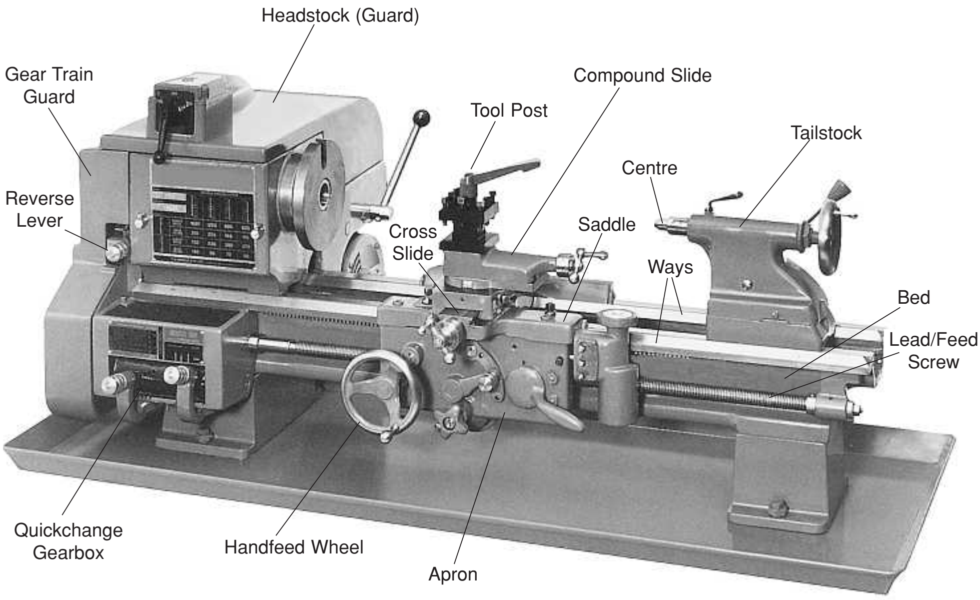
The lathe is a workshop machine that is designed to support and rotate a piece of material as it is being shaped by a cutting tool. The lathe is capable of producing cylindrical, conical, helical and spherical shapes that are co-axial with the centre line of the lathe. This type is often referred to as a centre lathe.

Small machines are usually mounted on a bench or a stand and are sometimes called bench lathes. Bench lathes are available in various sizes, capable of turning lengths between about 600mm and 1000mm.

There are two main types of centre lathe. Lathes in which turning speeds are varied by means of step-cone pulleys are belt driven and are usually called *belt-drive head* lathes. Lathes that are driven through a gear box are usually called *geared head* lathes. The drive mechanism of a lathe is contained within the headstock as shown in the illustrations which follow.

Parts Of The Lathe

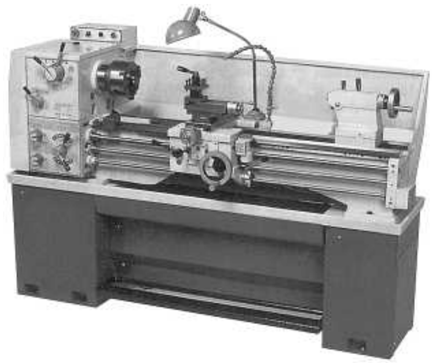
The photograph below shows a small bench lathe which has a belt-drive head. The main parts indicated in the illustration are common to most lathes.



Belt Drive Metal Lathe

The photograph on the right shows a typical geared head bench lathe.

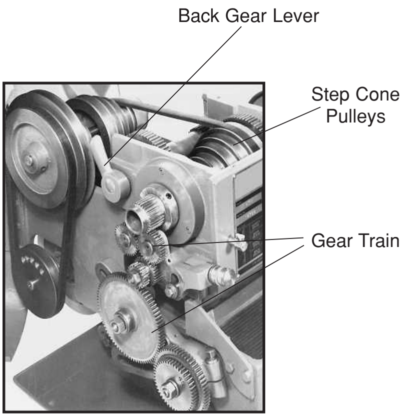
Except for the drive mechanism, the main parts of the geared head lathe are basically the same as the belt driven lathe.



Geared Head Lathe

The Headstock

The headstock is positioned at the left hand end of the lathe bed and can be of the cone pulley or fully geared type. The main spindle (shaft) is mounted in bearings in the headstock. These bearings must be capable of withstanding the heavy loads imposed by the turning operations and also capable of maintaining the accuracy required in the finished job.

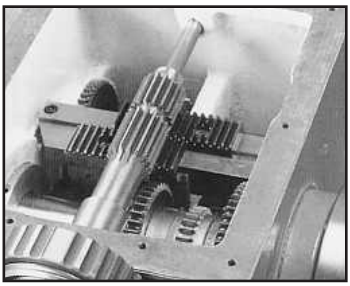


Belt Drive Head

Belt Drive: On a belt driven lathe spindle speed is changed by shifting the belt to a different pair of pulleys. Belt driven lathes also have a reduction unit in the headstock assembly.

This reduction unit is called *back gear* which is engaged for knurling operations where a very slow turning speed is required.

Back gear is engaged using the back gear lever shown in the upper illustration on the left which also shows the step cone pulleys, drive belt and the gear train which connects the headstock spindle to the lead screw.



Geared Head

Geared Head: On most geared head lathes spindle speeds are selected by simply moving gear levers.

The lower illustration on the left shows a simple configuration of gears in a geared headstock. This arrangement allows a number of different gear ratios to be selected providing a range of spindle speeds.

The Tailstock

The tailstock is comprised of two castings. One rests on the ways and may be clamped to the bed in any position to accommodate work of varying lengths. The tailstock spindle or quill is housed in the upper casting which has a sideways adjustment. The tailstock spindle is bored to a standard morse taper to take centres, drill chucks and other attachments.

The Carriage

The carriage is the part of the lathe that supports and controls the movement of the cutting tool. The carriage is comprised of the saddle which fits over and slides on the ways of the lathe and the apron which is fastened to the saddle and hangs in front of the lathe bed. The apron carries the handwheel mechanism for hand feed as well as the mechanisms for engaging automatic feed and the lead screw.

A dovetail way machined in the saddle at 90° to the axis of the lathe carries the cross slide which allows cross feed of the cutting tool. The cross slide is operated by a handwheel and is fitted with a graduated collar so the depth of the cut can be accurately read. When parallel turning, a movement of 1mm in the cross slide will reduce the turned diameter of the work by 2mm.

The Compound Slide

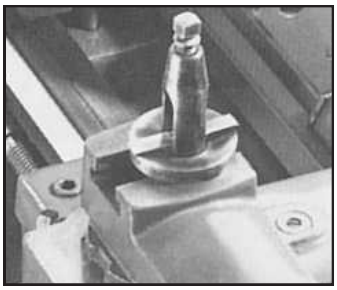
The compound slide rest is mounted on top of the cross slide and has a swivel base that can move through 360°. The base can be locked in any position denoted by graduations from 0° to 180°. A dovetail way allows the compound slide which holds the tool post to be moved by a screw feed. The compound slide is also fitted with a graduated collar to control the depth of the cut when facing the work.

Tool Posts

The tool post is a device for firmly clamping the cutting tool or tool holder on to the lathe.

The tool post is fitted to the top of the compound slide.

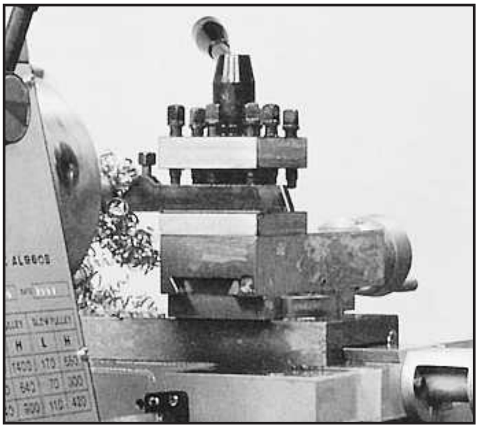
The photograph on the right shows a standard tool post. Standard tool posts are sometimes called American style tool posts.



Standard Tool Post

The photograph on the right shows a square tool post with a cutting tool and tool holder mounted. The square tool post is capable of holding multiple lathe tools.

The main advantage of the square tool post is that they can be quickly rotated into a new position when it is necessary to change the tool for the next stage of the work.



Square Tool Post

Centres

The headstock and tailstock spindles are bored out to a standard morse taper to receive the headstock and tailstock centres whose shanks are also morse tapers. The points are turned or ground to an angle of 60° to fit the countersink section of a centre drill. Plain and live centres are illustrated below.

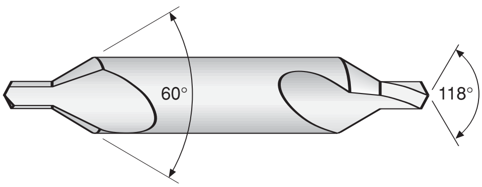
Plain Centre

Live Centre

Plain centres can be used in both the headstock and tailstock. A plain centre used in the tailstock is often called a dead centre because it does not rotate. The bearing surface of a dead centre must be hardened and well lubricated to resist wear.

Live centres are used in the tailstock and are constructed with ball or roller bearings which enable the point of the centre to rotate with the work.

Centre drills are used to bore the end of the workpiece to provide an accurate bearing surface for the centre.



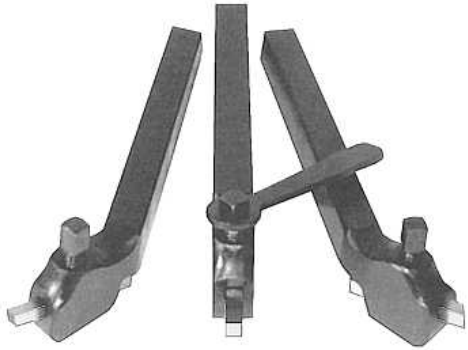
Centre Drill

Tool Holders

Tool holders for high speed steel cutting tools are available in straight, right hand and left hand styles as illustrated on the right.

The left hand tool holder is used when machining is required close to the headstock.

The straight tool holder is used for general purpose machining and for screw cutting on the lathe.



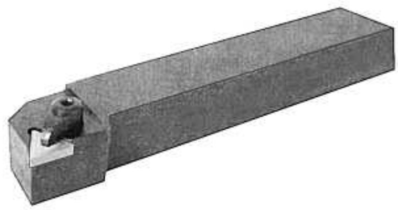
Left Hand Straight Right Hand

Tool Holders

The right hand tool holder is usually used for facing operations and for turning work close to the tailstock.

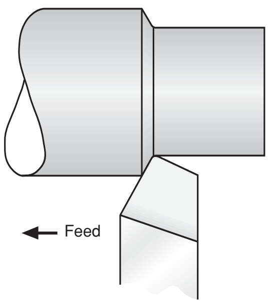
There are numerous other types of tool holders for special turning operations such as parting and a range of indexable tip holders which are used to hold tungsten carbide turning inserts or tips. Typical examples are illustrated below.

Parting Tool And Holder



Indexable Tip And Holder

High Speed Steel Cutting Tools



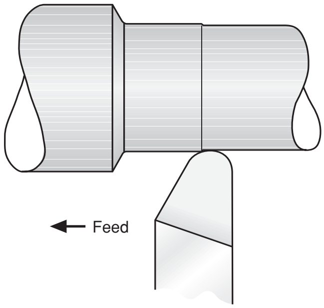
Rough Turning Tool

Lathe tools may be described as right or left hand according to the direction of travel when making a cut. Right hand turning tools are fed from right to left and left hand tools are fed from left to right.

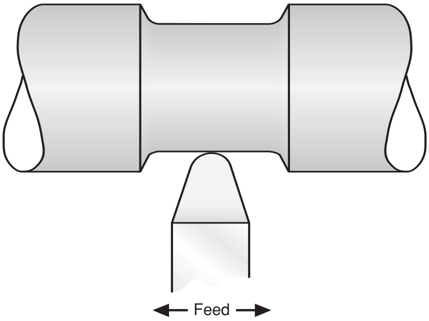
Some general purpose tools are ground to cut efficiently in either direction.

Rough turning tools, as illustrated on the left, are used to reduce the work close to the finished size.

Finishing tools are used to reduce the work to the finished size and to provide a good finish. The illustration on the right shows a right hand finishing tool.



Finishing Tool

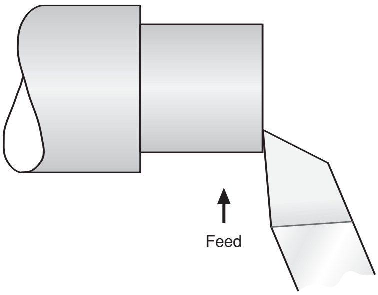


Straight Round Nose Tool

The straight round nose tool shown on the left is a general purpose tool which can make light cuts in either direction. It can also be used as a finishing tool.

The facing tool illustrated on the right is used to square ends of the job or turn shoulders.

The facing tool is usually ground to a reasonably sharp point which is intended to take light cuts only.

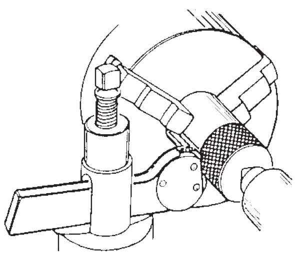


Facing Tool

Knurling Tool

Knurling is not a cutting process. The knurling tool, under pressure, actually displaces metal in the formation of a diamond shape or straight line pattern pressed into the surface of the work. The knurling rollers are cylinders of high grade tool steel which have formed teeth cut in their circumference.
Knurling is performed at very low speed.

Knurling Tool



Knurling

Three Jaw Chuck

The three jaw chuck is self centring. It is constructed so that the three jaws all move together and are always the same distance from the centre.

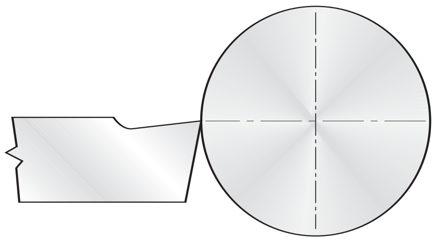
The three jaw self centring chuck is used to hold round and hexagonal work. Chucks that have jaws which can be moved independently are used to hold square and rectangular work.

Three Jaw Self Centring Chuck

Cutting Tool Position

All lathe tools should be positioned with the cutting edge at the same height as the centre line of the lathe, as shown in the illustration on the right.

When a square tool post is being used, the lathe tool can be adjusted to the correct height by placing strips of packing such as thin sheet metal, under the tool holder.



Tool Position - Cutting Edge At Centre

Safety

Students should use the metal lathe only when:

- Permission is granted by the teacher.
- Adequate instruction in the safe and proper use of the machine has been received.

Personal Safety

- Wear a face shield to protect the eyes and face.
- Hair that is long enough to present a safety hazard should be adequately restrained.
- Loose clothing which could be caught in moving parts of the lathe should be removed or fastened.

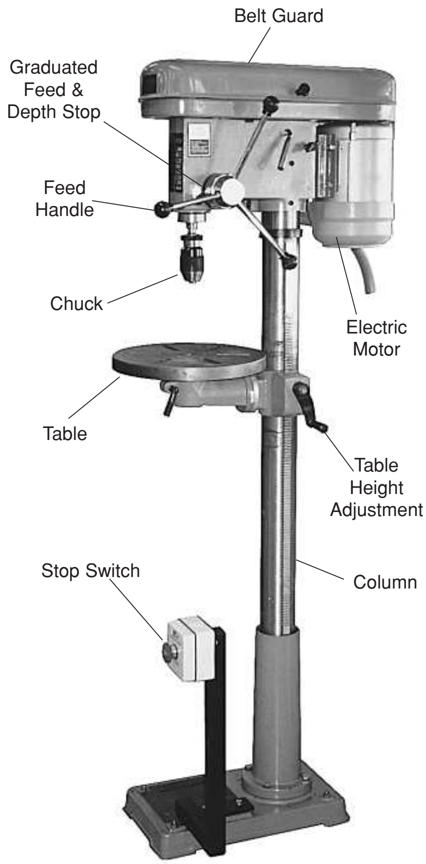
- Do not wear rings, watches, bracelets or other adornments which may come into contact with moving parts.
- When you are operating the metal lathe, make sure you are the only student in the designated work area.

Operating Safety

- Check to see that all guards are in place.
- Remove the chuck key and wrenches immediately after use.
- Make sure that all parts of the carriage and tool holder will clear any rotating part during the full length of the cut.
- Do not leave tools on the saddle or the bed.
- Ensure that the lathe area is free from obstructions.
- Turn the lathe through one complete cycle by hand before starting.
- Never leave the lathe area while the machine is running.
- Keep hands away from swarf (chips or shavings). Use a brush, pliers or piece of wood as applicable.
- Make adjustments, take measurements and clean the lathe only when it is stationary.
- Cuts that are close to the chuck or a shoulder should be finished by hand.
- Do not reset a tool while the lathe is in motion.
- Never put your finger in a bore, or on any other surface of the workpiece to feel the finish while the lathe is in motion.
- Always remove burrs from the workpiece.
- Remove the tool holder and the tool post before filing or polishing. Make sure that emery cloth used for polishing is shorter than the circumference of the workpiece.
- Never use compressed air to clean the lathe.
- Never use rags or cotton waste near rotating machinery.
- Dispose of rags or waste containing metal shavings into appropriate waste bins.
- Hold only regular hexagonal and cylindrical material in a three jaw self centring chuck.

THE DRILLING MACHINE

The photograph on the right shows the major parts of a typical drilling machine or drill press.



Column Drill

The Drilling Process

Drilling is the process of machining round holes in any solid material using end cutting tools called drills.

A typical twist drill is also illustrated on the next page. The drill is held in a chuck similar to the chucks used on portable electric drills and hand drills.

The drilling machine provides the rotary motion and the pressure required to cause the cutting edges of the twist drill to penetrate the material being drilled.

Drill Types

The type shown is a floor mounted, belt driven column drill. A similar machine with a shorter column would be mounted on a bench. Bench drills are sometimes called pedestal drills.

Belt Drive: Drilling machines that are belt driven are fitted with cone pulleys to provide a range of drill speeds from a few hundred revolutions per minute to a few thousand revolutions per minute.

Belts And Pulleys

Speed should be varied according to the work being done and the size of the twist drill being used. Generally a large drill requires a slower speed and a small drill requires a faster speed.

V-belts and pulleys transfer rotary motion and power from the motor to the drill spindle. Drill speeds are varied by changing the position of the belts on the cone pulleys.

A large pulley driving a small one gives a faster speed and a small pulley driving a large one gives a slower speed. The lower photograph on the previous page shows a typical belt and pulley arrangement which provides a range of drill speeds.

Geared Head Drill

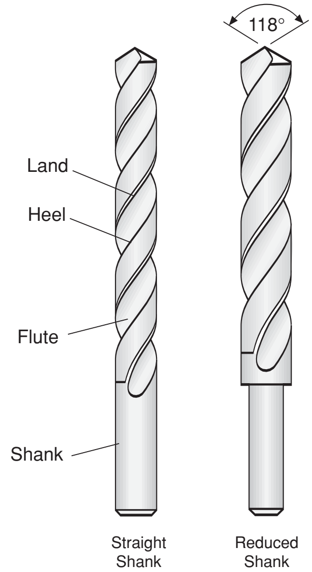
Geared head drilling machines usually have a motor mounted directly on a gearbox which provides the range of drill speeds. Speeds are changed by moving gear levers on the side of the gearbox.

A typical geared head column drill is shown in the photograph on the right. Apart from the drive mechanism, the construction and usage of this drill is similar to the belt driven machine shown on the previous page.

Twist Drills

Twist drills are usually made from high carbon steel or high speed steel. Good quality twist drills will usually be stamped HS for 'high speed' indicating that they are made from high speed steel.

The shank of the twist drill is the part which is held in the chuck. Straight shank drills are the ones most commonly used while reduced shank drills enable larger sizes to be fitted in a standard chuck.



Twist Drills

Flutes are the spiral grooves in the twist drill which provide a channel for the outlet of the waste.

The lands are the precision ground surfaces on the leading edges of the flutes. The lands have a slightly larger diameter than the diameter of the body clearance surfaces.

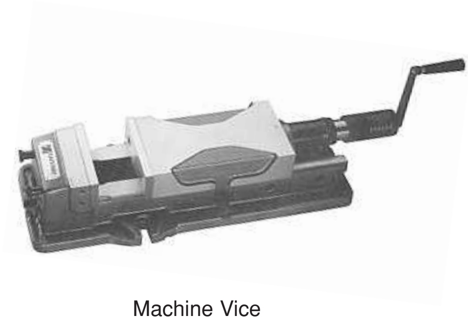
The heel is the trailing edge of the body clearance surface.

The point angle of a high speed twist drill is usually ground to 118°. This is satisfactory for most drilling operations. The point angle is sometimes reduced for softer materials.

Work Holding

A machine vice is generally used to hold flat work. A modern mechanical-hydraulic machine vice is shown on the right.

When used with small drills and where a great deal of accuracy is not required, the machine vice may be held by hand.

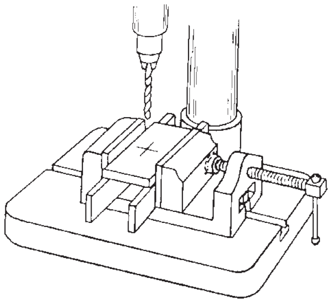


Machine Vice

Where very accurate drilling is necessary the machine vice should be bolted to the drilling machine table.

Parallel packing strips should be used to ensure that the drill does not damage the machine vice.

The illustration on the left shows a mechanical machine vice bolted to the drilling machine table with packing strips supporting the work.



Machine Vice Bolted To The Drilling Machine Table

A hand vice or vice grip pliers should always be used when drilling short pieces of thin material.

Holding short pieces of material in the hand can lead to serious injury if the drill sticks and causes the operator's grip to release allowing the work to rotate at a very fast speed with the twist drill.

When work is gripped by a hand held device it should generally be supported by a piece of wood on the drilling machine table.

Safety

Students should use the drilling machine only when:

• Permission is granted by the teacher.

• Adequate instruction in the safe and proper use of the machine has been received.

Personal Safety

- Wear a face shield to protect the eyes and face.
- Hair that is long enough to present a safety hazard should be adequately restrained.
- Loose clothing which could be caught in moving parts of the drilling machine should be removed or fastened.
- Do not wear rings, watches, bracelets or other adornments which may come into contact with moving parts.
- When you are operating the machine, make sure you are the only student inside the designated work area.

Operating Safety

- Secure the work adequately. Your teacher will advise you whether the job can be safely hand held or if a hand vice, machine vice or other clamping device should be used.
- Ensure that the job is set up so the drill will pass between packing strips, penetrate a wood support block or pass through a hole in the table without damaging the equipment.
- Check that the drill is correctly fitted in the drill chuck. Ensure that the chuck key teeth are fully engaged when fitting or removing twist drills.
- Make sure all guards are in place.
- Keep your hands clear of the drill and the swarf.
- Do not attempt to remove swarf with your hands. Use a brush or, in the case of swarf that is stuck in the flutes of a drill, a pair of pliers.
- Always stop the machine before making adjustments.
- If clamped work becomes loose or if the job is seized by the twist drill and spins, step away immediately and switch the machine off. Keep hands clear of all moving parts.
- Do not leave the key in the drill chuck.
- When the drilling operation is complete, turn off the isolating switch and sweep down the table and drill bench with a brush.
- Leave the drill in a tidy and safe condition. Replace the drill in the drill stand.

METALWORKING

SEAMS AND EDGES

Edge Treatment

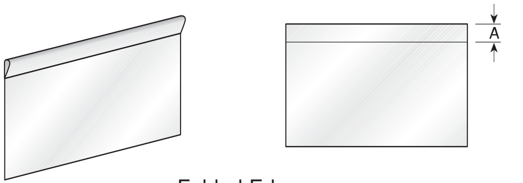
Sheet metal projects often require edge treatment:

- For decorative purposes
- To make edges stronger
- To make edges safe to handle.

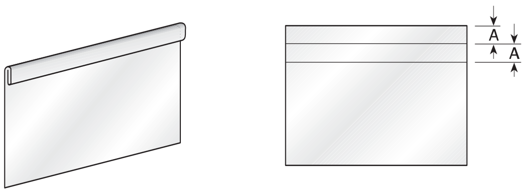
Common edge treatments used in basic sheet metalwork are:

- The folded edge
- The double folded edge
- The wired edge.

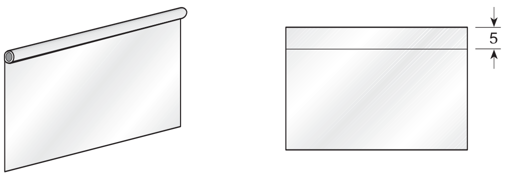
These edge treatments are shown in the pictorial sketches and pattern developments on the right. The illustrations show necessary allowances. The allowance (A) for a folded edge is the width of the edge. The allowance for a wired edge using 2mm (14g) wire is 5mm.



Folded Edge



Double Folded Edge



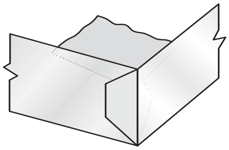
Wired Edge

Seams

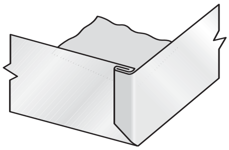
Depending on the basic design, sheet metal projects usually require some form of overlap to hold joins together. The most common seams used in basic sheet metalwork are:

- The lap seam
- The folded seam
- The grooved seam.

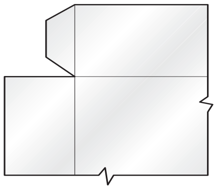
These seams are illustrated in the pictorial sketches and simple developments below. Folded seams will hold themselves together but lap seams require fixing with rivets, solder or adhesive.

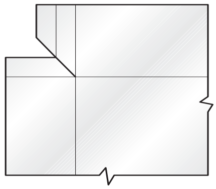


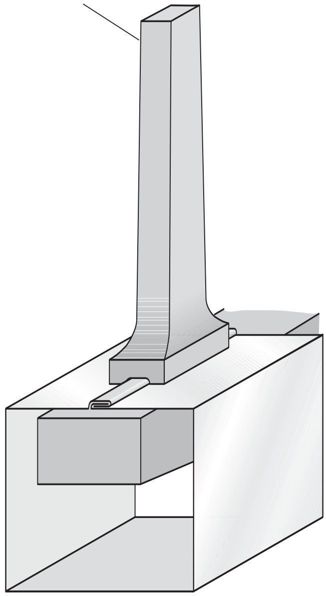
Lap Seam



Folded Seam





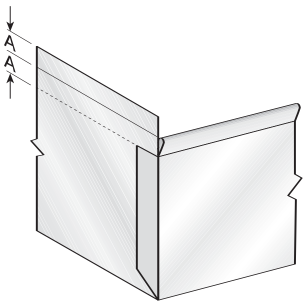


Grooved Seam

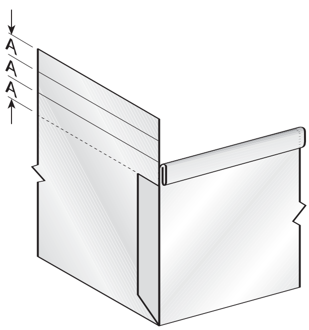
The grooved seam is similar to the folded seam in that the development requires a single allowance and a double allowance. The allowances are folded over, hooked together and the seam is formed using a special tool called a groover, as shown in the illustration on the right.

Notching

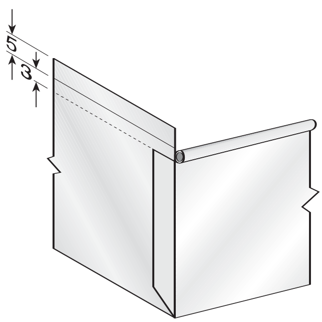
When a sheet metal project has seams *and* edges the development must allow for both to fit neatly together without overlapping. The illustrations which follow show typical notching (the part of the seam cut away to allow for the edge.)



Folded Edge



Double Folded Edge



Wired Edge

JOINING WITH RIVETS AND SCREWS

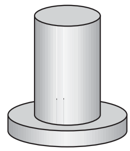
The three types of rivets commonly used to join sheet metals and light metal sections in basic metalwork projects are the tinman's rivet, the solid rivet and the blind rivet which is commonly called a pop rivet.

The Tinman's Rivet

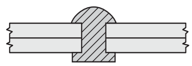
The tinman's rivet is a short galvanised rivet with a flat head used mainly for joining thin sheet metals such as tinplate and galvabond. The hole for the rivet may be punched with a solid punch into the end grain of a block of wood or punched by the rivet itself by drawing the rivet through the metal with a rivet set.

Waste material punched out of the metal is forced into the hole in the face of the rivet set and is eventually ejected from the hole in the side of the rivet set.

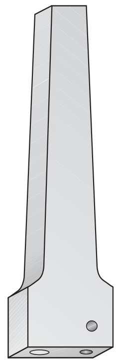
The shallow hole in the face of the rivet set is used for doming the tail of the tinman's rivet as shown in the illustration on the right.



Tinman's Rivet



Finished Rivet



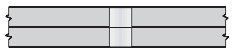
Rivet Set

The Solid Rivet

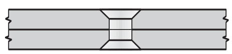
Solid rivets are available with a variety of shaped heads. The tails of these rivets would be domed in a similar fashion to the tinman's rivet. Most metal projects undertaken in the school workshop require flush rivets where this method is used to join light metal sections.

The illustrations on the right show the four stages of the solid rivetting process using round steel rivet material.

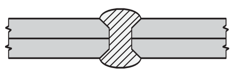
- Drill the rivet hole with a twist drill just large enough for the rivet to enter neatly.
- Countersink both sides.
- Burr the ends of the solid rivet until the rivet material is compacted into the countersinks.
- File off the waste material.



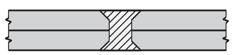
Drill Hole



Countersink



Burr Rivet

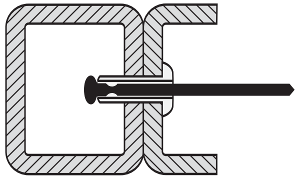


File Flush

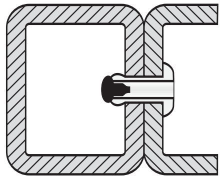
The Blind Rivet

Blind rivets or pop rivets are used when:

- It is not possible to support the rivet and fix it at the same time.
- When only one side of the material being rivetted is accessible.



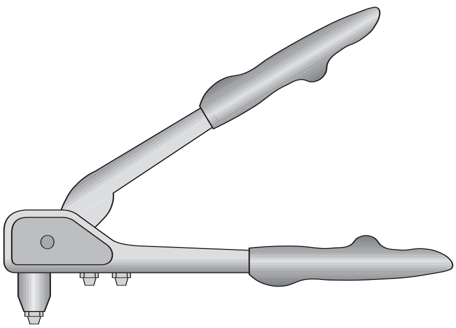
Blind Rivet Inserted



Blind Rivet Fastened

The pop rivet is placed in a drilled hole and the wire mandrel through the centre of the rivet is gripped by special pliers and pulled through.

The head of the wire mandrel spreads the tail of the rivet clamping the materials together firmly. The mandrel snaps when sufficient pressure is applied leaving the parts rivetted together.



Blind Rivet Plier
(Pop Riveter)

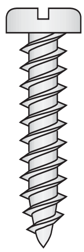
The illustrations above show how the tail of the blind rivet spreads when pressure is applied.

A basic blind rivet plier or pop riveter is illustrated on the left. Interchangeable tips allow the plier to be used for a range of rivet sizes.

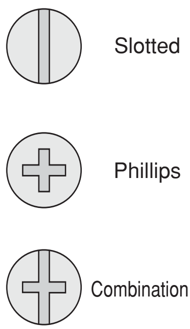
Self Tapping Screws

Self tappers are hardened screws often used in the assembly of sheet metal components. These screws cut their own thread in a hole drilled to the core size of the screw.

Their main advantage over rivets as a fixing system is that self tapping screws allow the parts to be separated when necessary. A typical pan head self tapping screw is shown on the right with the main slot types that are available.



Self Tapping Screw



SOFT SOLDERING

Solder

Soft solder is usually an alloy of the metals tin and lead but varies in composition depending on its use. It is made in stick form and is usually measured by weight.

For fine work solder is also made in wire form. Sometimes this wire has a core of flux (usually non-corrosive resin) and is most suited to electrical work.

The most common types of soft solder are listed in the table on the right.

Type	Tin %	Lead %	Melting Point °C
Plumber's Solder	40	60	210
Common Solder	50	50	190
Tinman's Solder	60	40	185

Fluxes

Unless metal is perfectly clean the solder will not adhere to it. All metals will oxidise when in contact with the air and these oxides are the main problem when soldering.

A flux is used to:

- Remove the oxide film.
- Prevent re-oxidisation while soldering.
- Reduce surface tension of the molten solder and so help it flow.
- Help the solder adhere.

Flux	Metals
Zinc Chloride (Killed Spirits)	Tin, tinplate, mild steel, copper, brass
Hydrochloric Acid (Spirits Of Salts)	Zinc, galvanised iron, wire
Commercial Soldering Fluids	Most metals listed above

Common fluxes and some of the metals that can be soldered with them are listed in the table above.

The Soldering Bit

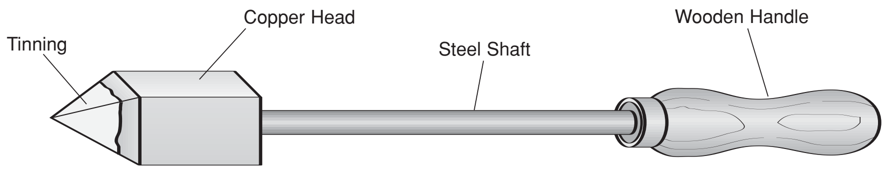
The soldering bit (commonly called soldering 'iron') has a copper head, steel shaft and a wooden handle.

Copper is used in the head because of its good thermal conductivity. It will heat quickly and then distribute the heat quickly and evenly.

Before a soldering bit can be used the point must be 'tinned'. This means the point has to be coated with a thin layer of solder which enables the bit to pick up and then distribute the solder to the job.

Procedure for tinning a soldering bit is as follows:

- Heat the soldering iron
- File the shape required, removing badly oxidised areas.
- Reheat the bit.
- Clean in dip pot solution (usually dilute flux).
- Roll in solder (with flux) until solder adheres to the point of the bit.



Soldering Bit

The Soldering Process

The key factors in successful soft soldering are:

- Heat
- Cleanliness

The bit and the metal to be soldered must be perfectly cleaned by using dip solution (dilute flux) to clean the bit and flux to clean the metal. The heat which is applied by the soldering bit is the harder factor to control. The area of metal where the solder is required must be heated to a temperature in excess of the melting point of the solder so that the solder can flow.

The soldering bit should be moved slowly along the seam allowing the metal to heat sufficiently. All flux must be washed from the job to prevent corrosive action from chemicals in the flux solution.

ART METALWORK

Art metalwork can take many forms. Some of the common ones practised in school workshops are briefly described below.

Copper Tooling

Copper tooling is the process of forming raised patterns and pictures in sheets of thin copper foil. The copper is usually annealed to a very soft state so that it can be easily worked.

A design is traced or drawn on the copper foil (usually with a ballpoint pen) and then shaped out with tooling sticks. These simple tools can be made from wooden dowel or similar material.

The thin copper foil can be easily stretched and formed to provide the three dimensional effect required. The hollows on the back of the finished work are usually filled with plaster of Paris or plastic putty.

Chasing and Matting

Chasing is the process of decorating the surface of art metal by forming patterns and designs with special shaped punches and chisels. The chisels are used to chase around outlines, corners, etc. The punches can provide a variety of textured surfaces to decorate the work.

Matting is similar to chasing but is done with special tools with patterned faces to provide the texture required.

Planishing

Planishing can produce quite smooth surfaces using a special planishing hammer and a specially shaped stake. Planishing stakes can vary in shape and size and planishing hammers are usually slightly round faced and very smooth. Planishing will work harden the metal which may be necessary to stiffen the job in the last shaping operation.

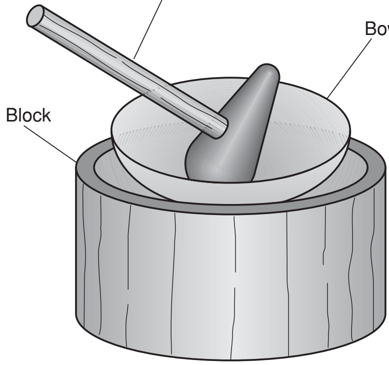
Beating

Beating the surface of art metal with a ball pein hammer can produce a very attractive finish but care must be taken to avoid thinning the metal too much. Beating will also work harden the metal quickly.

Dishing or Hollowing

Dishing or hollowing involves the formation of bowl shapes in soft art metals such as brass, aluminium and copper.

A dishing block and bossing mallet are used as shown in the illustration on the right.



Dishing

The best technique is to work gradually around the circumference of the piece of art metal using overlapping strokes of the bossing mallet.

Uneven areas should be smoothed out by working lightly and the surface could be finished by beating or planishing.

The metal will work harden very quickly and may have to be annealed several times before the job is complete.

DECORATIVE SURFACE FINISHING

Metal surfaces sometimes require further work after procedures such as cutting, grinding or filing, particularly where a decorative finish is required on the project.

Sheet Abrasives

Sheet abrasives are generally used to further smooth the metal surface after fine filing. Sheet abrasives consist of an abrasive grit bonded to a cloth or paper backing.

Emery cloth can be wrapped around a file to enable even pressure to be applied when rubbing the metal surface. A light lubricating oil used on the surface can often improve the finish.

The most common grits used in the manufacture of sheet abrasive materials are silicon carbide and aluminium oxide.

Silicon Carbide

Silicon carbide is manufactured from coke and sand fused together in a furnace and then ground into small particles. It is a shiny black synthetic abrasive which is brittle and fractures into sharp wedge-shaped slivers. It is very hard and is generally used on waterproof (wet-and-dry) abrasive papers.

Aluminium Oxide

Aluminium oxide is manufactured from bauxite, iron filings and coke fused together in a furnace and then ground. It is usually a grey-brown colour, extremely tough and resistant to normal wear.

Grading Of Abrasive Grit

After crushing and grinding, abrasive materials are sieved through accurately woven silk screens. The size of the mesh is determined by the number of openings per given area and this in turn determines the grade of the abrasive. The more openings per given area the finer the grit and the larger the number used to describe the grade.

Pickling

When metal such as copper has been exposed to the elements or heated, a film of oxide forms on the surface. This film can be removed by placing the metal into a bath of some chemical agent that will react with and remove the oxide, exposing the true natural colour of the metal.

Dilute nitric or sulphuric acids are used in industry but these are quite dangerous to handle. A safe and convenient pickling solution for copper can be made by dissolving salt in vinegar until the vinegar is saturated, which means it cannot absorb any more salt.

Polishing

After pickling, filing or rubbing with fine abrasives, metal surfaces can generally be highly polished using polishes such as ‘Brasso’, ‘Silvo’ or other liquid metal polishes that are available. Fine abrasive powder polishes are also available. Care must be taken to clean all traces of polish from the surface before coating with lacquer or paint.

Lacquering

Lacquer is usually sprayed on art metalwork projects after polishing to prevent tarnishing and to maintain the natural colour of the metal and polished finish. A coat of lacquer seals the metal surface off from the air thus preventing the surface oxidising.

Electroplating

Electroplating is the process of coating the surface of one metal with another metal. This process is described in the sections of this text which relate to galvanising and to refining of copper.

Anodising

Anodising is the process of thickening the oxide layer on the surface of aluminium using an electric current which is passed through a chemical solution. The thickened oxide layer provides a barrier to further corrosion.

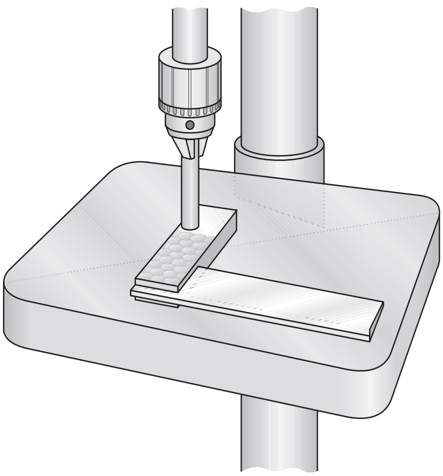
This protective layer is often coloured with special dyes to provide an attractive finish such as on aluminium saucepan or canister lids.

Fish Scaling

A metal surface can be decorated with an attractive pattern which resembles scales on a fish.

The pattern is produced on the surface of the metal by using a short length of wooden dowel in the chuck of the drill press.

An abrasive powder is sprinkled on the metal surface. When the drill is switched on and the dowel is brought into contact with the metal surface the end of the dowel picks up abrasive particles.



Fish Scaling

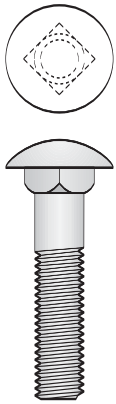
The circular motion of the dowel causes the abrasive grit to scratch a pattern on the metal surface. Overlapping of the circular pattern can produce a fish scale effect.

BASIC MECHANICS

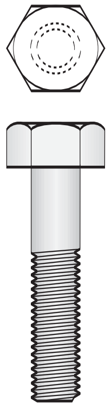
BOLTS

Cup Head Bolts

Cup head bolts are generally used to fasten timber members together or to fix plates and fittings to timber. The square section at the base of the head is driven into the wood to prevent the bolt from turning when the nut is being tightened.



Cup Head Bolt



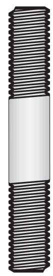
Hexagonal Head Bolt

Hexagonal Head Bolts

These are general purpose bolts used for a wide range of applications in all mechanical and structural trades and industries and are available in mild steel or high tensile steel for automotive and structural work.

Engineers Studs

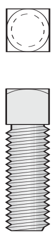
Engineers studs are used when a part is to be fixed to a surface, the reverse side of which is inaccessible preventing a bolt and nut from being used. One end is drilled and tapped into the surface, the stud is then screwed in and the part secured with a nut.



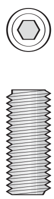
Engineers Stud

Set Screws

Set screws are used for securing pulleys to shafts or for coupling parts together. A spanner is used to tighten the square head set screw. An Allen key is used to tighten the Allen head set screw and a screw driver is used to tighten the grub screw.



Square Head



Allen Head

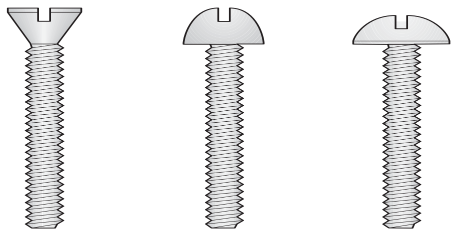
Grub Screw

There are many other types of bolts and machine screws used in industry. Some of them take their name from the shape of the head and some from the purpose for which they are used.

Metalthreads

Metalthreads are general purpose machine type screws that are used in a variety of metalworking applications.

Countersunk metalthreads are used where the head is to be flush with the surface.



Countersunk   Round Head   Roofing Bolt

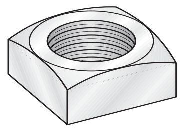
Round head metalthreads are generally used for fixing materials that are too thin to countersink.

Roofing bolts have a larger, flatter head than round head metalthreads and are used to fix thin sheet metals as well as for general applications.

NUTS

Square Nut

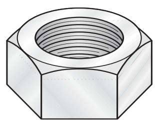
Square nuts are general purpose nuts often used on cup head bolts as well as other applications.



Square Nut

Hexagonal Nut

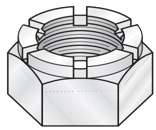
Hexagonal nuts are general purpose nuts used in the majority of engineering and mechanical applications. Both open end and ring type spanners can be used on a hexagonal nut.



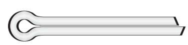
Hexagonal Nut

Castle Nut

Castle nuts feature a raised up section which is slotted to receive a cotter pin. The illustration on the right shows a castle nut and cotter pin.



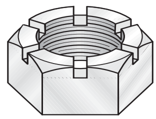
Castle Nut



Cotter Pin

Slotted Nut

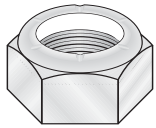
Slotted nuts are simply hexagonal nuts slotted to take a cotter pin. They are used in the same way as castle nuts.



Slotted Nut

Self Locking Nut

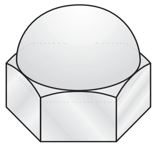
Self locking nuts have nylon or fibre inserts which lock the nut when the thread of the bolt cuts its way into the softer material.



Self Locking Nut

Dome Nut

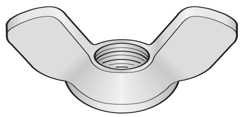
Dome nuts or acorn nuts are used when it is necessary to cover the end of the bolt to improve appearance.



Dome Nut

Wing Nut

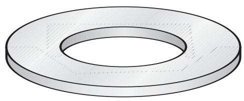
Wing nuts are used in situations where hand tightening is required.



Wing Nut

Flat Washer

Flat washers or plain washers provide a seat for a nut or a bolt head. These washers are often used as packing or spacers.



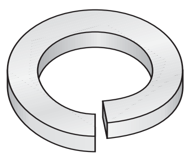
Flat Washer

LOCKING DEVICES

Vibration and movement can sometimes loosen a nut. Locking devices are used to prevent nuts from working loose.

Spring Washer

These are split washers, made from spring steel. Spring washers are twisted so they compress and place pressure back on the nut when it is tightened down. The split ends may also bite into the nut as it tends to loosen.

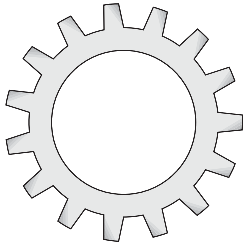


Spring Washer

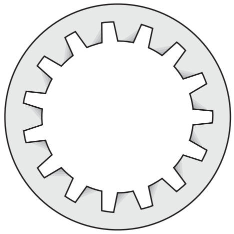
Tooth Lock Washers

Both external and internal tooth lock washers have twisted teeth which act in the same way as the spring washer.

There are several different types of tooth lock washers available, some of which are called star washers.



External Tooth Lock Washer



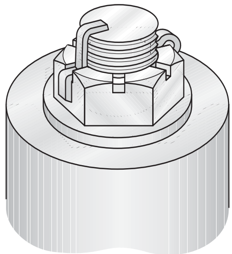
Internal Tooth Lock Washer

Cotter Pin

The illustration on the right shows a cotter pin fitted to a slotted hexagonal nut.

The cotter pin is fitted through a hole in the bolt or shaft.

The slot in the nut holds the cotter pin and prevents the nut from turning and becoming loose.

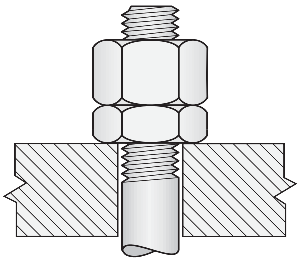


Cotter Pin

The Lock Nut

Lock nuts are often thinner than standard nuts as shown in the illustration on the right. However, it is quite common to use a standard nut as a lock nut.

The locking action is caused by tightening one nut against the other.



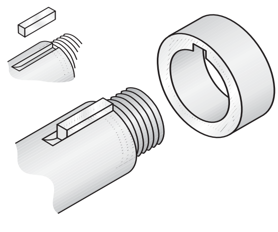
Lock Nut

Keys

Keys are used to secure components such as gears and pulleys to a shaft or spindle.

Keys are usually made from steel and are fitted with precision into grooves called keyways.

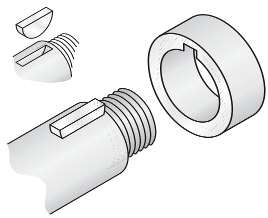
The illustration on the right shows a typical square key and its keyway.



Square Key

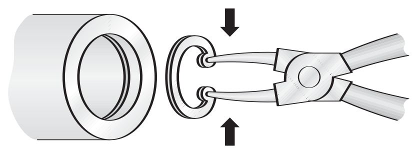
The illustration on the right shows a woodruff key and its keyway. The keyway is cut on a milling machine with a special circular cutter.

The woodruff key provides greater resistance against the thrust of the part on the shaft because it fits into a deeper groove due to its almost semi-circular shape.

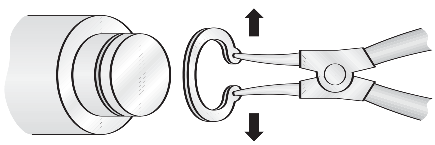

Woodruff Key

Circlips

Circlips are spring steel rings which fit into grooves, usually in shafts or spindles and are designed to prevent the part being held from coming off the shaft.


Internal Circlip

Internal circlips fit into grooves cut into the inside of holes and expand in diameter when placed in their grooves.


External Circlip

External circlips fit into grooves cut on the outside of a shaft and they contract in diameter when placed in their grooves.

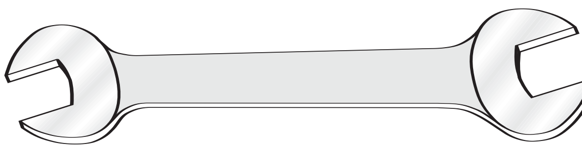
The illustrations of internal and external circlips above, show special circlip pliers which are used to expand or contract circlips when they are being fitted into their grooves or being removed.

SPANNERS

Spanners are used in the workshop for a variety of purposes such as assembly of components and setting or adjusting tools and machines. The most appropriate spanner should always be selected for a particular job. It should fit the nut perfectly and allow the job to be done quickly and efficiently.

Open End Spanner

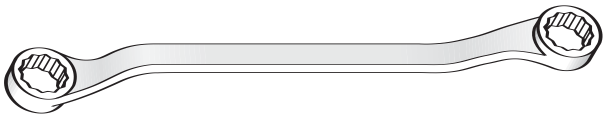
Open end spanners have a U-shaped opening at each end. The opening fits neatly across the opposite


Open End Spanner

flats of the nut or bolt head whose size is stamped on that end of the spanner. Open end spanners usually have a different size at each end.

Ring Spanner

The ring spanner has sockets at each end which grip all faces of a hexagonal nut.

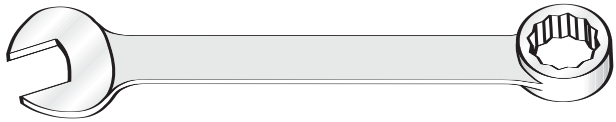


Ring Spanner

The ring spanner is useful in confined spaces where a full swing is not possible. Most ring spanners have a different size at each end.

Combination Spanner

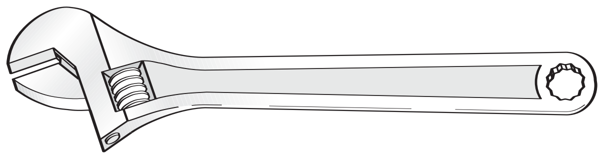
The combination spanner has a socket at one end and an open end spanner at the other. Each end of the combination spanner fits the same size nut.



Combination Spanner

Adjustable Spanner

The adjustable spanner is often called a shifting spanner or sometimes a crescent spanner.



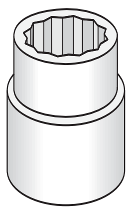
Adjustable Spanner

It has a movable jaw which can be adjusted to fit a range of sizes. Where available, a fixed spanner should generally be used in preference to an adjustable spanner because there is less chance of damaging the nut.

Sockets

Sockets, or socket spanners fit all faces of a hexagonal nut or bolt head. They are usually purchased in sets which contain a range of sizes.

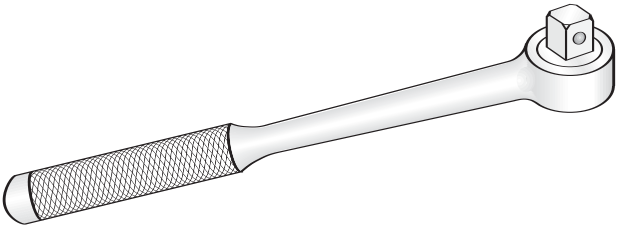
Sockets are used in conjunction with a variety of handles and extensions.



Socket

Ratchet Handle

Ratchet handles, or wrenches, are used in conjunction with sockets to provide the quickest action of all hand operated spanners.



Ratchet Handle

The ratchet action allows the operator to rotate the handle forward and backward, tightening or loosening the nut without having to lift or reposition the spanner.

LEVERS

The principle of the lever is used in many different types of machines from the most complex industrial equipment to the simple pair of pliers.

The most common mechanical application of the lever principle is to move loads or perform work far in excess of the effort applied. This implies that there is an advantage gained by the use of such a machine. This advantage is usually called the mechanical advantage.

Mechanical Advantage

The mechanical advantage is found by dividing the resistance overcome by the force exerted and be can expressed as a ratio. For example, if a load (resistance) of 100kg can be moved by an applied effort of 10kg the mechanical advantage can be calculated as shown below:

$$\text{Mechanical Advantage} = \frac{\text{Load}}{\text{Effort}}$$

$$= \frac{100}{10}$$

$$= 10$$

If a lever such as a crow bar is used to move a heavy object it should be placed so that minimum effort is required. The longer the lever used the less effort is required to move the load. Placing the pivot point closer to the load will also reduce the effort required.

Forces

A lever is a rigid bar arranged or used in such a way that it can turn about a pivot point or fulcrum. There are three forces acting in the operation of a lever.

- The effort applied.
- The resistance overcome.
- The reaction which occurs at the fulcrum.

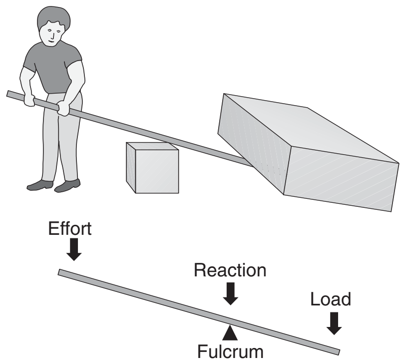
The relationship of these forces will vary according to the type or order of the lever. First, second and third orders are terms used to describe different types of levers.

First Order Levers

A first order lever means the fulcrum or pivot point is somewhere between the effort applied and the load.

In this order the reaction at the fulcrum equals the sum of the load (resistance overcome) and the effort applied.

The illustrations on the right demonstrate this principle. Other examples of first order levers are prising the lid off a paint tin, and operating pliers, tin snips and a see-saw.

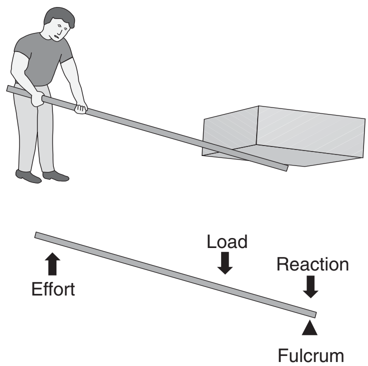


First Order Lever

Second Order Levers

In the second order, the load and effort are on the same side of the fulcrum. The effort required is still less than the load and the reaction at the fulcrum equals the resistance overcome minus the effort applied.

The illustrations on the right show a second order situation. Other examples of second order levers are a wheel barrow and a nut cracker.

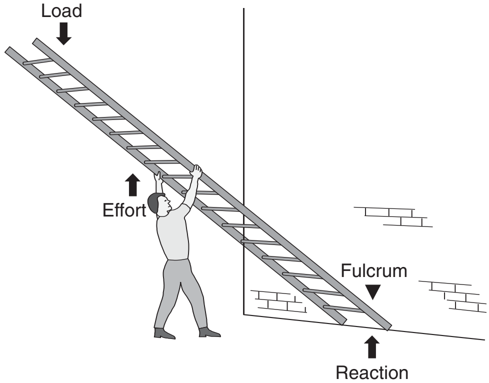


Second Order Lever

Third Order Levers

In the third order the load and effort are located on the same side of the fulcrum but the load is further from the fulcrum than the position of the applied effort. In this case the effort required is greater than the load.

The illustration on the right shows a third order situation where a long ladder is being placed against a wall. Other examples of third order levers are using a hand shovel and the human forearm.

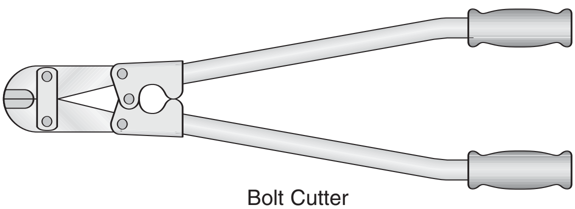


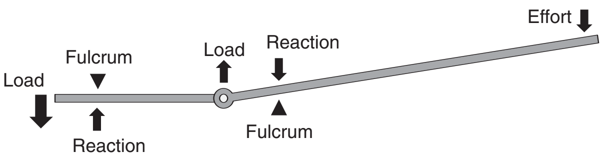
Third Order Lever

Double Action or Compound Levers

Extra mechanical advantage can be gained by coupling levers together so that the mechanical advantage of one lever is used to apply much greater effort to the second lever, therefore enabling the double action lever to overcome a much greater resistance with even less effort.

The bolt cutter shown on the right is a typical example of double action levers. Bolt cutters can cut through steel bars with very little effort.


Bolt Cutter



Double Action Lever

PULLEYS

The Wheel & Axle Principle

The invention of the wheel was a very important event in the history of the development of machines. Some early applications would have been the potter's wheel in cottage industry and wheels for carts and chariots in transport.

The wheel is of little practical value without an axle on which it can rotate. The wheel and axle is therefore considered as a unit in terms of the mechanical principle involved.

The wheel provides rotary motion which is a very important concept incorporated in the design of machines. A mechanical advantage can be gained using the wheel and axle principle. An example would be the steering mechanism of a car or truck.

The steering wheel moves through a greater radius than the shaft which connects the steering wheel to the steering box. Therefore the driver has the advantage that the actual work done is much less than that required to manually move the wheels of a car.

Most machines, particularly those driven by electric motors or internal combustion engines incorporate the wheel and axle principle in the driving mechanism as well as in other mechanical functions of the machine.

Pulleys revolve on a shaft or axle and therefore operate on the wheel and axle principle.

Changing Speed & Direction

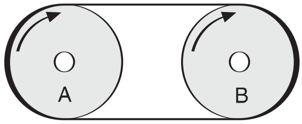
A pulley can be considered as a wheel fixed to a shaft and is used in conjunction with a belt. Belts and pulleys transmit rotary motion and power from one shaft to another, usually placed a reasonable distance apart.

The speed of the driven shaft can be changed by changing the ratio of the pulley diameters. The direction of rotation can by changed by using a different belt arrangement.

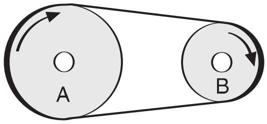
- Pulleys of the same size revolve at the same speed and in the same direction.
- A large pulley driving a smaller one will cause the smaller one to revolve faster than the large one.
- A small pulley driving a larger one will cause the larger pulley to revolve at a slower rate than the smaller one.
- The direction of rotation can be reversed by crossing the belt between the pulleys.
- The ratio of shaft speeds is inversely proportionate to the diameters of the pulleys.

The following diagrams illustrate changes in speed and direction.

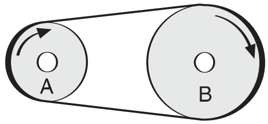
- A - Driver pulley
- B - Driven pulley



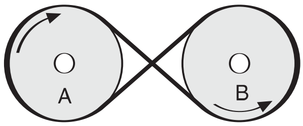
Same Direction
Same Speed



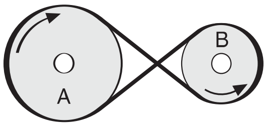
Same Direction
Increased Speed



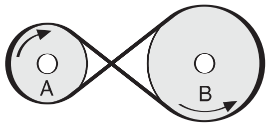
Same Direction
Reduced Speed



Opposite Direction
Same Speed



Opposite Direction
Increased Speed



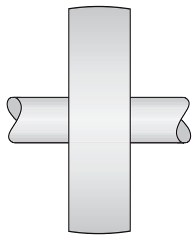
Opposite Direction
Reduced Speed

Belts and pulleys are used in mechanical applications where a slight amount of slipping can be tolerated. In some situations slipping may even be a necessary part of the mechanical operation. The main types of pulleys are listed below.

Flat Pulleys

Flat pulleys are rarely used today with the possible exception of some agricultural machinery. Flat pulleys are in fact slightly rounded to prevent the flat belt from running off.

The illustration on the right shows the rounded face of the 'flat' pulley.



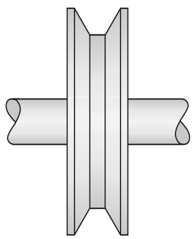
Flat Pulley

V Pulleys

V pulleys or V-belt pulleys are made to suit the shape of a V belt as shown in the illustration on the right.

The V belt tends to slip much less than the flat belt resulting in more positive drive.

The belt grips the pulley on two faces and wedges itself into the pulley as it rotates.



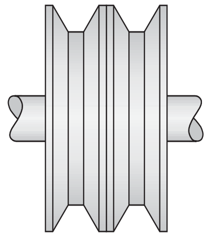
V-Belt Pulley

Double Pulleys

The illustration on the right shows two V-belt pulleys secured to the same shaft.

Double pulleys are sometimes required when the load is too great for a single belt.

Excessive load will cause the belt to stretch or even break. Additional pulleys and belts share the load.



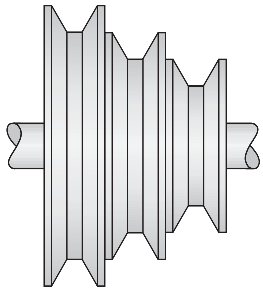
Double Pulleys

Step Cone Pulleys

Step cone pulleys consist of a series of pulleys of different sizes arranged on a shaft with a corresponding set of pulleys on the opposite shaft.

Step cone pulleys are used when the speed of rotation needs to be changed from time to time.

The largest diameter pulley on one shaft is opposite the smallest diameter pulley on the other shaft.



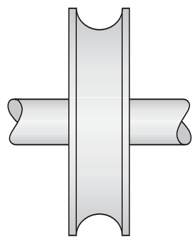
Step Cone Pulleys

Rope Pulleys

Rope pulleys are manufactured with a concave semicircular surface to fit the shape of a rope or circular belt.

Some household appliances have circular belts which run on pulleys of this type.

Rope pulleys are also used in pulley blocks as described below.

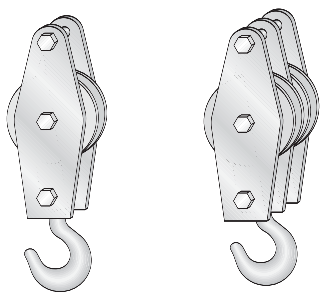


Rope Pulley

Pulley Blocks

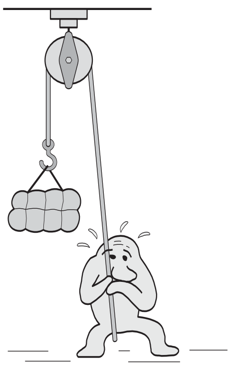
Rope pulleys are often used for lifting loads. The pulleys are generally housed in pulley blocks which can contain one or more pulleys.

The illustrations on the right show single and double sheave pulley blocks.



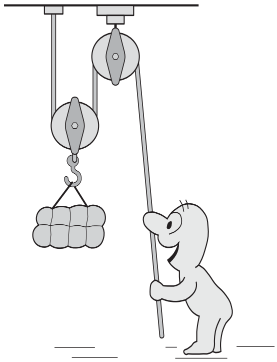
Pulley Blocks

If a single pulley is used to lift a load the only gain is a change of direction. There is no mechanical advantage to make the work easier for the operator.



The illustration on the right shows a cartoon character struggling to lift a heavy load using a single pulley.

If two pulleys are used a mechanical advantage is gained. The illustration below shows the cartoon character lifting the load with much less effort using two pulley blocks.



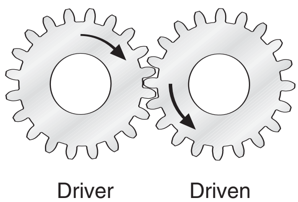
With two pulleys arranged in tandem the load is raised only half the distance when the operator pulls the rope downward. For example, if the rope is pulled down 600mm the load is lifted only 300mm.

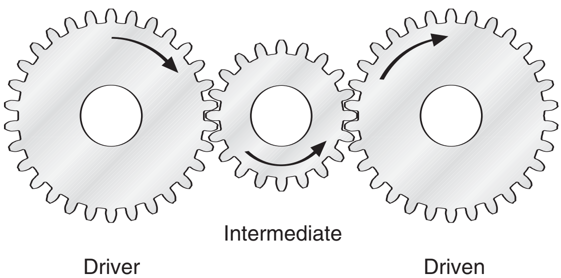
If more than two pulleys are used a greater mechanical advantage is gained but the rate at which the load is raised is substantially reduced.

GEARS

Gears are used to transmit motion and power with positive drive between two shafts a short distance apart. Gears in contact revolve in opposite directions but if shafts are to rotate in the same direction an intermediate gear must be used between the driver gear and the driven gear.

The illustration on the right shows two gears that are in contact. The driver gear is rotating in a clockwise direction. This causes the driven gear to rotate in an anti-clockwise direction.





The illustration on the left shows an intermediate gear placed between the driver and driven gears. The driven gear then rotates in the same direction as the driver gear.

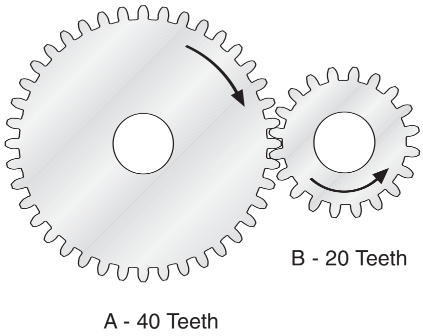
Ratios & Speed

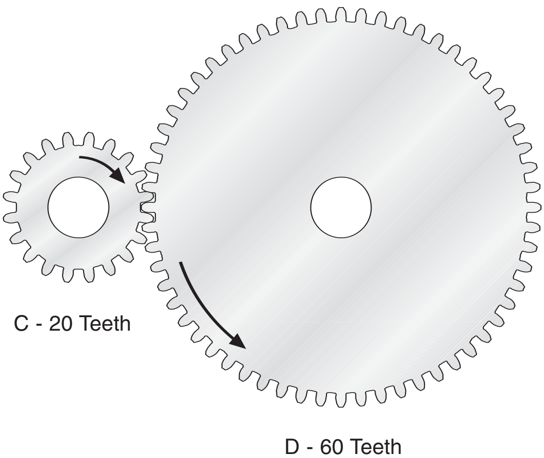
Gears that mesh must have teeth of the same size, irrespective of the diameter of the gear wheel. If the driven gear or shaft is to rotate at twice the speed of the driver, the driver gear must have twice as many teeth as the driven gear. In other words, the ratio of gear speeds is inversely proportionate to the ratio of the number of teeth.

In the illustration on the right driver gear A has 40 teeth and driven gear B has 20 teeth.

Therefore gear B rotates at twice the speed of gear A but in the opposite direction.

For example, if gear A rotates at 250 RPM, gear B will rotate at 500 RPM.





In the illustration on the left the driver gear C has 20 teeth and driven gear D has 60 teeth.

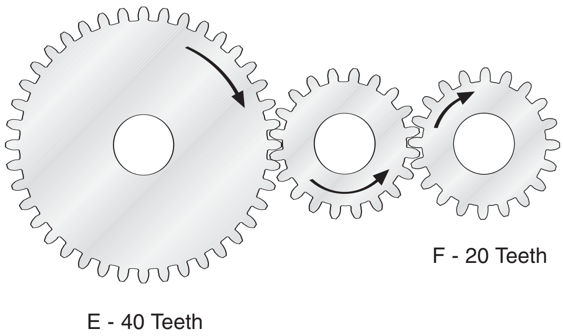
Therefore gear D rotates at one third the speed of gear C but in the opposite direction.

For example, if driver gear C rotates at 600 RPM, driven gear D will rotate at 200 RPM.

Using an intermediate gear to rotate the driven gear in the same direction as the driver gear does not change the ratio of speeds between the driver gear and the driven gear.

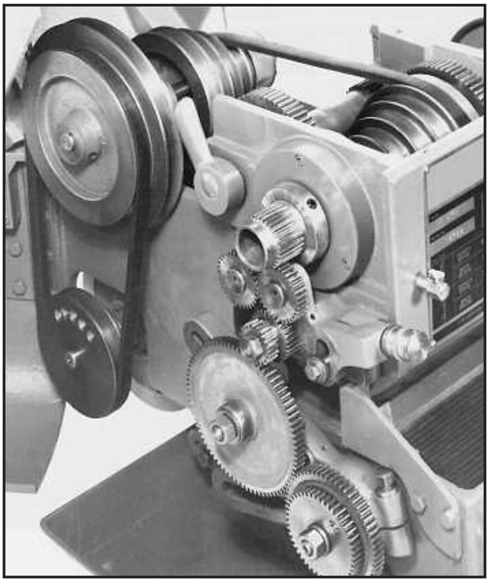
In the illustration on the right the driver gear E has 40 teeth and driven gear F has 20 teeth.

No matter how many teeth in the intermediate gear, driven gear F will still rotate at twice the speed of the driver gear E.



Spur Gears

Spur gears are wheels with teeth that are straight and parallel to the axis of the gear. They are the normal gears for driving parallel shafts. Spur gears have been used for the examples in the previous section which covers gear rotation, gear ratios and speed.



Lathe Drive Mechanisms - Belts, Pulleys & Gears

A typical example of spur gears can be found in the change gears of a belt drive metal lathe. The photograph on the left shows the drive mechanisms of a small metal lathe.

The rotational speed of the lead screw can be changed by fitting a different set of change gears.

The speed of the main shaft or headstock spindle can be changed by shifting the V-belt which drives the spindle, to a pair of pulleys that will give a higher or lower speed.

Other Gears

Many different types of gears are used in the design and manufacture of machines, automobiles and other mechanical devices. For example, bevel gears are used to connect shafts which form an angle to one another, helical gears have teeth which twist around a cylinder and worm gears are used to connect non-intersecting shafts at right angles to each other.

Lubrication

All moving machine parts such as gears must be lubricated. By reducing friction lubrication reduces wear.

No surface is absolutely smooth and when two surfaces are put together there will always be some interlocking between the surfaces.

The introduction of a suitable lubricant such as oil actually separates the surfaces providing oil to surface contact and significantly reducing wear.

ELECTRICITY

A BRIEF HISTORY

- The effects of static electricity had been known since about 600 BC.
- About 1600 AD Dr William Gilbert, Court Physician to Queen Elizabeth I, observed that a force was generated by rubbing an amber rod with wool.

  He noticed that the amber rod was then capable of attracting light objects. The word 'electric' has been derived from the Greek word 'elektron' which means 'amber'.
- In 1752 Benjamin Franklin, when flying a kite in a thunderstorm, discovered that lightning was an electrical discharge.
- During the 19th century many scientists around the world were developing theories and experimenting with electrical energy.

  For example, Volta of Italy made the first cell that produced electricity and Ampere of France developed the science of electromagnetism.
- Michael Faraday, in 1831 discovered that an electrical pulse could be generated by moving a magnet in and out of a coil.

  In 1879 Thomas Edison perfected the first incandescent electric lamp. This was the first major step in taking electricity from the laboratory to the home and factory.

ELECTRON THEORY

No one knows exactly what electricity is. It is weightless, yet it can lift or haul thousands of tonnes of material. It is shapeless yet it is everywhere. We can't see it, yet is produces light. Scientists do know, however, what electricity does and how to harness it.

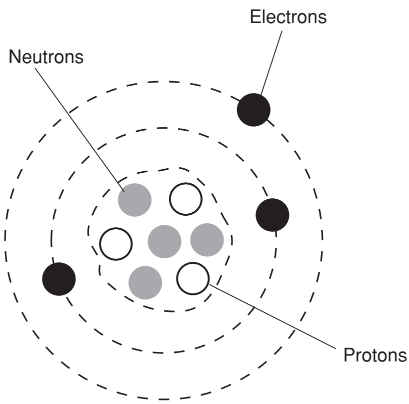
The electron theory, briefly described below, has been developed from observations of the behaviour of electricity and is the basis for most scientific studies in this area.

The Atom

All matter is made up of atoms. Atoms are very small, for example it takes millions of them to make a speck of dust.

The diagram on the right illustrates the structure of an atom comprising the following sub-atomic particles:

- *Electrons* which are negatively charged.
- *Protons* which are positively charged.
- *Neutrons* which are neutral.



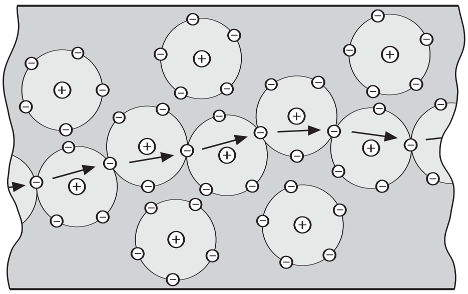
Atom

The negative charge of the electron is equal to the positive charge of the proton. The protons and neutrons form a closely packed group called the nucleus.

If the atom is not disturbed and no electrons are removed from the space around the nucleus, the atom itself is neutral. If electrons have been removed the remaining structure is positively charged and is called a positive ion. A negative ion is an atom which has gained extra electrons.

Electrical Conductors

Matter which contains a relatively large number of free electrons which may be moved from atom to atom is an electrical conductor.


Electron Flow In An Electrical Conductor

Substances in which electrons are not free to move when a moderate force is applied are electrical insulators.

Most of the metals are electrical conductors and most non-metals such as plastics are electrical insulators.

The diagram on the left illustrates a greatly magnified section of an electrical conductor.

Electric Current

Nature acts to restore the balance of electrical charge whenever possible. If a negatively charged object is connected by a conductor such as copper wire to a positively charged object, the excess electrons in the negative object will move in the conductor towards the positive object until the balance is restored.

This movement of electrons is called *electric current*. The *ampere* (amp) is the unit of measurement for the strength of an electric current.

Electrons in a conductor are never completely free to move, therefore some work has to be done to move them. The property of interfering with the flow of electrons is called *resistance* and is measured in units called *ohms*. Good electrical conductors have little resistance and poor conductors have much resistance.

If electrons are to move against this resistance it is necessary to supply them with energy. Energy which can be converted into electron motion is called *electromotive force* or *voltage*. The unit of measurement for electromotive force is the *volt*.

PRODUCING ELECTRICITY

Luigi Galvani, an Italian, in 1792 observed an unusual twitching reaction when two dissimilar metals came into contact with a frog's leg. What had occurred was a small flow of electricity.

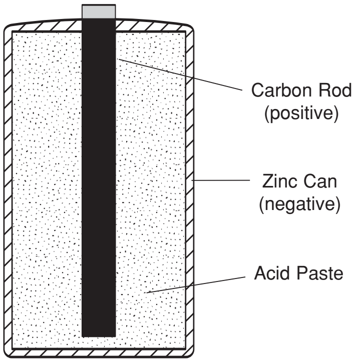
Chemical Methods

Allesandro Volta later developed Galvani's discovery and constructed the first practical means of producing electrical energy from chemical energy. The 'voltaic' cell consists of a zinc rod and a copper rod partly immersed in dilute sulphuric acid and connected with a wire conductor through which an electric current flows.

The copper rod is called the positive electrode (anode) and the zinc rod the negative electrode (cathode) and the sulphuric acid is called the electrolyte solution. The action of the zinc atoms dissolving in the acid causes a loss of electrons and the zinc atoms become positively charged zinc ions. The electrons flow in the wire conductor from the zinc rod to the copper rod.

The electrons enter the electrolyte solution from the copper electrode where they combine with hydrogen ions to form hydrogen atoms which are given off in the form of hydrogen gas. The zinc gradually dissolves in the acid but the performance of the cell will deteriorate before the zinc and acid are used up.

Modern dry cell batteries, such as those used in torches, operate on the same principle by dissolving zinc in an acid paste (usually ammonium chloride). The illustration below represents a section through a dry cell battery.



Dry Cell Battery

The zinc rod of the voltaic cell is replaced by a zinc can which contains the acid paste and a carbon rod which replaces the copper rod of the voltaic cell.

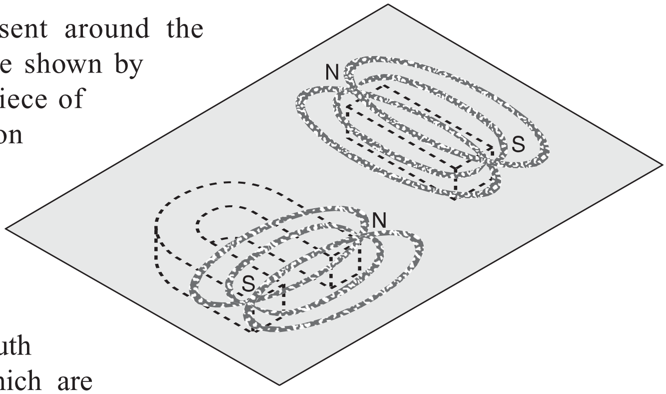
A flow of electrons is produced when the zinc dissolves in the acid paste. A car battery also produces electricity by chemical change.

The generator or alternator causes chemical processes to take place resulting in electrical energy being stored in the battery for use in the electrical circuits of the car. A car battery contains acid and plates made from lead.

Using Magnetism

The magnetic field present around the poles of a magnet can be shown by using iron filings on a piece of cardboard as illustrated on the right.

The iron filings align themselves in magnetic lines of force between the north and south poles of the magnets which are positioned below the cardboard. It is these magnetic lines of force which produce an electric current in a conductor.

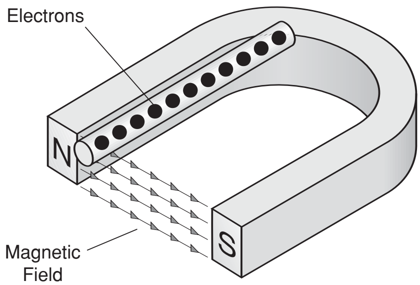


Magnetic Lines
Of Force

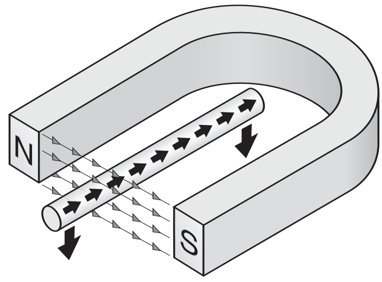
When a wire is passed close to a magnet the magnetic lines of force cause electrons to flow in a certain direction in the wire. When the wire moves in the opposite direction, the electrons in the wire flow in the opposite direction.

However, electrons in the wire flow inside a magnetic field only when there is motion. If the wire was brought to a stop while crossing the magnetic lines of force electricity would cease to flow.

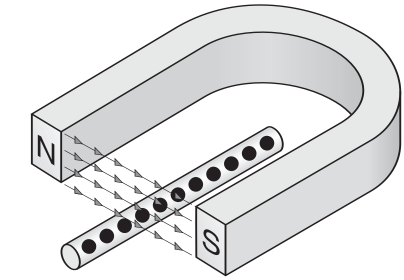
The following illustrations demonstrate the relationship that exists between the magnetic field, electrons and motion.



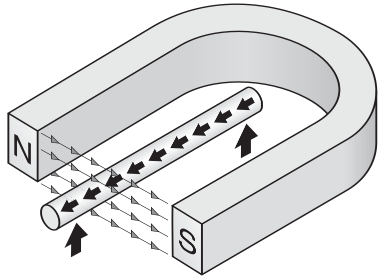
1. Electrons motionless in wire above the magnetic field.



2. Electrons flow in one direction as wire moves through the magnetic field.



3. Electrons again motionless after wire has passed through the magnetic field.



4. Electrons move in opposite direction as wire passes through the magnetic field again.

The pulse of electricity produced by passing a wire through a magnetic field would not be enough to light the smallest bulb. However if a coil of wire is rotated through a magnetic field at high speed a flow of electricity can be produced.

The strength of the current will depend on:

- The strength of the magnetic field.
- The length of wire in the coil (number of turns).
- The speed of rotation of the coil through the magnetic field.

An increase in any or all of these factors will increase the strength of the electric current produced.

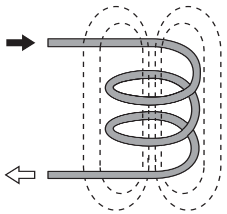
Modern methods of generating electricity depend on the basic principles described above.

ELECTROMAGNETISM

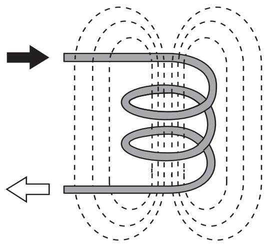
When a wire is passed through a magnetic field an electric current flows in the wire. Conversely, when a wire has a current flowing through it, the wire sets up a magnetic field around itself. This field is called an *electromagnetic field*.

The field near a single wire which carries an electric current is too weak for most useful purposes, but if the wire is wound into a coil the same current will produce a much stronger electromagnetic field. Each loop of the coil creates its own field therefore strengthening the total electromagnetic field around the coil.

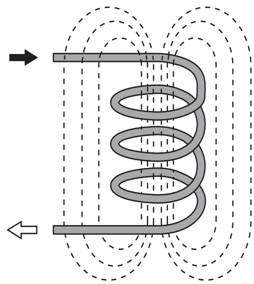
The strength of the field can be increased by increasing the strength of the current passing through it or by increasing the number of loops or turns in the coil as shown in the illustrations below.



Current creates an electromagnetic field.



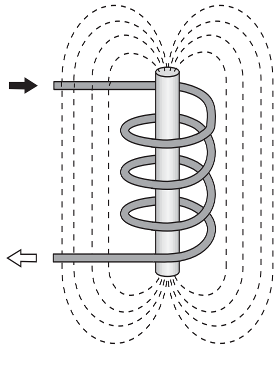
Stronger current increases the field strength.



More loops in the coil increase strength of the magnetic field.

The illustration below shows a piece of soft iron placed in the coil. The magnetic lines of force are concentrated in this iron core which becomes magnetised. When the current is switched off the soft iron core loses its magnetism. This iron core is called an electromagnet.

Permanent magnets can be made from hard steel and some metal alloys. When manufactured, steel and alloys are not magnetised, but when placed in a strong magnetic field large numbers of electrons are induced to move in one direction and the material is said to be magnetised.



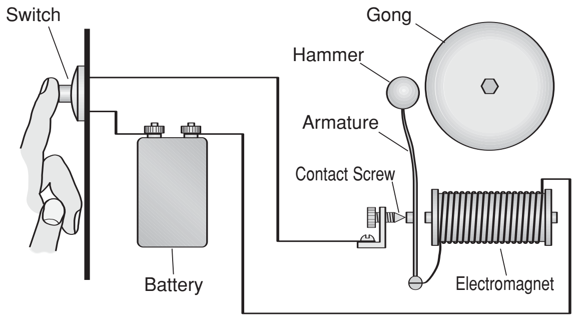
Soft iron core concentrates the magnetic field and becomes magnetised.

These hard materials will retain their magnetism when the electric current is switched off, however a soft iron core will lose its magnetism rapidly. Electromagnets are used in generators, electric motors, starter motors and many other products and appliances.

The electric bell is a simple application of an electromagnet. The diagram below illustrates the basic circuit and operation of a simple electric bell.

When the switch is pressed, current flows in the circuit and the soft iron core of the electromagnet becomes magnetised and draws the armature to it, causing the hammer to strike the gong.

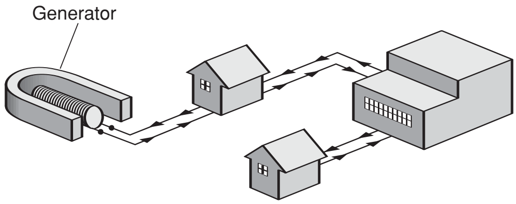
As the armature moves, contact is broken at the contact screw, the iron core loses its magnetism, the hammer springs back to its original position and the cycle starts again. While the switch is on the hammer moves back and forth.



Electric Bell

CURRENT FLOW

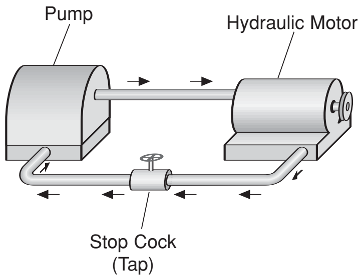
The diagrams which follow illustrate the analogy between the flow of electricity and the flow of water. In the illustration below left, electrical energy flows from the generator to the buildings where it is used to operate lights and machines, then it is returned to the generator.



Why is a wire needed to return the electricity to the generator?

The following illustration may help in understanding why this is so. If water is pumped into a pipe and a secure plug is placed in the other end of the pipe, the water will cease to flow. Regardless of the amount of pressure built up by the pump, the water will still not flow.

The illustration on the right shows a different situation where the water will flow in a closed system of pipes connecting a pump and a hydraulic motor. The circuit of pipes allows the water to flow continuously through the system until the stopcock (tap) is closed.



An electrical generator can be thought of as a kind of pump. It is a machine which creates a pressure (voltage) which makes electrons move or flow in the wire.

If a wire does not make a complete circuit then the flow is stopped. Regardless of the amount of pressure or voltage generated, the electrons will not flow.

Direct and Alternating Current

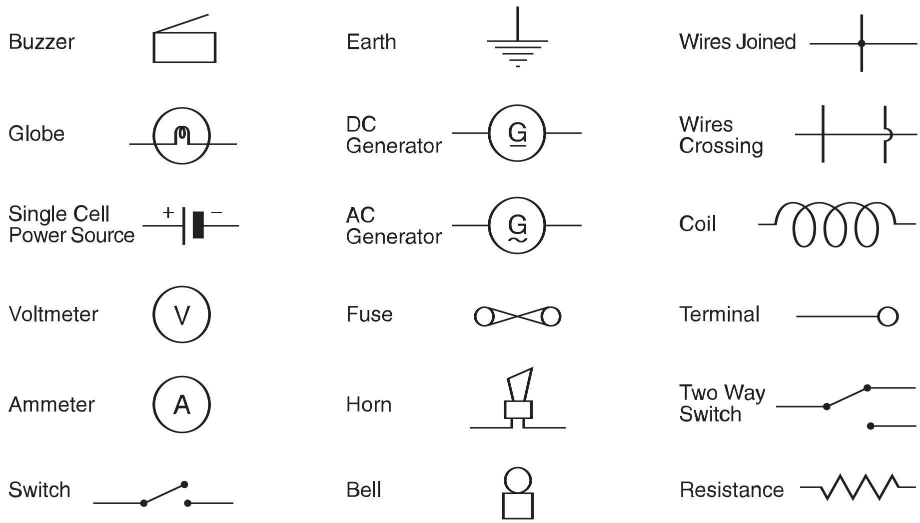
If the electrons flow continuously in one direction along a conductor, the current is said to be *direct current* or DC. This is the type of electrical current produced by a battery or DC generator.

If the electrons flow firstly in one direction, then back in the opposite direction and continue this back and forth motion the current is said to be *alternating current* or AC. This type of current is produced by an alternator or AC generator and is the type of electricity found in home electrical circuits.

SYMBOLS CIRCUITS & SAFETY

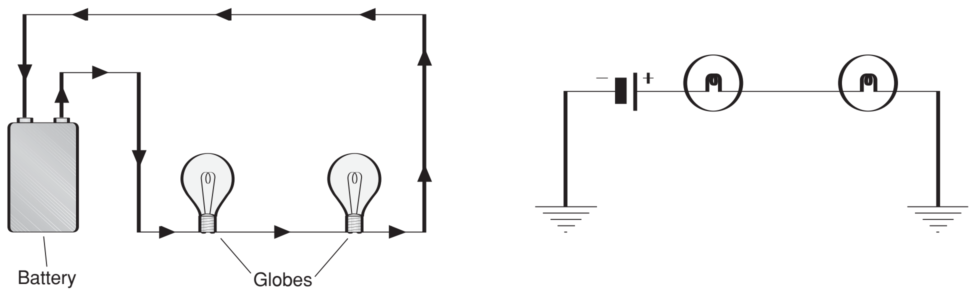
Some Electrical Symbols

Electrical symbols are simple graphic representations of electrical components which are used when electrical circuits are being drawn.



Series Circuits

When circuit components are connected with only one connecting path they are said to be connected in *series* as shown in the following diagrams.



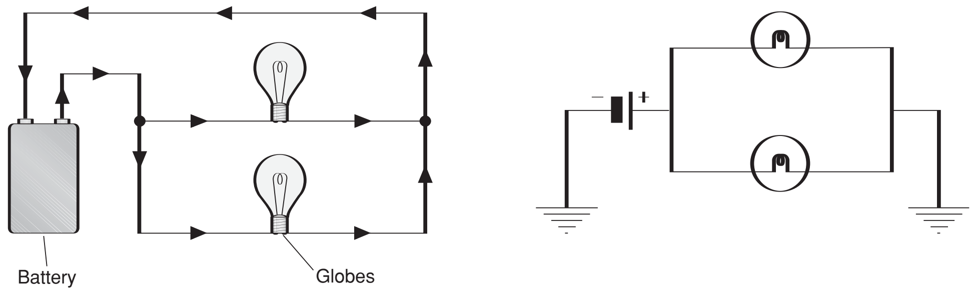
Series Circuit

In a series circuit the same current is in all components. When batteries are connected in series the voltage obtained in the circuit is the sum of the voltage in the batteries. For example a torch might have four 1.5 volt batteries connected in series to give a total of 6 volts.

If resistors are placed in series the resistance in the circuit will be equal to the sum of the resistors.

Parallel Circuits

When circuit components are connected with several conducting paths they are said to be connected in parallel as shown in the following diagrams.



Parallel Circuit

If batteries are connected in parallel the circuit voltage remains the same as in each cell. For example, if four 1.5 volt batteries were connected in parallel, the circuit voltage would be 1.5 volts.

Parallel circuits are used in home wiring. There are as many circuits as there are appliances to be run and each appliance receives the same voltage.

If resistors are wired in parallel, then each resistor uses only the power required for its own purpose.

Open & Closed Circuits

It is desirable that electrical circuits can be used when necessary and the current stopped when not required. To enable this to be done without dismantling part of the circuit each time, a switch is usually placed in the circuit.

When the switch is in the *off* position there is a break in the circuit and electrons cannot flow. This is called an open circuit. When the switch is in the *on* position the electrons can flow and it is called a closed circuit.

In your home, light bulbs and other appliances are connected in parallel with each other. If one bulb is broken or switched off, current can still pass through other bulbs and appliances connected in parallel with it.

If a number of light bulbs were connected in series and one bulb was broken the circuit would be open and current could not flow. Therefore none of the bulbs would light up.

Safety

Electricity is potentially very dangerous to human life, but it can be used safely if reasonable precautions are taken. The following are a few simple precautions that should be observed in everyday use of electricity.

- Never use an appliance with a cracked plug or damaged cord.
- Keep liquids away from electrical equipment and never use equipment with wet hands or in wet conditions. Minerals and other substances in water cause it to be an electrical conductor.
- Switch off before removing plugs.
- Do not touch a live element, such as in a toaster, with a metal object.
- Leave all repairs of appliances and home wiring to a qualified electrician.
- Restrict your own experiments and projects to a safe level, for example 15 volts maximum.

CHANGING ELECTRICITY

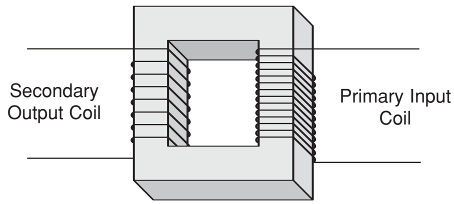
Transformer

The purpose of a transformer is to increase or decrease the value of an alternating voltage. Transformers consist of a soft iron core on which are wound two coils of insulated wire. These coils are known as the primary and secondary windings.

The alternating voltage which is to be changed is the input and is connected to the primary coil. The output, which is the required voltage, is produced in the secondary coil.

The voltage produced in the secondary coil will generally depend on:

- The primary voltage.
- The ratio of the number of turns in the secondary coil to the number of turns in the primary coil.



Step Down Transformer

If an alternating voltage of 12 volts is required from 240 volts, a step down transformer is used in which the primary coil has 20 times the turns of the secondary coil. In this example 240 volts is applied to the primary coil and 12 volts is produced at the terminals of the secondary coil.

Because the secondary coil has only one twentieth the number of turns in the primary coil the output voltage is one twentieth the input voltage.

If an increase in voltage is required a step up transformer is used in which the number of turns in the secondary coil is greater than the number of turns in the primary coil.

Rectification

A rectifier is a device which enables direct current to be produced from an alternating current. However it cannot work in reverse. A rectifier cannot produce an alternating current from a direct current.

A simple metal rectifier consists of stacked copper discs alternated with larger metal plates to radiate the heat developed in the discs during the rectification process.

Alternate sides of the copper discs are oxidised giving a series of copper/copper-oxide boundaries at which rectification takes place.

A diode is also widely used as a rectifier.

Ohm's Law

Ohm's law describes the relationship between current, voltage and resistance in an electrical conductor.

Ohm's Law: $\text{Voltage} = \text{Current x Resistance}$

or $\text{Current} = \dfrac{\text{Voltage}}{\text{Resistance}}$

or $\text{Resistance} = \dfrac{\text{Voltage}}{\text{Current}}$

Ohm's law is usually expressed as:

$$V = I.R$$

where I is the current measured in amperes, V is the electromotive force or voltage measured in volts and R is the resistance measured in ohms.

For example, if a battery supplies 12 volts and the circuit has a resistance of 4 ohms, the current flowing through the circuit can be calculated as follows:

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$$

$$= \frac{12}{4}$$

$$= 3 \text{ amps}$$

BASIC ELECTRONIC COMPONENTS

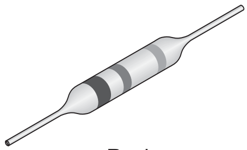
Resistors

These components used in electronic circuitry are neither conductors nor insulators but are somewhere in between allowing some current to flow in varying degrees. The lower the resistance the more current can flow in the circuit.

Generally, resistors are used to limit the supply of current to the amount required by certain components in a circuit. In some cases too much current is likely to damage components.

Fixed value resistors are not polarised, which means they can be connected either way in a circuit.

The amount of resistance in a resistor of this type is denoted by a system of coloured bands on the body of the resistor as shown in the illustration on the right.



Resistor

Symbol

Variable resistors are versatile components which have a special sliding arm that allows the amount of resistance to be varied. The volume control on a radio is a typical example of a variable resistor in an electrical circuit. Alternative symbols are shown below.

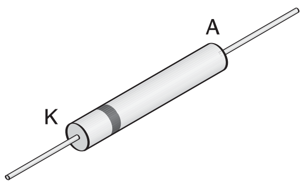
Variable Resistor - Alternative Symbols

Diodes

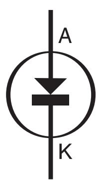
There are several different types of diodes used in electronic circuitry and all have one basic feature in common.

They allow current to flow in one direction only. It is this feature which allows some diodes to be used a rectifiers.

Power diodes are used in electronic circuits to protect components against possible damage which may be caused by accidental reversing of the electric current. For example, if a battery is wrongly connected to the circuit.



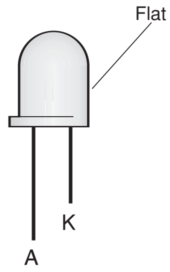
Power Diode



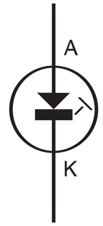
Symbol

The band on one end of the diode indicates which way the diode is to be connected in the circuit. In the symbol shown above, the arrow is the positive or anode (A) side of the diode and the bar is the negative or cathode (K) side.

Light emitting diodes glow brightly when they are correctly connected in a circuit. If they are connected incorrectly with the polarity reversed, light emitting diodes may be damaged.



Light Emitting Diode



Symbol

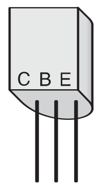
The polarity is usually shown in two ways. The longer lead is the positive side and the shorter lead the negative side. The body of the LED often has a flat on the side near the negative lead.

Transistors

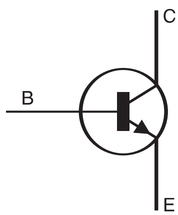
Transistors are components which control and amplify electric current. Most transistors have three leads, all of which must be connected correctly for the transistor to operate.

These leads are called the base (B), the collector (C) and the emitter (E) as shown in the illustrations below.

Transistors can be used as very fast switches in a circuit and they can also be used to amplify.



Transistor



Symbol

If a certain amount of current is fed into the base lead a larger current is made to flow into the collector and then out of the emitter.

For example, in a transistor radio a very weak radio signal can be amplified thousands of times because the transistors can produce a greatly amplified copy of the signal in the current which flows between the collector and the emitter.

The diagrams above illustrate one of the common types of transistors used in electronic circuitry.

Capacitors

Capacitors are components which are capable of storing an electrical charge. The higher the capacitance the more electric charge the capacitor can store.

The capacitor has the ability to supply electricity from its stored charge as required. Capacitors are often called condensers.

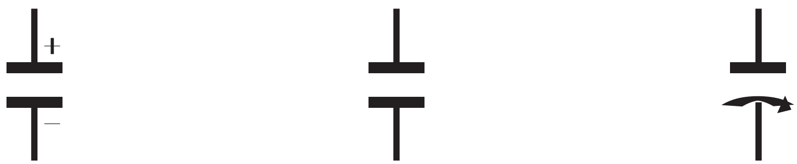
The main parts of a capacitor are two fine metal plates which are insulated from each other and usually wound into a cylindrical shape. These plates can be charged and discharged as required.

Capacitors are usually marked with their capacitance or storage capacity and a voltage rating. If the voltage rating is exceeded the capacitor may be seriously damaged.

There are many different types of capacitors which can be classified into three main groups:

- Polarised capacitors which are marked positive and negative.
- Non-polarised capacitors which may be connected either way in a circuit.
- Variable capacitors in which the storage capacity can be altered by turning a shaft which changes the position of two sets of inter-leaving plates.

Symbols for the three types of capacitors are shown below.



Polarised Non-polarised Variable

DESIGN & PLANNING

INTRODUCTION

No matter what article is to be made, a certain amount of preparatory work must take place before construction can commence. This could involve developing a design from a completely new idea, or modifying an existing design to suit the circumstances, or even using an existing design without changing it in any way.

Whatever the design entails, each part of the article's construction should be carefully planned so that the article can be completed exactly according to the original design.

Design and manufacture depend on each other. For example, there is no point in designing something that you cannot make in your workshop because you don't have a special machine or piece of equipment that would be necessary to complete the article according to the design.

It must be possible for you to construct the article with the tools, equipment, materials and skills that are available to you. On the other hand the design itself must be an accurate link between the original idea and the article that is finally produced.

Careful planning will be necessary through all stages of the project to ensure that the finished article satisfies all requirements of the design.

A DESIGN CASE STUDY

The following is recommended as a general approach to the design and manufacture of any practical project you may wish to undertake. The following sequential steps form a logical procedure that can be applied to most design problems:

- Situation
- Brief
- Investigation
- Solution
- Realisation
- Evaluation

Situation

What is the particular design problem?

Make sure you understand exactly what is required.

For example, if you were asked to design a tool box to keep in the boot of the car and you had no idea what it would look like, would you simply make one the same as your woodwork tool box? Or course you wouldn't. You would make it your business to find out what a mechanic's tool box is like and proceed from there.

Brief

What are the needs related to the design problem?

Using the example of the mechanic's tool box, consider the following:

Should the tool box be designed to fit in a certain part of the boot compartment? If so what design factors might this affect? Should the design allow access to the tools without having to remove the box from the boot? Should the box be large enough to store a complete kit of tools or just an emergency kit?

These are only a few of the things a designer would have to consider while writing a brief for the project. Can you think of any others?

Investigation

What are the required specifications of the project?

After determining the needs of the project it becomes necessary to decide the best way to meet these requirements. Some aspects to consider in the case of the tool box might be:

- Overall sizes should suit the space available and the tools to be stored. For example, the length of the tool box might be determined by the length of a large screwdriver or crescent spanner.

- Should storage be arranged so that small items can be separated from large ones to make them easier to find? How might this be achieved?

- Does the box require a lid? How could a lid be attached? Does it need to be lockable?

- What type of finish is required? This often determines the choice of materials to be used in construction. For example, if a painted finish was not required you might need to use a galvanised sheet to prevent rust.

- Availability of materials: Before you finalise your design you should make sure all the materials in the sizes you require are readily available.

- Cost: The total cost of materials to be used should be considered carefully while the materials are being chosen for the project. For example you may have to decide if a more expensive material is worth the extra cost in terms of function and appearance.

- After deciding on such things as shape, size, storage, finish and materials you should think about the actual construction of the project.

  Does your design combine materials in such a way that joints will have maximum strength? Have you got the right tools to do the job? Have you got enough room in your workshop? Have you got the manual skills required to make the article to the design you are considering?

Solution

After having considered the situation and investigated it thoroughly, you should be in a position to bring all your ideas together and formulate your design. Generally it is desirable to draw sketches that show all necessary construction details. If you have a working knowledge of graphical techniques you should be able to make pictorial drawings or orthographic drawings showing two or three different views.

Realisation

Realisation is the actual construction of the project from raw materials through to the finished product, working from the design drawings and any other specifications that have been noted during the design process.

Efficient realisation depends not only on having the practical skill to do the work, but also on systematic planning of construction procedures. You may consider doing all the marking out at once or all the cutting at once to save time.

This, however may not be possible. For example the location of one part might require the prior completion or part completion of another part before it can be worked on. If your work is planned thoroughly you may detect problems before they occur and possibly work out ways to overcome them.

Evaluation

When a project is completed it should be tested and evaluated. Try to determine if it really does the job that was originally intended or if it could be improved in some way.

Evaluation procedure should be designed to test all the needs of the project stated in the design brief as well as specifications that were determined during the investigation.

The evaluation should discover any faults in the design. At this stage it might be necessary to make some modifications to the project to correct design faults.

Notes

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