COURSE OF TECHNICAL INSTRUCTION

ENGINEERING WORKSHOP PRACTICE

Engineering Training Section, Headquarters, Postmaster-General's Department, Melbourne C.2

THE AUSTRALIAN POST OFFICE
COURSE OF TECHNICAL INSTRUCTION

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ISSUED 1949

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Engineering Division,
Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2.

PREVENTION OF ACCIDENTS.

1. INTRODUCTION.

1.1 A good technician possesses the knowledge and skill to avoid accidents to himself, his workmates, his work and to the equipment he is using. Do not attempt to use any machine or equipment until you are familiar with its operation. The best known safety device is a careful individual.

A machine tool can be a good servant but a bad master. Operated intelligently and with forethought it will do all it is intended to do. Carelessness, negligence, thoughtlessness and over-confidence on the part of the operator, may result in serious personal injury or damage to a costly machine.

1.2 Cause of Accidents.

Carelessness. Many accidents in the workshop are caused by carelessness. Concentration on the work being carried out eliminates the possibility of most accidents. Skylarking often causes accidents.

Ignorance. A technician must understand the uses and functions of his machine. If you don't know, ask.

Unsuitable Clothing. Loose sleeves, unbuttoned or torn sweaters, flapping ties or ribbons should not be worn.

Untidiness. Keep all passage ways, etc. clear and clean. Circular rods if stepped upon cause nasty falls. Never work under heavy materials unless they are properly packed. Keep workshop floors free from grease and oil. Use clean waste. Old waste may contain metal cuttings, etc. Watch for bad practice of leaving tools on ladders, etc. without precautions being taken to prevent them falling.

Hand Tools. Hammers with loose fitting handles, or chipped faces should never be used. Chisels with burred heads are dangerous, as broken pieces from the edges may cause injury. Files should have tight fitting handles, otherwise the tang may be forced into the hand. Files or similar hardened tools should not be struck with a hammer owing to the danger of flying chips. Spanners which fit incorrectly may slip. When drilling always hold work tight in a machine vice. Always use goggles when grinding.

Machinery. Never use waste near moving parts while they are in motion. Don't attempt to remove or adjust a belt on a rotating shaft by hand.

Electricity. Never use a damaged portable lead. Use insulated tools where possible. If in doubt consider all wires alive.

1.3 Care of Machines. When placed in charge of a machine tool, you should appreciate the fact that you accept responsibility for a piece of mechanism which may cost up to £1,000 or more.

Don't regard your machine as so much cast iron and steel; treat it as you would your watch. Take pride in its appearance and give it proper attention. Lubricate it with the right kind of oil. Report any fault or unsatisfactory running.

1.4 Care of Tools. Tools entrusted to your care must be carefully looked after, especially tools of hardened steel. These must not be allowed to make contact with each other or with other types of tools or measuring instruments. All files when not in use must be inserted in their proper sleeves.

Keep all tools tidily arranged in your drawer. Take a pride in keeping your tool kit in first class order.

The breaking or damaging of tools during an operation must be avoided, for example, drilling and tapping, as it entails time to remove the broken part from the work, the expense to replace the broken tool, and probably mutilating the work to the extent of its having to be done again.

All tools issued from the store must be returned before ceasing duty each day. Grinding wheels of the carborundum type are provided for the sharpening of cutting tools. They must on no account be used without the permission of an instructor.

1.5 First Aid. All injuries, however slight, should receive treatment. Infection is always possible. If it is necessary to remove a foreign substance from the eye, do not probe with any hard pointed object. Clean paper doubled over to a point and damped slightly is often effective. If the particle is embedded in the eye, seek medical attention at once. The greater the delay the more difficult is the removal.

END OF PAPER.

Engineering Division,
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COURSE OF TECHNICAL INSTRUCTION.

METALS AND ALLOYS.

CONTENTS.

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1. INTRODUCTION.

1.1 Nature has provided more than 50 different kinds of metals, but for many reasons such as scarcity, rapid oxidation, etc., only about 12 can be used for general purposes.

Different metals possess different qualities and it is these qualities which make one metal suitable for a particular purpose and useless for another purpose. For example, elasticity is essential in the metal used for making a spring, also lustre will be useful to prevent oxidation, but whether the metal can be welded or not does not matter in the least. The chief characteristic needed in a metal from which a bell is made is sonorousness, while the metal's power of conductivity would not count. On the other hand, conductivity is the most important feature of a metal to be used for electrical purposes, and its sonorousness need not be regarded.

It is important, therefore, that the different qualities possessed by metal should be known and understood.

1.2 The following terms are commonly used relative to metals and alloys -

Hardness. The resistance of a metal to cutting or abrasion.

Frequently the hardness of a metal is increased by the presence of impurities within the metal, so that a pure metal is often softer than an impure one. Thus, for example, gold is hardened by alloying it with a small quantity of copper.

The softness of metals increases (or their hardness decreases) with increase in temperature. Manganese, cobalt and nickel are the hardest of the common metals, lead constituting the softest of such metals.

The property of hardness depends upon the inner attractions of the molecules of the metal for one another. The hardness of metals is nowadays commonly given in terms of their Diamond Hardness Number or their Brinell Number.

Brittleness. A metal which easily breaks upon the application of a sudden shock or one which fractures readily when subjected to a hammering or compressing force is considered to be brittle. Metals are usually increased in brittleness by the presence of impurities within them. Thus, phosphorus in iron renders the metal brittle or "short".

Crystalline metals are usually brittle because of the feeble degree of cohesion between their component crystals.

Distinguish carefully between brittleness and hardness of a metal. The two terms are by no means synonymous. Thus, for example, manganese steel is hard, but it is not brittle, whereas metallic tellurium is brittle but it is not hard.

Malleability. The degree to which a metal can be flattened out in all directions by rolling or hammering. The malleability of a metal depends upon its toughness and also upon its tensile strength. Metals having coarse crystalline structures are not malleable. Hence, any impurity in a metal or any mechanical or physical action to which it is subjected, which results in an increase of its coarseness of grain or crystalline structure, will decrease its malleability. Some metals increase in malleability with increase in temperature. Gold is the most malleable of all metals, it having been beaten into sheets as thin as .0000004 inch thickness.

The following well-known metals are arranged in order of decreasing malleability- gold, silver, copper, tin, platinum, lead, zinc and nickel.

The relative malleability of metals is a measure of the thinness to which they may be reduced from the same thickness.

Fusibility. The property of a metal becoming liquid when heated. This is a most important characteristic of metals and makes metal casting possible. It also permits the combination of metals, thus producing alloys, also the joining of metals by soldering, brazing and welding. Metals expand on heating and contract on cooling. Cast iron being an exception. It expands at the moment it becomes solid. Bismuth and type metals also occupy a larger space when cold than when liquid.

Toughness. Referring to metals, this may be defined as the property of resisting fracture by bending, twisting, hammering, etc.

Tenacity. The property possessed by a metal or alloy of resisting forces tending to tear it asunder. It depends upon the degree of cohesion of the molecules of metal.

Tensile Strength. A measure of a metal's resistance to rupture by the application of a tensile stress or stretching force. The tensile strength of a metal is usually expressed in tons/sq. inch or sometimes in lb. per square inch. Various machines for estimating the tensile strength of metals are now used.

The term "tenacity" is sometimes used to denote tensile strength.

Ductility. The degree of which a metal is capable of being lengthened by the application of a tensile stress or drawing-out force. The readiness with which a metal may be drawn-out depends upon its softness, but the thinness to which it may be so drawn is dependent upon its tensile strength.

Conductivity. The power of metals and alloys of transmitting heat and electricity. Hence the terms "Thermal Conductivity" and "Electrical Conductivity". The electrical conductivity of a metal is practically equal to its thermal or heat conductivity, and in both these instances the presence of even a very small amount of impurity in the metal will diminish its conductivity. The electrical conductivity of a metal is much decreased by rise in temperature. Of all metals, silver has the highest thermal and electrical conductivities.

Elasticity. The property of metals (and other bodies) in virtue of which force is required to change their bulk or shape, and by means of which they recover their original shape when the force is removed from them.

If a metal recovered its shape perfectly after an applied force has been removed from it, it would be said to be perfectly elastic.

Fatigue. Term used to denote the gradual deterioration in properties of some metals after they have been in use over long periods. Metal fatigue is due to internal changes proceeding within the metal. Such changes are brought about by frequent alterations in the conditions of temperature, stress, vibration, etc., to which a metal may have been subjected.

Welding. The joining together by pressure of two pieces of metal which have previously been sufficiently softened for this purpose by the application of heat. The term usually denotes the joining of iron or steel in this manner.

Readily weldable metals are - iron, nickel, platinum, gold, silver, lead and tin.

Lustre. The property of reflecting rays of light. A highly polished metal surface is less likely to tarnish than an unpolished one, as gases do not as a rule react on such surfaces.

Sonorousness. The property possessed by harder metals giving a ringing sound when struck. This is particularly noticeable in alloys of copper and tin. If a piece of solder is bent it will give a crackling noise sometimes called "the cry of tin". This is supposed to be on account of the particles of tin sliding upon one another. In solder with a high percentage of tin this "cry" is very pronounced. Lead, if cast mushroom shaped, becomes sonorous.

Specific Gravity. The number which expresses the weight of a metal (or other body) compared with that of an equal volume of water being taken as unity (1). It is sometimes referred to as the Density or Specific Density of the metal.

The Specific Gravity is sometimes increased by mechanical treatment of the metal, such as rolling, hammering and stamping, since all such treatments tend to close the pores of the metal and thus to increase its compactness. The Specific Gravity of a metal may be regarded as a measure of its degree of inner compactness. Lathium (specific gravity = 0.534) has the smallest specific gravity of all metals; Osmium (specific gravity = 22.47) the greatest. With the exception of Bismuth, all metals have a smaller specific gravity when molten than in the solid state.

Sheradizing. A method of coating iron or steel with zinc by surrounding it with powdered zinc mixture and heating it for some time. A thin, uniform and firmly adherent coating of zinc is thus imparted to the iron. Finished iron articles can conveniently be treated in this manner.

Chemical Properties. The affinity of most metals for oxygen especially in a damp atmosphere, produces rust or tarnish. The more polished a surface, the greater the resistance against atmospheric action.

The well-known metals will dissolve in acids, and this is made use of particularly in cleaning metals before polishing and lacquering. Iron, zinc, silver, lead and copper will dissolve in nitric acid, while, with the exception of platinum, silver, lead, gold and copper, all metals will dissolve in hydrochloric acid.

A mixture of nitric and hydrochloric acid will dissolve gold and platinum.

1.3 Standard Metals and Alloys for Electrical Contacts used by the P.M.G. Department.

(i) Metals. Platinum, Gold, Tungsten and Silver.

(ii) Alloys. Platinum-gold-silver and Gold-silver.

Platinum-gold-silver consists of 7 per cent. platinum, 67 per cent. pure gold and 26 per cent. silver. Gold-silver consists of 10 per cent. gold and 90 per cent. silver. Pure silver is also extensively used. In all cases the percentages are by weight. Cost is an important factor in the use of alloys for electrical contacts. Platinum is the most efficient contact metal, but its cost being six times that of gold renders its use prohibitive, except where contacts are subjected to heavy loads likely to give rise to sparking at the contact points at the instant of breaking an inductive circuit. Springs having platinum contacts are identified by a single V notch cut in the end of the spring near the contact.

Tungsten contacts are used in circuits where it is necessary to break currents up to 5 amperes or more, that is, automatic R.A.X. charging equipment. Tungsten, being extremely hard, cannot be fixed directly to the contact springs, so they are usually welded to a disc of iron or mild steel and the disc is rivetted to the springs.

Contacts of the other metals and alloys mentioned are of wire form cut into small pieces and pressed into a hole in the spring with a punch which is either domed or conical shaped.

2. METALS.

2.1 Metals frequently used in telecommunication practice are defined in this Section.

2.2 Cast Iron. The cast iron generally used is dark grey in colour , crystalline, brittle, weak in tension but very strong in compression, and being easily and cheaply moulded is used most extensively for the manufacture of castings of all descriptions, such as the frame work of machinery, machine parts, steam and motor cylinders, large gas, steam and water pipes, flywheels, pulleys and stoves, and also as the raw material for the production of wrought iron, mild steel and cast steel. The carbon content varies from 2 per cent. to 5 per cent. and the melting point is approximately 2100°F. Cast iron cannot be forged.

2.3 Wrought Iron. This metal is considered for all practical purposes pure iron, as it does not contain more than 0.25 per cent. carbon. It is light grey in colour, fibrous, tough, ductile at a high temperature, is very easily forged and welded but cannot be cast. Owing to the comparative cheapness and general utility of modern mild steel the production of wrought iron has greatly decreased of late years. It is now used mainly for chain making on account of its unique welding properties and also for the production of cast steel by the cementation process.

2.4 Steel. The word "Steel" embraces both "mild" and "cast" steel, and the usual method of determining the difference between the two classes is as follows - mild steel (which contains less than 0.5 per cent. carbon) when heated to redness and quenched in water does not appreciably harden, whereas cast steel (0.5 per cent to 1.5 per cent. carbon) does harden when so treated. The two classes merge one into the other, so that it is almost impossible to draw a dividing line.

2.5 Mild Steel. Is greyish-white in colour, has a medium fine grain, can be forged and welded, is strong in compression and tension and is used for structural steel work, shipbuilding, rails, shafting, bolts, nuts, rivets, motor car bodies, etc.

Cast steel is greyish-white in colour, malleable, ductile, tough, but rather brittle, very hard to weld and when fractured shows a very fine crystalline grain. It is used chiefly for making cutting tools of all descriptions and machine parts that are required to withstand extreme wear. Cast steel is also referred to as "carbon" or "tool" steel. In passing, it is interesting to note that carbon steel has been very largely superseded of late years insofar as cutting tools for engineering and woodworking machinery is concerned, by "high speed" steel, and this being a special alloy carbon steel, varying somewhat in its constituents but generally containing one or more of such elements as chromium, tungsten, vanadium, etc. High speed steel will stand up to much higher speeds and feeds than ordinary carbon steel and, generally speaking, no tempering is required, the steel being hardened by a quick cooling off in an air blast, or whale or cottonseed oil, from a white heat.

2.6 Tin. Pure tin is white in colour tinged with yellow. It is soft, malleable, ductile, takes a high polish, cannot be forged or welded, does not oxidise and is used as tinfoil for wrapping purposes, for coating purposes (for example, in the manufacture of tinplate) and for mixing with other metals to form such alloys as soft-solder and gunmetal. Melting point is 450°F.

2.7 Zinc. This metal is bluish-white in colour, cannot be forged or welded, does not readily oxidise, is soft and malleable but very brittle when worked and, therefore, requires constant annealing by dipping in boiling water and allowing to cool slowly. It is used in sheet form for such things as linings for packing cases and dry cells, for coating sheet steel to form "galvanised iron" and also forms part of numerous alloys as, for example, brass, brazing spelter and nickel silver. Melting point is 780°F.

2.8 Copper. Copper is reddish-brown in colour, very malleable and ductile, can be highly polished, forged hot or cold but cannot be welded in the forge. It is an excellent conductor of heat and electricity, resists corrosive action and is used for electrical wire and accessories, cooking utensils, nails, rivets, tubing, repouses work, etc., and also for alloying purposes in the manufacture of brass and bronze. It does not make good castings and sheet copper requires constant annealing by heating to redness and quenching in water when being worked into shape by the mallet or hammer. Melting point is 1980°F.

2.9 Lead. This metal is bluish-grey in colour, very soft and malleable, ductile, heavy, may be cast but not forged or welded in the forge and is practically indestructible. It is used for sinks and dishes in chemical laboratories, waste pipes, ballast, shot, dampcourse, the manufacture of paint, roofing, etc., and forms part of such alloys as soft-solder, pewter and white-metal. Melting point is 620°F.

2.10 Aluminium. Aluminium is greyish-white in colour, very light in weight, takes a high polish, does not corrode except with strong alkalies or concentrated acids, is very malleable, may be cast, rolled or pressed but not forged or welded in the forge, and is a good conductor of heat and electricity. Pure aluminium is too soft and weak for most purposes but its alloys (for example, duralumin) are very useful, and these are mainly used in the manufacture of airship, airplane and motor-car parts such as crank cases and pistons. Other uses of aluminium are cooking utensils, surgical splints and instruments. As this metal does not satisfactorily soft-solder it is usually oxy-welded or riveted.. Melting point is 1215°F.

2.11 Silver. This metal is lustrous white in colour, soft, extremely malleable, takes a high polish and does not oxidise. Used (generally alloyed with copper) in the manufacture of coins and jewellery and also for alloying purposes. Melting point is 1760°F.

2.12 Gold. Gold is bright yellow in colour, extremely malleable, may be highly polished, not subject to corrosion and is used, alloyed with copper or silver, in the manufacture of coins and jewellery. Pure gold is said to be "24 carat". Melting point is 1945°F.

2.13 Platinum. This metal is white in colour, extremely malleable, rare, does not readily oxidise, is very heavy and is practically non-fusible. Used in the manufacture of jewellery and also electrical and chemical apparatus in cases where resistance to the oxidising effect of high temperatures is essential. Melting point is 3190°F.

2.14 Tungsten. The metal was first isolated by J J. Don Fausto d'Elhuyar in 1783, and was for many years known by the alternative names of Wolfram and Tungsten (from the Swedish words tung, meaning heavy; sten meaning stone) in allusion to the weight of its ore, wolfram. The name "Wolfram" is nowadays only applied to the element in Germany, yet the chemical symbol, W, still persists.

Added in small amounts to steel, tungsten hardens and toughens the metal. Tungsten is nowadays universally employed for making the filaments of electric lamps, as it is almost infusible and is thus able to withstand the prolonged heating to whiteness. In many of its properties, tungsten is allied to molybdenum and chromium alloys of tungsten with aluminium, antimony, bismuth, cobalt, copper, lead and nickel have been obtained. Of all the known metals, tungsten has the highest melting point.

3. ALLOYS.

3.1 Alloys used in telecommunication are defined in this Section.

3.2 Alloy. An alloy is a mixture and/or combination of two or more metals forming an apparently homogeneous mass. Alloys can be produced by the simple admixture of the molten metals by the smelting of mixed ores, by electrolytic methods or by the compression of mixed metallic powders. Alloys containing mercury are called amalgams.

When metals are alloyed together they -

(i) Dissolve in each other in any proportions but without actual chemical combination; or

(ii) Chemically combine with one another, such resulting compounds in some cases dissolving in the excess of pure metal present; or

(iii) Dissolve in one another to a limited extent; or

(iv) Remain undissolved in one another, in which latter case they will tend to separate out in layers when metal cools.

The general effect of alloying metals together is to lower the melting point and conductivity, increase the hardness and sometimes the strength of the metal. Colour changes are often brought about by alloying, and in many other ways, the properties of the alloying metals are profoundly modified in the resultant alloys.

3.3 Alloy Steels. These are varieties of steel containing considerable percentages of other metals such as tungsten, chromium, nickel, manganese, etc. which have been added for the sake of increasing the hardness, strength or corrosion resistance of the metal, or for some other special purpose. Such steels are also known as "Special Steels". They are detailed under their individual names.

3.4 Alnico. An aluminium-nickel-cobalt steel used for making permanent magnets and magnet cores. It offers a maximum amount of magnetic energy per unit mass of metal and, in this respect, constitutes a great advance on the old magnet steels. Composition - steel, 50 per cent; aluminium, 20 per cent; nickel, 20 per cent; cobalt, 10 per cent.

3.5 Brass. This alloy is light yellow in colour and consists of copper and zinc, a representative alloy consisting 70 per cent. copper and 30 per cent. zinc. The proportions vary, however, according to the ultimate use of the alloy, a mixture as low as 60/40 often being used. It is very malleable and ductile, takes a high polish, will not easily corrode, is a good conductor of heat and electricity and is utilised extensively in sheet, tube and bar form and makes excellent castings. It is used in the manufacture of electrical apparatus, scientific instruments, screws, locks, parts of machinery exposed to water and ornamental fittings, etc. Sheet brass requires constant annealing in the same manner as sheet copper when being worked into shape by mallet or hammer. Melting point is 1650°F.

3.6 Gunmetal. Name given to a group of bronzes. Gunmetal is composed of copper alloyed with from 8 per cent. to 12 per cent. of tin, the strength of the alloy increasing (and its ductility slightly decreasing) as the percentage of tin increases. Was formerly used for making cannons. Is now employed for instrument work, etc. Technically known as "Soft Bronze".

3.7 Bronze. The name given to a large class of copper-zinc-tin alloys. Approximate limitating proportions of these constituents are - copper, 70-90 per cent; zinc, 1-25 per cent. and tin 1-18 per cent.

Such bronzes are much used for making castings, coins, ornaments, etc. Bronze has been known from very ancient times.

3.8 Nickel. When pure, it is a highly lustrous white metal. It is hard, easily polished, ductile and malleable. Nickel, like cobalt, is slightly magnetic. Until recent times it was used enormously as a plating metal, since plated nickel gave a fine finish to base metal. Added in small amounts to steel, the metal forms the various nickel-steels which are exceedingly hard and which have been employed for armour-plating purposes, as well as for other uses. In these, the proportion of nickel may be as high as 20 per cent.

Nickel is a most ubiquitous alloying metal. It enters into a large number of alloys of widely varying characteristics and properties and it is, indeed, as an alloying metal that it is mostly made use of nowadays. A certain amount of pure nickel is employed for the making of instruments, etc. Melting point is 1435°C.

4. MISCELLANEOUS ALLOYS.

4.1 This Section includes miscellaneous alloys of interest.

4.2 White Metal. A generic name given to all copper-zinc alloys containing more than 60 per cent. of zinc. Such alloys are silvery in colour. Strictly speaking, of course, they are brasses. There are many different varieties of white metal.

4.3 Babbit's Metal. The original alloy recommended by Babbit was made up of the following ingredients; copper, 4 lb; antimony, 8 lb; tin, 24 lb. To every pound of the above, 2 lb. more of tin was added.

Many soft lining and anti-friction bearing metals have subsequently borne the name of "Babbit", but the above is the original alloy devised by Babbit himself.

4.4 Ferrous Alloying Elements. These are the various elements which are employed for alloying with steel in the preparation of the now very numerous "alloy steels" or "special steels". They are -

Nickel.	Zirconium	Molybdenum	Aluminium.
Manganese.	Cobalt.	Beryllium.	Uranium.
Vanadium.	Chromium.	Copper.	
Silicon.	Tungsten.	Titanium.	

4.5 Ferrous Alloys. Alloys containing iron or steel.

4.6 Nickel-Silver. Also called "German Silver". Contains copper (56-60 per cent.), zinc (20 per cent.), nickel (20-25 per cent.) and sometimes a small amount of cobalt, lead and iron. Inferior qualities contain not more than 7 per cent. of nickel. Owing to its white colour, lustre, toughness, tenacity, malleability, ductility and chemical resistance, any good quality nickel-silver or German silver is a very useful metal for ornamental work. It has a high electrical resistance, and is also used for the manufacture of electrical resistance wire apart from its many other important uses.

The nickel or German silvers have a fairly high tensile strength of from 25 to 40 tons per square inch.

5. TEST QUESTIONS.

1. Define Hardness, Brittleness and Toughness as applied to metals.
2. What is specific gravity?
3. What metals and alloys are used for electrical contacts?

END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

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COURSE OF TECHNICAL INSTRUCTION.

HAMMERS AND VICES.

CONTENTS.

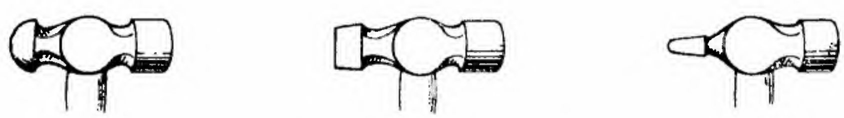
1. TYPES OF HAMMERS.

1.1 Hammers are shaped to suit the particular work on which they are to be used. There are two general kinds, those with hard heads made of good quality steel forgings and those with soft heads of lead, copper, babbit, rubber, fibre or rawhide. The forged head bench hammers used in a general workshop may weigh from 1/4 lb. to 2 lb., and the three common types only differ in the shape of the pane or peen.

The Ball Pane (Fig. 1a) with spherical pane is the most common type. A few blows with the pane of this hammer on the centre of a rivet quickly spreads out the metal.

Straight Pane (Fig. 1b) in which the pane is in the same direction as the axis of the handle, is a useful hammer for work in corners such as could not be carried out with a ball pane hammer.

Cross Pane (Fig. 1c) in which the pane is at right angles to the axis of the handle, has similar uses to the straight pane hammer.



(a) Ball Pane. (b) Straight Pane (c) Cross Pane.

HAMMERS.

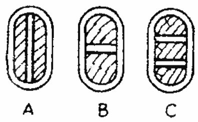
FIG. 1.

2. FITTING HANDLES TO HAMMERS.

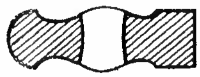
2.1 The oval hole in the head is shaped to take the handle which must be tight fitting. Wedges are driven into the hickory handle spreading it out, thereby tightening the head.

The chief fault is in the manner of wedging. In Fig. 2a three forms are shown. The common form A does not remain fast in the head very long. A much better method is shown at B. The head never tends to loosen sideways but always vertically. Wedges are sometimes inserted as at C. This is unnecessary, except for large hammers, as it tends to weaken the shaft. The hole for the shaft is in the form shown in Fig. 2b.

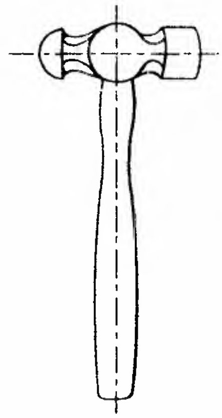
2.2 The length of the hammer handle is governed by the weight and purpose for which the hammer is required. To obtain complete control of the hammer, and to exert the maximum force, the handle should be firmly grasped near the end. A suitable length of shaft for 1/4 lb. or 1/2 lb. hammer is 10 inches. Fig. 2c shows that the head should be at right angles to the shaft, so that the head receives the impact on the face instead of on the edge. Hickory is an excellent wood from which hammer shafts can be made.



(a) Methods of Wedging Heads on Shafts of Hammers.



(b) Shape of Hole in Head.



(c) Angle of Shaft.

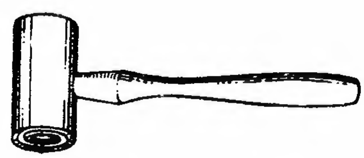
FIG. 2. HAMMER HANDLES.

3. SOFT HEAD HAMMERS.

3.1 It is often necessary to strike a blow on finished work so that no damage is caused to the part. On iron or steel an ordinary wooden mallet (Fig. 3a) can be used. The metal head is recessed at both ends and blocks fixed in position as shown. These can be easily renewed when worn or damaged.

3.2 In the softer metals such as brass or copper, the mallet would mark the work almost as much as an ordinary hammer, and for such conditions a suitable type is shown in Fig. 3b. The head of this hammer is made of hide compressed by hydraulic pressure, the shaft being inserted direct into the hide.

(a) Mallet with Inserted Wooden Blocks.



(b) Hide Headed Hammer.

(c) Lead Headed Hammer.

SOFT HEAD HAMMERS.

FIG. 3.

3.3 A lead hammer is shown in Fig. 3c and is frequently used on account of its cheapness. It is made in a mould with the handle moulded in, and a heavy blow can be struck with it. This hammer does not bounce away from the work when the blow is struck. The lead head may weigh 3-1/2 lb. to 6 lb. depending upon the force required and the material being worked on.

3.4 Brass and copper hammers are sometimes used. These are not really hammers but blocks of the metal around which a strong wire is bound and then twisted up to form the handle. They are placed on the work and the desired effect obtained by striking them with an ordinary forged head hammer.

4. SLEDGE HAMMERS.

4.1 These are a much heavier hammer and may range from 7 lb. to 14 lb. depending upon the type of work they are going to be used on. They are employed for driving large keys, wheels on shafts and other work requiring heavy blows. Types commonly used are square face, straight pane, cross pane and ball pane as shown in Fig. 4.

Square. Straight Pane. Cross Pane. Ball Pane.

TYPES OF SLEDGE HAMMERS.

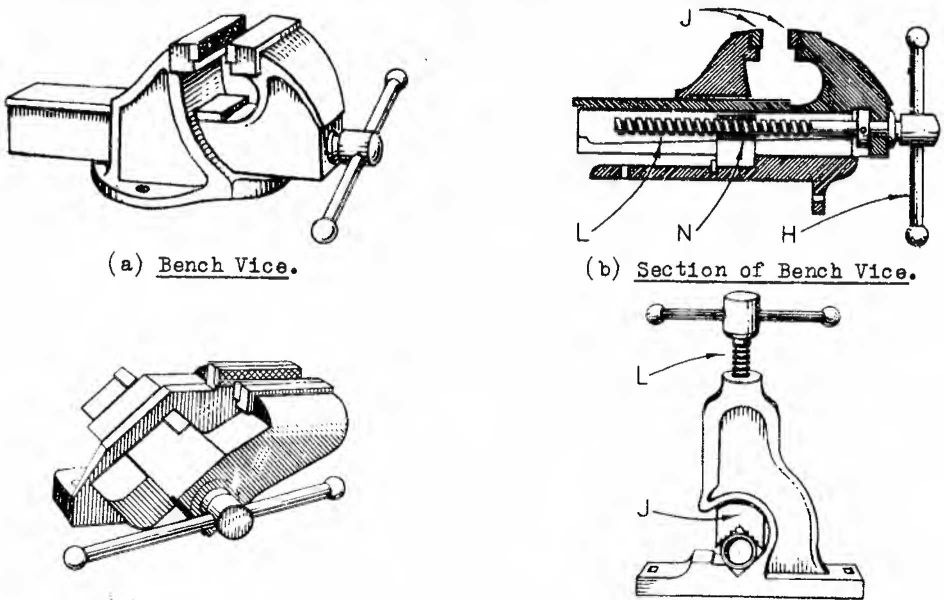
FIG. 4.

5. VICES.

5.1 Bench vices used for general work vary in size, weight and pattern to suit the many and various types of work on which they may be used.

5.2 Types of Vices. The Ordinary Bench Vice (Fig. 5a) has parallel jaws, (J in Fig. 5b) usually made of hardened tool steel and screwed on to the faces of the moving and fixed jaws (Fig. 5a). These jaws are moved outwards or inwards by rotating the handle (H in Fig. 5b) of the bar to which the lead screw L, is attached. This lead screw engages a fixed solid nut N, in the body of the vice.

The Quick-Release Bench Vice is similar to the ordinary type, except that it is fitted with a split nut which is opened by means of a lever placed near the lead screw bar. When the split nut is opened clear of the lead screw, it allows the front jaw to be moved backward or forward as desired without rotating the handle.



(a) Bench Vice. (b) Section of Bench Vice.

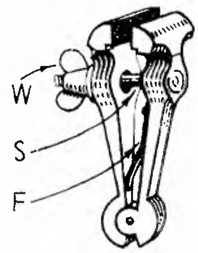
(c) Offset Vice. (d) Pipe Vice.

FIG. 5. BENCH VICES.

The Offset Bench Vice has the jaws offset as shown in Fig. 5c, to allow angular or wide work to be gripped at a distance from the normal line of bench vice operation.

The Pipe Vice (Fig. 5d) is adapted to hold round sections and metal tubes. It has either V-shaped or semi-circular jaws, into which are cut heavy serrations to grip the work. The top jaw J, is moved by turning the lead screw L, usually in the vertical position shown.

The Hand Vice (Fig. 6) is used for gripping small jobs which are to be worked on. This allows freedom of movement which is not possible with a fixed vice. The jaws are moved by turning the wing nut W. This nut bears against the front jaw which is free to move along the screw S. Tension is kept on the jaws by means of the feed spring F.



HAND VICE.

FIG. 6.

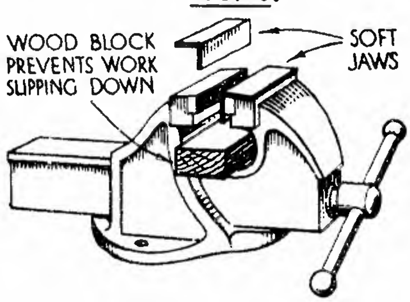
5.3 Points to Remember. In setting up a vice, ensure that it is firmly bolted to the bench and that the jaws are level.

The face of the back jaw must slightly overhang the edge of the bench to enable long work to pass down in front of it.

The top of the jaws should be at elbow height from the floor or approximately 40" above floor level for average use.

Clean the vice frequently and oil the screw occasionally.

Place a pair of soft jaws on the jaws of the vice to protect any work which is likely to be damaged when clamped in position. If necessary, put a block below the work to prevent it from slipping down in the vice, as shown in Fig. 7.



USE OF SOFT JAWS AND WOOD BLOCK.

FIG. 7.

Care should be taken that thin sections are not cracked or circular pieces bulged out of round by too much pressure being set up between the jaws.

Never strike the handle of a vice with a hammer to tighten it, or use the vice as an anvil.

6. TEST QUESTIONS.

1. Describe the more common hammers and state the purpose for which each is used.
2. What are soft hammers and why are they used?
3. Why should a hammer handle be gripped near the end?
4. Why does the eye in a hammer head taper from each end toward the middle?
5. Why must a hammer handle be set square with the head?
6. Name three types of vices and state what each is used for.
7. How can work be protected from being damaged by the jaws of the vice?
8. How can a piece of metal be prevented from working down in the vice?
9. What is the correct height for a vice on a bench?

END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

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COURSE OF TECHNICAL INSTRUCTION.

ENGINEERING WORKSHOP PRACTICE I.

HACKSAWS, CHISELS AND FILES.

CONTENTS.

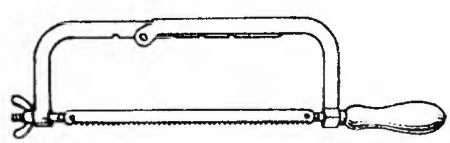
1. HACKSAWS.

1.1 Hacksaws are generally used in telecommunication engineering work as metal cutting saws and, because saw blades vary in length, the frame is usually of an adjustable type.

1.2 The common adjustable type, Fig. 1, has a series of slots provided in the solid arm, into which the second part of the frame can be fixed as shown, the position depending upon the length of blade used.

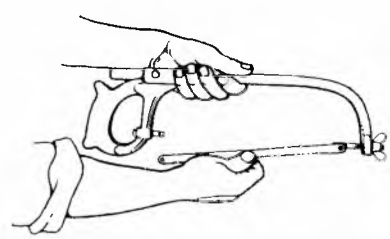
When inserting a hacksaw blade in the frame, Fig. 2, care should be taken to ensure that the teeth point away from the handle, that is, in the direction of the cutting stroke. It can then be placed between the two pins provided and tightened up to finger tight tension ready for use.

1.3 To prevent side movement, with the consequent danger of breaking the blade, a hacksaw should never be held by one hand when in use. Fig. 3 shows the proper method to hold and control a saw when work is being carried out.



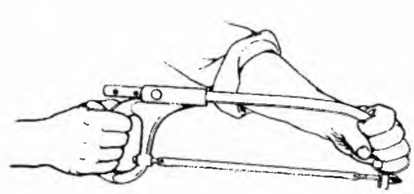
HINGED ADJUSTABLE HACKSAW.

FIG. 1.



METHOD OF INSERTING BLADE.

FIG. 2.



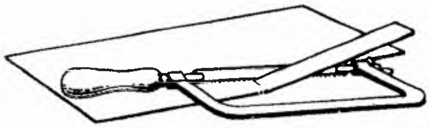
METHOD OF USING HACKSAW.

FIG. 3.

1.4 When metal has to be cut, which is of larger size than the capacity of the hacksaw frame with the blade in its usual position, the blade can be turned and the saw used as shown in Fig. 4. Different sizes of hacksaw frames are used to suit different working conditions.

1.5 Blades are made with various numbers of teeth per inch and the following will be a guide to ensure satisfactory results -

Mild steel materials and large sections.	14 teeth per inch.
Tool steels and hard materials.	18 teeth per inch.
Brass, Iron, Copper, etc.	24 teeth per inch.
Conduit, Sheet Metal, Piping.	32 teeth per inch.



USING HACKSAW FOR SIDE CUTTING.

FIG. 4.

When sawing material, it is good workshop practice to use a blade in which no less than two teeth are in contact with the metal at any time. Correct cutting position is shown in Fig. 5 and incorrect in Fig. 6.

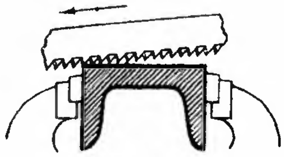
1.6 Hints to Remember.

(i) Hold the work securely, otherwise it may loosen under the pressure of the cut and the blade will be broken.

(ii) Do not, however, pinch a frail piece too hard.

(iii) The smaller pieces will break off easily when the saw-cut is two-thirds through.

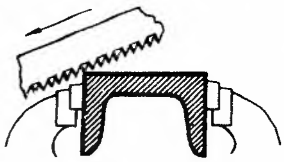
(iv) The tendency is to cut too fast with a hacksaw. Fifty to sixty strokes per minute is right for average work. The forward stroke is the cutting stroke; pressure should be relieved on the return stroke.



CORRECT CUTTING POSITION.

FIG. 5.

(v) The amount of pressure necessary depends on the kind of material, width of the cut and the conditioning of the blade. If, for example, a fairly thick piece of machine steel is to be cut, considerable pressure will be necessary to make the teeth "bite". If the same pressure is applied on a narrow piece or on soft material such as copper, the teeth biting too deeply will catch and probably break. The same reasoning applies when starting a cut on a corner or on a small rod or any thin section. It is good practice for the beginner to make a small nick with the edge of a file to start the cut.



INCORRECT CUTTING POSITION.

FIG. 6.

(vi) Be careful as the finish of the cut is approached or the teeth will dig in the thin section and break.

(vii) If a saw blade breaks when the cut is only partly finished start the new blade on another place on the stock. The "set" of the teeth of an old blade is slightly worn and the original cut is too narrow for the new blade, consequently the new blade will bind if it is attempted to continue the cut.

(viii) Keep the saw-cut straight. When the cut runs, the blade is cramped and will probably break. A blunt saw is very prone to run. If the cut starts to run, give the bar (round stock) about a quarter turn and begin a new cut. The first cut will help to keep the second one straight.

(ix) Never use oil as a hacksaw lubricant. Generally, lubricating is unnecessary when hand sawing. In some cases water may be used on a long cut as the water washes away the particles. Oil on the other hand causes the particles to become clogged in the teeth of the saw and eventually break it.

2. CHISELS.

2.1 Technicians use a variety of chisels to cut and chip or remove metal. When the chisel is used to sever pieces of metal, the cutting action resembles a wedging process, while in chipping the cutting action resembles a combination of wedging and shearing.

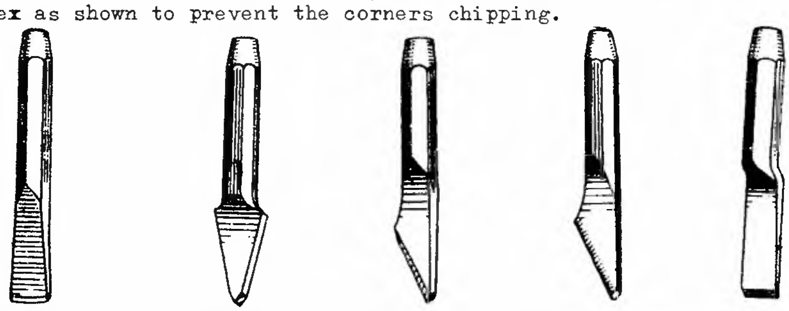
Chisels are driven either with a hammer or some form of pneumatic device. The pneumatic chisel is usually employed where a great deal of metal is to be removed.

The chisel is used to do special work or to remove surplus material roughly. Chipping is resorted to in cases where great accuracy is not essential and when it would be too expensive or impractical to set up the work in a machine.

2.2 Chisels are usually forged from octagonal or oval section tool steel containing about .8 per cent. carbon.

Chisel steel, when properly hardened and tempered, should be tough enough to withstand the impact of a blow delivered and yet sufficiently hard to maintain its cutting edge.

2.3 Types of Chisels. The Chipping or Flat (Fig. 7) is the most commonly used for general work. If employed on hard metals, the cutting edge is usually ground slightly convex as shown to prevent the corners chipping.



Chipping or Flat — Cross Cut or Cape — Diamond Point — Round Nose — Side Cutting.

TYPES OF CHISELS.

FIG. 7.

The Cross Cut or Cape chisel (Fig. 7) should have clearance ground back from the cutting edge. It is frequently used for cutting keyways in shafting or pulleys.

The Diamond Point chisel (Fig. 7) has the cutting edge ground to the shape shown and, for example, is used for cutting grooves in large diameter pipes or metal plate to enable them to be broken off.

The Round Nose chisel (Fig. 7) should also have clearance ground back from the cutting edge. It is used in cutting oil grooves in bearings etc., in positions or circumstances where machinery cannot be employed.

The Side Cutting chisel (Fig. 7) is most useful for chipping metal in corners or otherwise inaccessible places where the ordinary type could not be used.

2.4 Cutting Angles. The cutting angle of a chisel depends on the strength and class of material being cut (see Fig. 8). Chisels used on hard or tough metal require a strong cutting edge (included angle B, Fig. 9). This angle can be decreased for softer metals where less pressure is required in the cutting process.

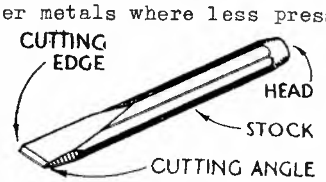


FIG. 8. COLD CHISEL.

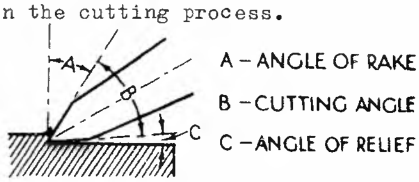


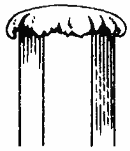
FIG. 9. CUTTING ANGLE.

Approximate cutting angles for common metals are - Cast Steel 70°, Cast Iron 60°, Brass 45°, Copper 45°.

2.5 Care of Chisels. The head of a chisel should be dressed if it becomes "mushroomed" while in use (Fig. 10). Always keep your chisel in good condition as it cuts the metal quicker, makes a better finished job and minimises the danger of accident.

Chisels with cracks or flaws should not be used, as the fracture may cause pieces of the steel to break off when a blow is delivered and the impact taken up by the chisel.

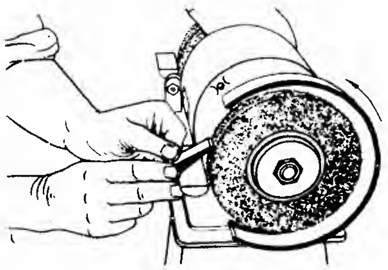
These cracks and flaws are caused by improper forging or heat treating. Cracks indicate that the tool was either forged too cold or heated above the critical range of the steel in the hardening process. Breaks are usually caused by poor tempering.



MUSHROOMED HEAD.

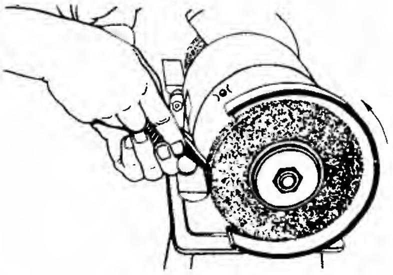
FIG. 10.

When grinding your chisel (Figs. 11 and 12), remember not to apply too much pressure or hold it too long on the wheel without cooling occasionally in water, otherwise sufficient heat may be set up to draw the temper of the steel.



CORRECT POSITION WHEN GRINDING.

FIG. 11.

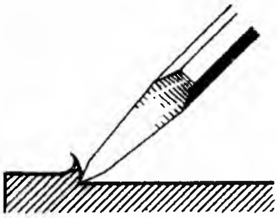


INCORRECT POSITION WHEN GRINDING.

FIG. 12.

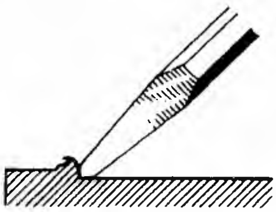
Care should be taken to grind the chisel to the correct cutting angle (see Figs. 13, 14 and 15). Always use goggles or a guard when grinding.

A greasy or oily surface on the head of a chisel may cause the hammer head to slip off when a blow is struck.



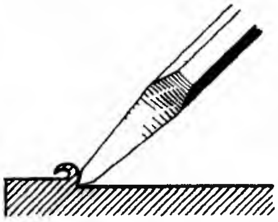
CUTTING ANGLE TOO SHARP.

FIG. 13.



CUTTING ANGLE TOO BLUNT.

FIG. 14.



CORRECT CUTTING ANGLE.

FIG. 15.

2.6 Using a Chisel. Chipping is the process of removing metal by means of a hammer and chisel, even although the use of the milling machine, planer and shaper are more efficient methods of removing metal accurately and rapidly. The use of a chisel is indispensable on many jobs in awkward positions, or where accuracy is not important and only a small amount of metal is to be removed.

Always see that the job is firm and secure before starting operations, and where possible fix it in a vice. If the work has finished surfaces or will be damaged by the hardened jaws of the vice, place "vice clamps" of some soft material such as copper between the vice and the job.

Grasp chisel with the thumb and fingers of left hand (Fig. 16), taking care that the thumb and forefinger are slightly relaxed so as to take up the shock of the hammer blow. Remember the head of your chisel must not be "mushroomed" as the particles may break off and cause injury.

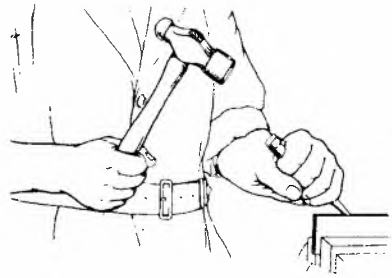
Place cutting edge of chisel on the job where cut is to be made, holding the tool at the proper angle.

If the chisel is held too high, it will cut deep; if held too low it is apt to slip while chipping.

Grasp the hammer near end of hickory handle (Fig. 16), so that it can be swung with an easy forward motion and strike head of chisel with a firm sharp blow.

Watch the cutting edge of your chisel, not the head, as by so doing you can control the cutting process.

Raise or lower the chisel as needed in order to chip to the desired depth. It is good practice to chip from the outer edges of a piece of work toward the middle. This prevents tearing and breaking away of the edges and corner.



METHOD OF HOLDING HAMMER AND CHISEL.

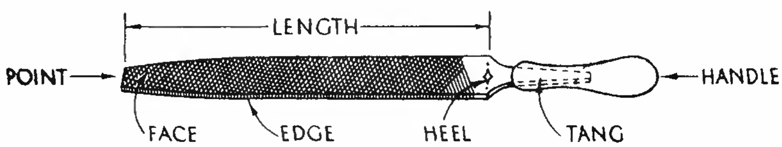
FIG. 16.

3. FILE.

3.1 The file is an indispensable workshop tool. It has a wide range of application for roughing and finishing surfaces. It may be used to shape small parts, slightly reduce the size of parts to fit together, remove tool marks, prepare surfaces for polishing and for many other operations where a job is to be altered or shaped.

The file is a cutting tool which has a large number of teeth cut diagonally on the face. Most files are made of high grade tool steel and are properly hardened and tempered. They are manufactured in a variety of shapes and sizes suited to the job on hand and are known either by the cross section, the general shape or by their particular use. The cuts of files must be considered when selecting them for various types of work; such as roughing, finishing or draw-filing.

3.2 Description. The parts of a file are known as the tang, heel, face, edge and point (see Fig. 17).



PARTS OF FILE.

FIG. 17.

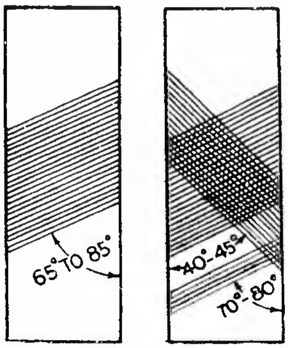
There are three general distinguishing features -

(i) Length.
(ii) Cut, and
(iii) Kind.

Length, as shown in Fig. 17, is the distance from the point of a file to the heel.

Cut has reference to the character and grade of the teeth (see Fig. 18). A single-cut file is one in which a single unbroken series of teeth are cut across its surface parallel to one another, and this is known as the overcut. A double-cut file is one which has a second series of teeth, or an upcut, cut across the surface. The teeth are shaped to form a cutting edge similar to a lathe tool bit; they have a rake and clearance angle.

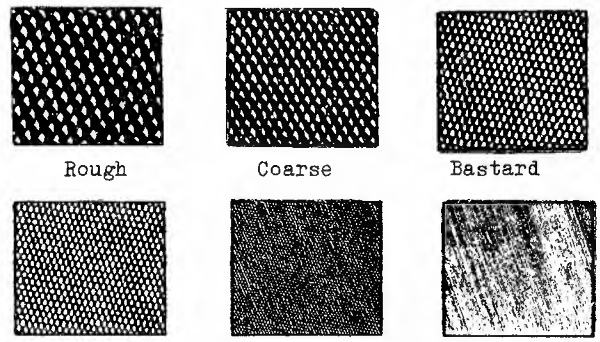
The grade of teeth is shown in Fig. 19, and has reference to the distance apart of each tooth.



Single-Cut Double-Cut

CUTS OF FILES

FIG. 18.



Second Cut Smooth Dead Smooth

GRADE OF FILE TEETH.

FIG. 19.

Rough - 10-15 teeth per inch.

Coarse - 15-20 teeth per inch.

Bastard - 20-30 teeth per inch.

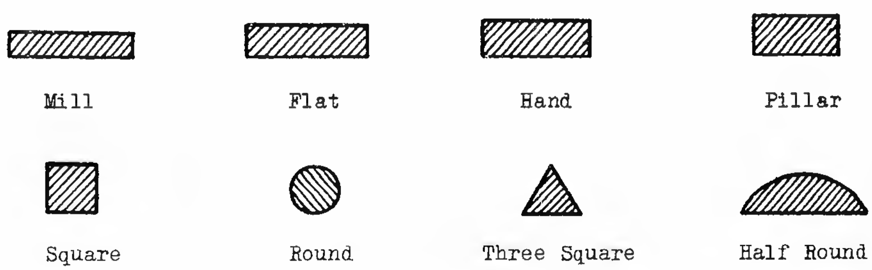
Second cut - 30-40 teeth per inch.

Smooth - 50-60 teeth per inch.

Dead Smooth - 90-160 teeth per inch.

Kind - means the variety of shapes and cross sections which may be divided up into circular, quadrangular, triangular and miscellaneous types.

3.3 The proper selection of a file for the job on hand requires a knowledge of the various shapes and their application. A flat file is used to file flat surfaces (see Fig.20). The mill file is a general all-round file especially adapted for finish filing on the lathe. Half round files are used on concave surfaces and large radii, while round files are better suited to small radii. When the edge of a file is left smooth, it is called a "safe" edge file.



SHAPES OF COMMONLY USED FILES.

FIG. 20.

3.4 Types of Files and their Particular Uses. Types and uses of files are included in this Section.

Half Round. This file is generally double-cut on the flat face and single-cut on the rounded back. If tapered, and it is usual to find it so, all the tapering is carried out on the rounded back and in the width, the flat face being literally flat. The section is not actually semi-circular as the name implies, but is a minor segment of a circle. The half round file is largely used for bedding in bearings, filing out grooves and general work.

Round. This type can be obtained either taper, (in the smaller sizes frequently referred to as rat tail) or blunt, is single-cut and is generally used for enlarging holes or forming grooves.

Three Square. This file is an equilateral triangle in section, is frequently tapered but can be obtained blunt and is always double-cut. The three long edges are left sharp but uncut and it is used for cleaning out sharp angles and square corners. This type must not be confused with the saw-file which it so closely resembles.

Saw. This file is also an equilateral triangle in section but is practically always single-cut on the faces and the edges, these latter being slightly rounded to leave a rounded bottom in the gullet of the saw-tooth, this tending to prevent the formation of cracks. Used for sharpening wood-saws for hand use, band-saws, etc., it is made either taper or blunt according to requirements.

Square. This file is square in section, can be obtained blunt or taper and is double-cut. It is used for enlarging square holes, cleaning out square corners, converting drilled holes to square holes and for trueing up concave surfaces such as engine bearings, the taper square being particularly suitable for this work.

Flat. This file is usually double-cut on the faces and single-cut on the edges, is rectangular in section and usually tapers both in width and thickness. It is a very popular and useful type and is used mainly for roughing down flat surfaces and for general work.

Hand. This type is also rectangular in section, is made parallel in width, tapers in thickness and is double-cut on the faces and single-cut on one side. The remaining edge is left uncut, this safe edge as it is termed, ensuring that the particular edge will not cut if it rubs against the completed surface of an internal angle whilst the other face is being filed. Apart from this special use it serves the same purpose as the flat file with which it is often confused. Hand files have more belly than flat files. The name does not mean that these files are particularly made for use by hand, it is merely a trade name denoting a particular type of file.

Warding. The chief characteristic of this file is its extreme thinness, this being necessary because it is used for forming the narrow wards in keys and locks. It is rectangular in section, double-cut on the faces, single-cut on the edges, tapers considerably in width but is always uniform in thickness.

Mill. These files are sometimes rectangular in section but are often made with one or both edges rounded. They are supplied taper or blunt and are always single-cut on sides and edges and are used for sharpening mowing and reaping machine blades and certain types of mill saws, filing in the lathe, etc.

Needle. These are small slender files from 4-1/2" to 6" in length (measured over-all) and are made in all the different conventional sections. Only half the length is cut, the balance of the file being formed into a long cylindrical handle. These small files are used for intricate and delicate work and for jewellers purposes.

Dreadnought. This file is used for filing lead. It is single-cut on both faces, the cuts being a semi-circular form.

3.5 Use of Files. When filing, the work should not be hurried and an even pressure should be exerted on the file. Remember that the angle of the teeth on a file is set to cut the metal when the file is pushed forward and this should be the time to exert the greatest pressure on the file.

With new files the points of the teeth are very keen and fine, and great care should be taken not to break these. It is good practice first to use a new file on finishing non-ferrous metals such as brass or bronze which require keen cutting teeth, and then employ it on the harder metals. A file should not be used without a handle, as the tang may be driven into the palm of the hand resulting in injury.

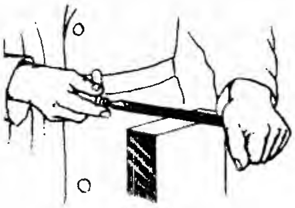
The correct stance for filing at a bench vice is shown in Fig. 21. The filing is done at elbow height of the workman and the feet are slightly apart. The left foot should point forward toward the bench with the right foot close enough to the left to give the necessary balance. When filing, the body should lean forward at the hips on the forward stroke for about two-thirds of the distance, returning to the original position at the end of the stroke.

CORRECT STANCE FOR FILING.

FIG. 21.

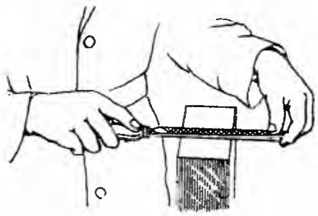
For heavy filing, Fig. 22, a coarse file is generally used and the greatest pressure exerted on the file. When filing a flat surface do not keep the file moving on the same part of the work, but use it all over the surface thereby ensuring a level finish.

Light filing (Fig. 23) and finishing (Fig. 24) are used after the rough work is completed and very little metal has to be removed. Usually a finer grade of file is employed when the finishing operation is being carried out.



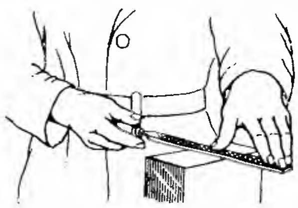
HEAVY FILING.

FIG. 22.



LIGHT FILING.

FIG. 23.



FINISHING.

FIG. 24.

Draw filing is sometimes used to produce a "grained" finish and where a very little metal has to be removed, especially on edges and narrow surfaces of work. Tool marks, coarse file marks or deep scratches are easily removed by draw filing.

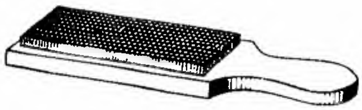
Single-cut files are frequently used because the angle of the teeth produces a shearing action in removing the metal. This type of file is held crosswise and an even pressure applied to both ends, so that it lies flat on the surface to be draw filed. Push and pull the file along the entire length of the job, being careful not to rock the file on straight surfaces. On rounded surfaces, follow the contour of the work making sure that an even grain is produced all over.

To prevent deep scratches in the work a file must be kept clean at all times when draw filing. "Pinning", or the wedging of small metal particles between the teeth, can be partly avoided by chalking the file. The degree of smoothness is determined by the cut of the file. Usually a coarse file is used for draw filing soft materials and a second cut where a smoother surface is required. The surface may be polished still finer by holding a piece of emery cloth under the file and moving it over the work in the same manner as draw filing.

3.6 Care of Files. The cutting action of a file produces small chips called filings, and these small particles of metal frequently become wedged between the teeth of the file due to the pressure exerted. When drawn across the work, these tend to scratch the surface and impair the free cutting action of the file. Frequent cleaning is necessary in order to give satisfactory results.

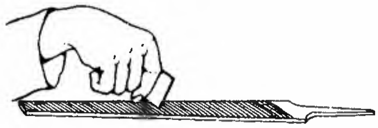
Card wire nailed upon a board furnished with a handle, as in Fig. 25, is frequently used to clean the file teeth. If particles of metal are so firmly wedged that they cannot be removed with a file card, a good method is to use a narrow strip of brass or copper. The strip of metal is pushed across the file parallel with the teeth, and this action should dislodge the particles from the file (Fig. 26).

Rapping a file on the bench, vice or work should be avoided, since the hard edge of the file damages softer materials.



FILE BRUSH.

FIG. 25.



CLEANING A FILE.

FIG. 26.

4. GRINDING WHEEL.

4.1 The grinding wheel is perhaps the most dangerous and most abused tool in the workshops. Special care is needed when using this tool (see Figs. 11 and 12).

Two wheels are usually provided, one for general work and one for tools only.

Light pressure only should be used when grinding and the work must be kept moving across the face of the wheel. A groove in a wheel denotes careless use of the wheel. The side of the wheel should not be used.

Goggles should always be worn when grinding and the operator should stand out of the plane of rotation. Remember that sparks and chips of metal travel at about one mile per minute when they leave the wheel.

Do not use a damaged wheel but report it to your senior officer.

5. TEST QUESTIONS.

1. When using a hacksaw, which stroke is the cutting stroke?
2. Which way should the saw be placed in the frame?
3. How should a chisel be grasped? How tightly?
4. What is the best cutting angle for a cold chisel?
5. What is the difference between a "single-cut" and a "double-cut" file?
6. What is meant by a "safe edge" on a file? When is it advisable to use a file with a safe edge?
7. Should the file be lifted from the work on the return stroke. Why?
8. What is the difference between a "double-cut" and a "second-cut" file?

END OF PAPER.

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COURSE OF TECHNICAL INSTRUCTION.

MARKING OUT AND MARKING-OUT TOOLS.

CONTENTS.

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1. MARKING OUT.

1.1 "Marking Out" or "Lining Out" is the process of placing lines on castings, forgings or any type of engineering work, to indicate the exact position and nature of the operation specified in the drawing.

1.2 The principles applied in marking out are the same as those involved in mechanical drawing, yet the application is entirely different. The draughtsman may obtain his centres and lines for one view or side of a piece by projecting those from another view or side of a piece, whereas, in marking out, the lines in some instances must be transferred from one side of the work to the other. Marking out requires also to be more accurately performed than do the lines on a drawing, because the variation to an amount of the thickness of a line may involve the spoiling of a piece of work or entail a great deal of extra labour in fitting the parts together.

Exact measurements are necessary. The tools and measuring instruments must always be kept in good order.

1.3 Before any marking or work is done on a job, it should be carefully examined and checked with the drawing to decide whether marking is necessary, and if so, to what extent.

The job should then be carefully measured to ensure that sufficient metal is left on the various parts to be machined, thereby enabling them to be machined in the proper relation to each other. It should also be checked over to ensure that there are no defects that would cause it to be rejected later.

1.4 The actual marking and the tools used vary with the particular type of work, but all parts to be machined should be marked with lines for setting up and guide lines for machining. These lines should be made permanent by light punch marks usually carried out with a prick punch and sometimes work is partly marked and then partly machined before the marking is completed.

Owing to the difficulty of marking surfaces finely and plainly, the job to be marked is usually coated with some type of marking medium which enables the lines to be distinctly seen. For small rough work such as castings, chalk well rubbed in can be used, and for larger surfaces white lead and turpentine or whiting mixed with water may be painted on.

For finished or polished iron, and steel surfaces, a commercial line of "lay out" stain is available. A remover is used to remove the stain after use. Tool makers sometimes blue the steel by heating and this oxidised surface enables the finest lines to be clearly seen.

1.5 Types of Lines. A foundation line is a line made on the work from which a number of dimensions are measured, to avoid the cumulative error which may occur when measuring is carried on from line to line in progression. This line may be a machining line or it may be laid out for the purpose of measurement only.

A data line is a line marked on work to assist in establishing the position of dimension lines, such as a centre line from which to mark circles or radii.

A dimension line is a line which indicates the dimension or size to which work is to be finished, such as a circle indicating the size and position of a hole.

1.6 Hints on Marking Out.

(i) True base or line to work from is essential.
(ii) Careful reading of measurements is essential.
(iii) Check itemised measurements to conform to over-all dimensions.
(iv) Surfaces to be marked out must be smooth, clean and coloured.
(v) Prick punch must be held perpendicular and struck with hammer in line with axis of punch.
(vi) Vertical and horizontal lines are preferred to arc lines.
(vii) How to use a scale for measuring -

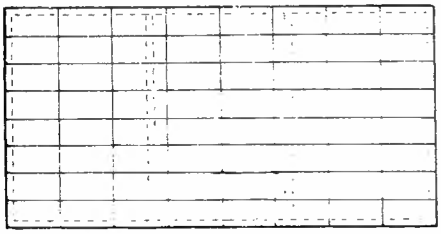
(a) Place the rule on its edge so that the scale is as near as possible to the object to be measured.
(b) See that the line of sight from the eye to the scale is at right angles to the scale.
(c) Place one end or line of the object to be measured exactly opposite the first unit mark on the scale
(d) Setting the divider, place one leg in a convenient graduation line on the scale, that is, 1 inch line, and adjust the other leg until it exactly splits the graduation line the correct distance away. The graduation lines being V-shaped, the divider point can be more exactly set by feeling than by sight. Adjust until no give can be felt on either side of the "V".

2. MARKING-OFF TABLE.

2.1 The basic essential for lining out is the surface or marking-off table, and this is usually a strong cast iron plate with a rigid webbed section. It has an accurately machined flat surface and the edges are finished at right angles to this surface. This is often crossed at right angles by parallel lines at convenient distance for truing up distances, laying off angles, etc. (Fig.1).

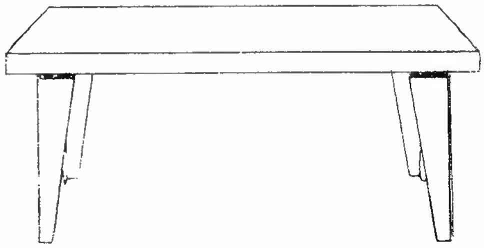
A common method of mounting a table on stoutly constructed legs is shown in Fig.2, while others have three-point suspension in which the table is supported on three adjustable screw pivots which allow it to be levelled up.

The marking-off table should be well lit and placed free from obstructions so that the users are free to walk around it and work from any side.



TOP OF MARKING-OFF TABLE.

FIG. 1.

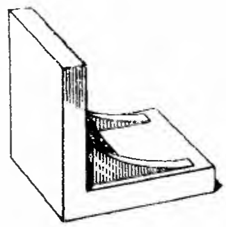


MARKING-OFF TABLE.

FIG. 2.

3. ANGLE PLATE.

3.1 The angle plate is an "L" shaped piece of cast iron or steel (Fig. 3) carefully machined to an angle of 90°. It is used when the job must be held at right angles to the bench or surface table, thus being securely held and fixed on the angle plate while lining out or checking is carried out.



ANGLE PLATE.

FIG. 3.

3.2 Before using the angle plate, check the job with the blue print or drawing to determine the locations of lines to be scribed and then select an angle plate of suitable size to accommodate the job on hand.

Now remove all burrs from surfaces of work and prepare them for marking. If rough, use chalk or whiting and turpentine in the form of a paste, or if the surface is machined, use copper sulphate. The surface table, angle plate, job, etc. should all be clean and the plate set in position on the table with the machined surface of the job against it. In the example shown in Fig. 4, the job has been placed on two parallel strips before being secured to the angle plate by clamps. With the clamps placed so that they do not interfere with the scribing of lines, set the surface gauge to the desired height and scribe a centre line. Now scribe other parallel lines in relation to the centre lines as required, and then turn the angle plate in the positions necessary to enable all other lines to be lined out. Work can then be removed from angle plate and centre punched where necessary after the lay out has been checked for errors.

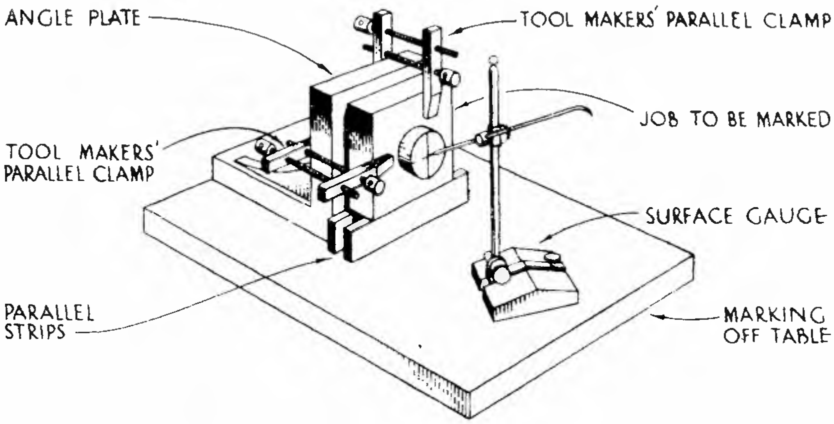


FIG. 4. METHOD OF LAYING OUT WORK ON AN ANGLE PLATE.

4. VEE BLOCKS.

4.1 Vee blocks (Fig. 5) are made of either cast iron or steel in many different sizes to accommodate a wide range of work. They may be machined with a "V" slot of 90° in the top, with a slot top and bottom, or with four slots, the additional two being machined along the two sides.

In the example shown, the sides are grooved to receive the clamp yoke which is used to hold the job securely in place while being marked out, drilled or machined.

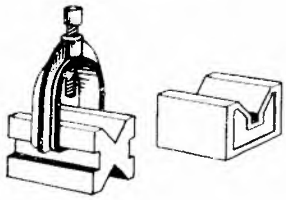


FIG.5. VEE BLOCKS.

FIG. 6. BOX SQUARE.

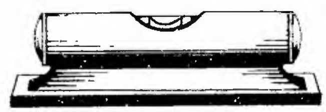


FIG. 7. ENGINEER'S LEVEL.

5. BOX SQUARE.

5.1 This is a straight edge of L section and is used for marking lines along the surface of round sections parallel with the axis (Fig. 6).

6. ENGINEER'S LEVEL.

6.1 The Engineer's Level (Fig. 7) is used to test or adjust horizontal surfaces. The frame of this level is of metal, the flat base frequently being grooved to enable it to be used on round shafts etc. To check a level for accuracy turn it end for end on a flat surface, and if it is accurate the two readings should be alike or in other words the bubble will come to rest in exactly the same position when the level has been reversed.

7. SCRIBERS.

7.1 The Scriber is a tool used to lay out and mark off lines on metal surfaces. All lines must be sharp and clear and this necessitates a hard sharp pointed tool.

7.2 Types. (See Fig. 8.) Straight scriber, usually of hardened steel with fine point ground on end.

Pocket scriber, in which the scriber is gripped in a small chuck. This detachable portion can be reversed so that the point is held inside the handle as shown. It enables the scriber to be carried in the pocket without danger.

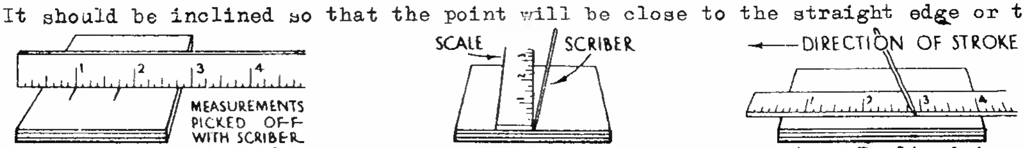
FIG. 8. TYPES OF SCRIBERS.

The Knife Edge type is used for marking out very fine lines.

The Bent or Hook type has one end bent as shown, making it very useful for marking off through holes etc. and in positions where a straight scriber could not be used.

7.3 Using the Scriber. (See Fig.9.) The scriber should be used in the same manner as a pencil.

It should be inclined so that the point will be close to the straight edge or template.



Rule Used on Edge when measuring.

Scriber Inclined Away from Rule.

Scriber Inclined in Direction of Stroke.

FIG. 9. USING A SCRIBER.

It should also be inclined slightly in the direction of the stroke.

Scribe only one firm line, as a retraced line is apt to make two confusing marks.

In scribing lines a marking medium of whiting, copper sulphate, Prussian blue, etc. is often used to show up the lines more clearly.

In scribing lines on wood (ebonite or such materials) good results can be obtained by using French chalk or very soft lead pencil well sharpened.

8. CENTRE PUNCH AND PRICK PUNCH.

8.1 These punches are usually made from cast steel, or from steel with approximately 0.5 per cent. carbon. They are made of hexagonal or round section, tapered at one end with a point ground to the suitable angle.

8.2 Types. (See Fig.10.) The Prick punch should not be confused with a centre punch. It has a finer point approximately 30°, and is used for making light indentations as for the point of the divider.

The Centre punch is commonly used for marking centre points preparatory to drilling, for outlining work previous to machining, etc. and is usually greater in section than the prick punch. The point may be ground to angles between 60° and 90° and a heavy indentation is made in the material.

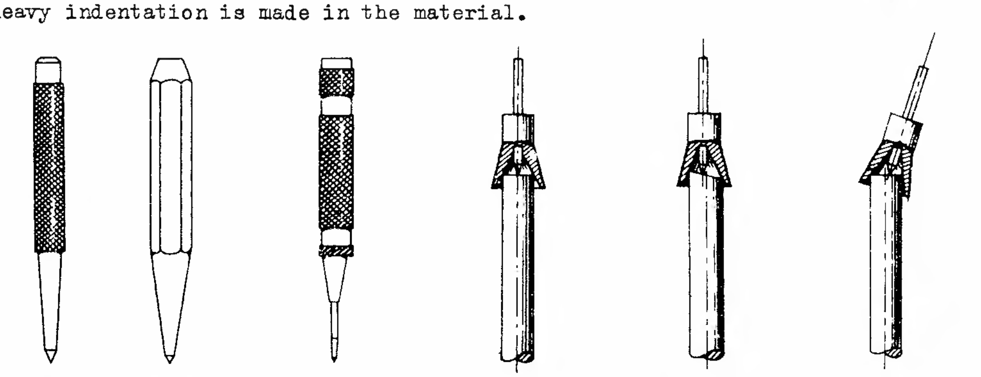


FIG. 10. TYPES OF PUNCHES.

The Automatic centre punch does not require to be struck with a hammer when used. When the top of the punch is pressed down by hand a spring is released which forces the point of the punch into the material against which it is held.

The Bell punch is a useful tool for centring small diameter round stock. The end of the material must be properly squared off before the punch is employed, and accurate results will not be obtained if it is used on rough stock or held off-square.

8.3 Using Centre and Prick Punch. The punch is held between the thumb and first and second fingers, being steadied in position by placing the small finger on the material as shown in Fig. 11.

The punch is brought to the perpendicular position and a light hammer blow struck on the head. If the indentation is in the exact position required, a heavier blow with consequent deeper mark is now carried out.

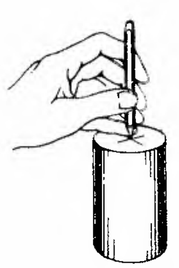


FIG. 11. USING PUNCH.

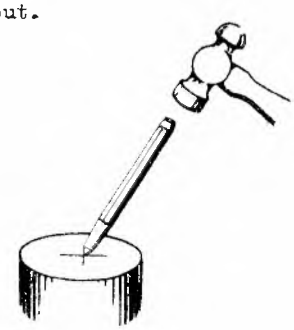


FIG. 12. MOVING OVER PUNCH MARK.

If the original mark is not in the correct spot, it may be moved over by holding the centre punch at an angle and striking as shown in Fig. 12.

When using the punch, remember to watch the point, not the head of the punch, which is being hit with the hammer.

9. DIVIDERS.

9.1 Dividers are a two legged marking out tool used for marking distances and scribing circles. Both legs are pointed and attached to each other to allow the points to be set a specified distance apart and fixed at that measurement.

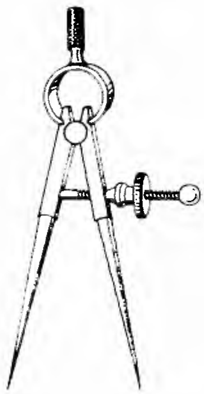
9.2 Types. The common Quadrant type is shown in Fig.13, in which the legs are pivoted together and a quadrant fixed to one of these, passing freely through the other. A screw fitted through the latter leg bears against the quadrant and so keeps the dividers in the required position. Fine adjustment is made by the knurled nut.

In the Spring type (Fig.14), the legs are pivoted, and an outward tension is maintained on them by means of the spring at the top. The screw-thread is fixed to one leg and passing through the other, allows the movement of the divider legs to be controlled by the knurled adjusting nut.

9.3 How to Use Dividers. Inspect the hardened points of the dividers to make sure they are sharp. When necessary, the sharpening can be done on an oilstone (Fig.15), thereby ensuring fine lines being marked out. Care should be taken to keep the legs an equal length.

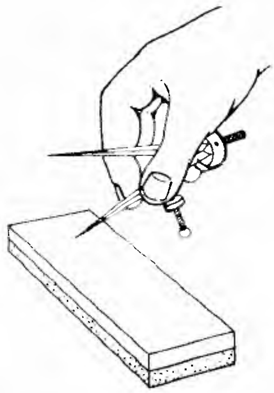
QUADRANT TYPE DIVIDERS.

FIG. 13.



SPRING TYPE.

FIG. 14.



SHARPENING POINTS ON OILSTONE.

FIG. 15.

To set the dividers hold in left hand and place the point of one leg in a graduation on steel rule (Fig.16). By turning knurled adjusting nut with the thumb and forefinger of right hand, adjust the divider until point of other leg rests in the graduation which gives the required measurement.

To scribe an arc or circle with the dividers, grasp the knurled attachment on top with the thumb and forefinger of the hand (Fig. 17).

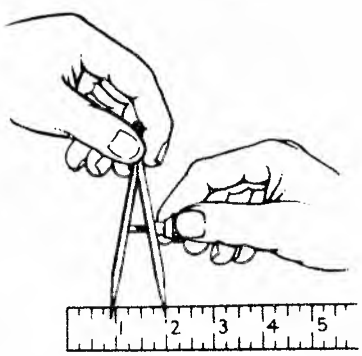


FIG. 16. SETTING DIVIDERS.

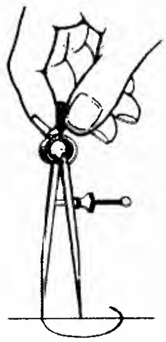


FIG. 17. USING DIVIDERS.

10. HERMAPHRODITE CALIPERS OR JENNIES.

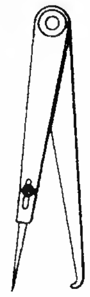
10.1 These Jennies, or odd legs as they are also called, consist of one divider leg and one caliper leg, which are usually rivetted together to provide a firm joint. They are used for locating centres of round pieces, centres of bosses etc., and also to scribe a line or locate a point parallel with a surface or shoulder.

10.2 Types. In the fixed leg type (Fig.18), the divider leg is in one piece as shown, and so with repeated regrinding and sharpening becomes useless when shorter than the caliper or bent leg.

The adjustable type is shown in Fig.19. The scriber is made of tool steel and has a locking adjustment as shown, to secure and keep it at the correct length to suit the caliper leg. This means the scriber can be easily removed, replaced or renewed when necessary.

FIXED LEG JENNIES.

FIG. 18.



ADJUSTABLE LEG JENNIES.

FIG. 19.

11. USING HERMAPHRODITE CALIPER.

11.1 To set the jennies for use, place the caliper leg on the end of rule and set the scriber point to required dimension (Fig.20). For external measurements reverse the jennies as shown in Fig. 21.

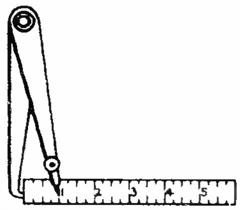


FIG. 20. SETTING CALIPER.

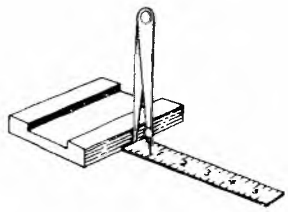
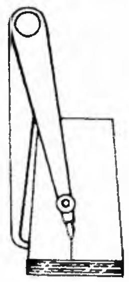


FIG.21. SETTING FOR EXTERNAL MEASUREMENT.

To scribe a line parallel to an outside edge, set caliper leg against the edge and scribe the line as in Fig. 22.

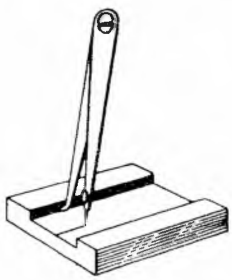
To mark off line parallel to an internal edge set jennies and use as in Fig. 23.

To find centre of circular stock set jennies at the approximate radius, and scribe lines when the caliper leg is placed in four different positions round the periphery. The centre will be in the middle of the small rectangle as marked in Fig. 24.



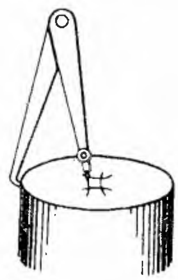
SCRIBING PARALLEL LINE.

FIG. 22.



LINE PARALLEL TO INTERNAL EDGE.

FIG. 23.



FINDING CENTRE.

FIG. 24.

12. THE SURFACE GAUGE.

12.1 The Surface gauge is an instrument used for scribing lines at a given height from some face of the work or for the construction of lines around several surfaces of a job. The gauge consists of a heavy base and a spindle pivoted upright, to which is attached a scriber held by a clamp. The scriber may be turned through a complete revolution, while in some types the pillar can also be set at different angles from the perpendicular.

12.2 Types. The Common Surface gauge (Fig.25) consists of the pillar rigidly fixed into a base, and a scriber, the adjustment of which is made with the clamping device shown.

The Universal type (Fig.26) is provided with a pillar P which is pivoted to the base B and can be secured in any desired position.

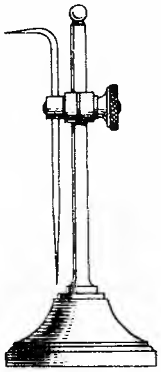


FIG. 25. COMMON SURFACE GAUGE.

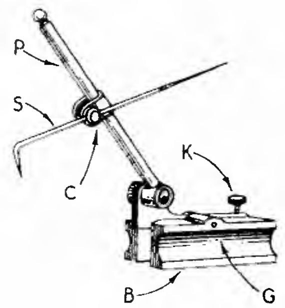


FIG. 26. UNIVERSAL TYPE SURFACE GAUGE.

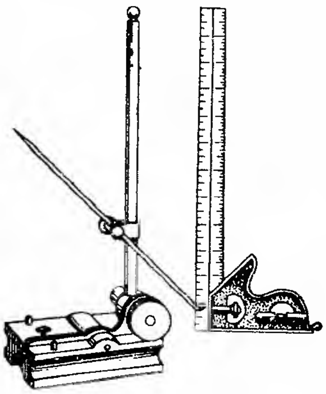
The preliminary setting of the scriber S is made with the usual clamping device C, while a fine adjustment to pillar and scriber is carried out by means of the small knurled screw K. The bent end of the scriber permits lines to be drawn on horizontal surfaces, while a groove G in the base makes it possible to mark out desired distances from the outside of a circular piece of work.

12.3 Using Surface Gauge. By resting both the surface gauge and work upon a plane surface, it is possible to set the point of the scriber at a given height either by using a scale (Fig. 27) or some other standard, and draw lines at this height on all faces of the work or on any number of pieces when duplicate parts are being made. The use of the gauge is not confined to the scribing of horizontal lines, but may also be used on other surfaces from which it can be conveniently guided or held.

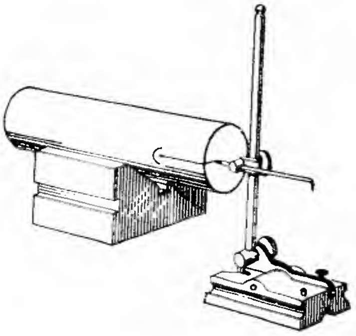
The surface gauge can also be used as a height gauge and for levelling work on a machine vice or plate. To scribe lines, grasp the surface gauge at the base and move it along the surface plate or table with the scriber point bearing against the work to be marked off.

In Fig. 28, the gauge is being used to mark out a piece of round work placed in a Vee block, while Fig. 29 shows its use in scribing parallel lines on a horizontal surface.

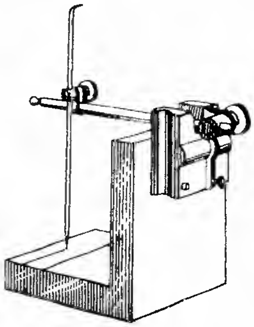
The surface gauge will be more rigid if the scriber is clamped close to the spindle, and as near the base as possible.



USING SURFACE GAUGE WITH SCALE.
FIG. 27.



USING SURFACE GAUGE ON ROUND WORK.
FIG. 28.



USING SURFACE GAUGE ON HORIZONTAL SURFACE.
FIG. 29.

All rough projections etc. should be removed from surfaces upon which lines are to be drawn as well as those upon which the work rests.

Always clean the base of the surface gauge, the plate or table etc. on which it rests, and the work; then decide on the best position in which to set the spindle and scriber on the gauge.

A marking medium, such as chalk for rough or unfinished surfaces, and Prussian blue or lay out stain, should be used to make the lines and marking more legible on finished surfaces.

Colouring by heat is sometimes used on jobs where the temper of the metal is not to be considered, and it provides a blue colour through which the scribed lines are plainly seen.

13. TRAMMELS.

13.1 In the workshop, trammels are used for the same purpose as dividers but usually for marking out work of larger dimensions.

13.2 Types. In the adjustable type shown in Fig. 30, each leg can be moved along the round metal beam B and secured in any desired position. These legs are provided with small colletts C, which will hold the variety of points etc. required for different types of work. Attached to one leg is a small adjusting screw S, thereby enabling fine adjustments to be set.

A type for small work is shown in Fig. 31. The beam in this one is also made of metal, although some trammels are provided with a graduated wooden rule along which the legs are moved and fixed at the required dimension. With this latter type the measurements can be quickly obtained from the wooden beam without resource to any other rule, etc.

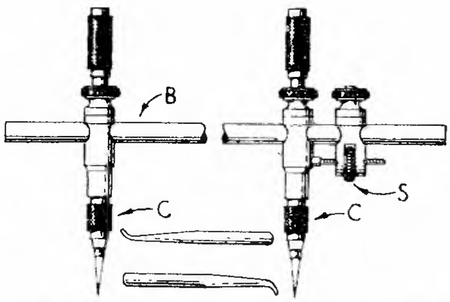


FIG. 30. ADJUSTABLE TYPE TRAMMEL.

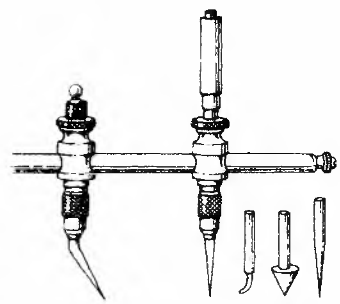
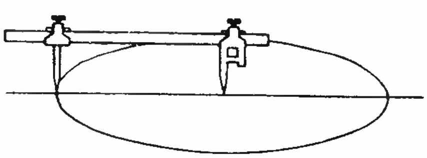


FIG. 31. TRAMMEL FOR SMALL WORK.

13.3 Using a Trammel. The measurements may be made by setting one point on unity or some intermediate mark, and then adjusting the second point to the measurement required, as shown in Fig. 32.

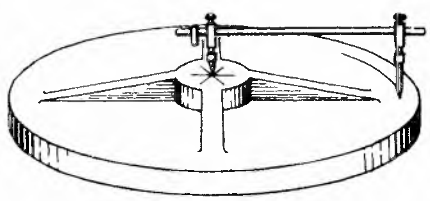
FIG. 32. ADJUSTING TRAMMEL TO MEASUREMENT.

A circle may be scribed by placing one point in centre punch mark, denoting centre of circle, and other leg and point used to mark out the circumference of the circle(Fig.33).



SCRIBING CIRCLE WITH TRAMMEL.

FIG. 33.



MARKING OFF CASTING WITH TRAMMEL.

FIG. 34.

In Fig. 34, trammels are being used to mark off a casting before machining is carried out. Notice that in this example the legs are of unequal length to suit the special requirements.

14. PARALLEL STRIPS.

14.1 These consist of a pair of cast iron or hardened steel strips of rectangular section (see Fig.35). They are planed or finished off by grinding in pairs to equal widths and thicknesses, and are frequently used to pack up work, for precision marking out or machining. Pairs can be obtained of various lengths and sizes.

15. PROTRACTOR.

15.1 The protractor is a precision instrument which is used to mark off, measure or form any angle required between lines or surfaces. The ordinary protractor is semicircular in shape and is graduated in degrees and half degrees from 0 to 90 in both directions as shown in Fig. 36.

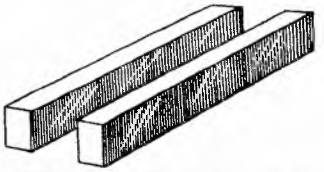


FIG. 35. PARALLEL STRIPS.

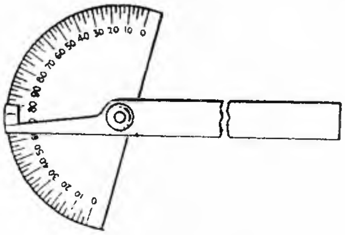


FIG. 36. PROTRACTOR.

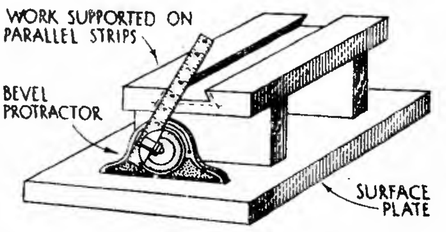


FIG. 37. SETTING OUT ANGLE WITH BEVEL PROTRACTOR.

For accurate measurement the protractor is fitted with a vernier scale, the principle of which is explained in Paper No.6, Section 5.

An example of a bevel protractor being used for setting out an angle is shown in Fig. 37.

16. STRAIGHT EDGE.

16.1 The Straight Edge is usually made from steel in the shape of a rule with a bevelled edge and is accurately finished all over. As the name implies, the edges should be perfectly straight. This tool is used to test surfaces for straightness or flatness, to align components when work is being set up, and in conjunction with a scriber or similar aid, to enable straight lines to be marked out.

17. TEST QUESTIONS.

1. What is meant by "Marking Out" or "Lining Out"?

2. What is the difference between a prick punch and a centre punch?

3. What is meant by a foundation line, a data line, and a dimension line?

4. What do you mean by checking the lay out? When is it advisable?

END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

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Postmaster-General's Department,
Treasury Gardens,
Melbourne, C.2.

COURSE OF TECHNICAL INSTRUCTION.

MEASURING TOOLS.

CONTENTS.

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1. INTRODUCTION.

1.1 The measuring of material and machined work involves the use of a number of measuring tools to secure sizes of length, width, thickness and diameter. One or more of these factors may be involved when determining the size of material or a piece of work.

The British standard of length is the Imperial Standard Yard, and is represented by the distance between two lines inscribed on two gold plugs, which are inserted into a bar of bronze. This standard is preserved at the Standards Department of the Board of Trade, London.

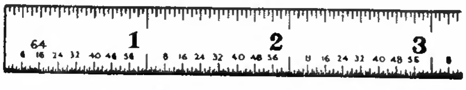
In machine-shop work the more commonly used unit is the inch, the thirty-sixth part of a yard, and the inches may be divided into smaller parts by means of either common or decimal fractional divisions.

The fractional divisions of an inch are found by dividing the inch into equal parts; first into halves, then into quarters, eighths, sixteenths, thirty-seconds and sixty-fourths. When smaller units of measurement are required, the decimal system is used, in which the inch is divided into tenths, hundredths, thousandths and ten-thousandths of an inch.

2. STEEL RULE.

2.1 The steel rule is used for measuring either common fractions up to sixty-fourths of an inch or decimal fractions up to one-hundredth of an inch. Rules are made of spring steel in various lengths, widths, thicknesses, and methods of graduation, and may be flexible or rigid as required. For general workshop use they are usually 6" or 12" long, but many different lengths can be obtained to suit the various requirements.

2.2 Types. A common type is shown in Fig. 1. Graduations on the side shown are thirty-seconds and sixty-fourths.



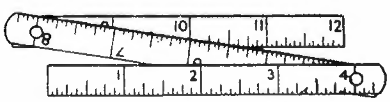
ENGINEER'S STEEL RULE.

FIG. 1.

In addition to the measuring of material or work, this rule may be used as a scale whereby measurements can be set on tools, such as dividers, calipers, jennies, trammels, etc. Its edges may be used in conjunction with a scriber to mark off straight lines, and by placing the edge of the rule along a piece of work and then holding them up to the light, it can be used to see if the work is flat, especially when filing is being carried out.

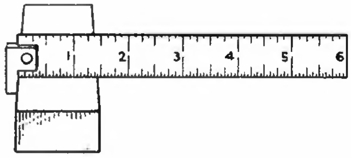
The folding steel rule is shown in Fig. 2, and is similar to the usual type, except that it is made in a series of short lengths neatly hinged together, so that it can be folded into a small space.

A hook rule is shown in Fig. 3. This rule is fitted with a short hook at one end, and by placing this over the end of a piece of work it enables measurements to be obtained in otherwise inaccessible positions.



FOLDING STEEL RULE.

FIG. 2.



USING A HOOK RULE.

FIG. 3.

The flexible steel tape is usually housed in a neat cylindrical case with a spring operated by a button for quick return to the case. It is very useful for obtaining dimensions which are too long for a single measurement with an ordinary rule.

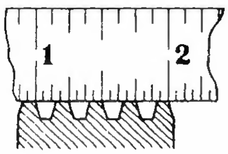
Other types of rules include -

(i) Key seat rule, for scribing lines parallel with the longitudinal axis on round shafts for keyways, etc.

(ii) Contraction rules, to enable pattern-makers to make the required allowance for metal shrinkage when a pattern is being made without having to calculate each measurement.

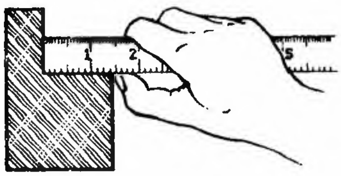
(iii) Gear rules, for setting the caliper used to measure the outside diameter of gear blanks.

2.3 Uses. The measurements which can be obtained with the ordinary rule are numerous and include a big percentage of those carried out in everyday work. With practice, a rule can be read with great accuracy. It is one of the most valuable workshop tools and should always be kept clean, and when not in use, carefully stored away.



MEASURING THE PITCH OF A THREAD.

FIG. 4.



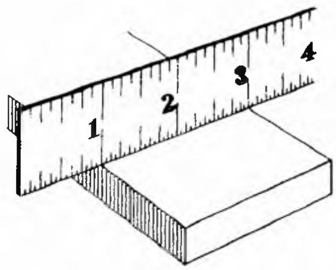
METHOD OF MEASURING A RECESS.

FIG. 5.

Fig. 4 shows the pitch of a thread being measured.

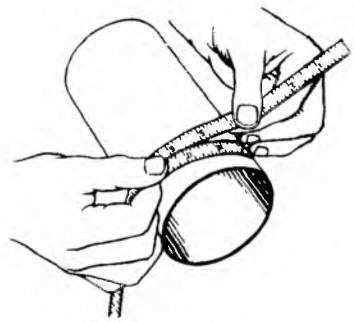
Fig. 5 shows the method of measuring a recess.

To measure a piece of stock, place the rule flat across the surface or distance to be measured. Steady the work with the left hand and hold the rule in the right hand, with its edge on the surface of the work to be measured, as shown in Fig. 6. It is better to commence measuring at a graduation other than zero, as the end of the rule may be worn and it is difficult to align.



POSITION OF RULE WHEN MEASURING.

FIG. 6.



USING A FLEXIBLE RULE FOR MEASURING ROUND STOCK.

FIG. 7.

In Fig. 7, the circumference or perimeter of a piece of round stock is being measured by means of a flexible rule. Care must be taken to see that the rule does not "sag" and give a false reading.

2.4 Points to Remember.

(i) Always keep a rule clean and free from grit.

(ii) Do not use a rule as a screw-driver or scraper.

(iii) Do not stow a rule among files or damage will result.

(iv) A steel rule should not have identification marks stamped on it.

(v) Marking should be carried out by etching or engraving.

(vi) Do not use a rule to measure work revolving in a machine.

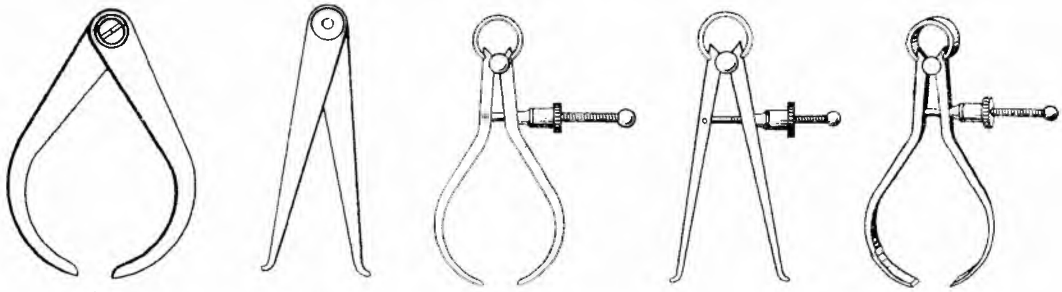
(vii) Always remember a rule is an accurate measuring tool.

(viii) Do not carry rules loosely in your clothes, they may fall out and be damaged.

3. CALIPERS.

3.1 The two tools most commonly used to transfer measurements from the work to the measuring scale, or from the scale to the job, are the outside and inside calipers. As their names imply, they are constructed to take external or internal measurements and are made on that basis, and can be obtained in a variety of types to suit different classes of work. It should be remembered that the ordinary type of caliper is not a measuring tool, but is used in conjunction with some type of measuring scale to obtain a definite size.

3.2 Types of Calipers. The firm joint outside and inside types are shown in Figs. 8a and 8b, in which the legs are firmly screwed or rivetted together, so that when set in any position they will maintain that dimension. When the calipers are set to an approximate size, the legs can be slightly opened by tapping the top, or closed by tapping the leg.



(a) Firm Joint Outside. (b) Firm Joint Inside. (c) Spring Type Outside. (d) Spring Type Inside. (e) Thread Calipers.

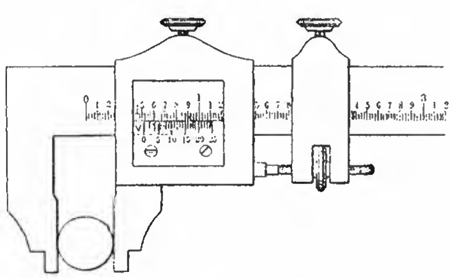
CALIPERS.

FIG. 8.

The spring type, outside and inside calipers, are shown in Figs. 8c and 8d. The legs of the calipers are attached to a pivot at the upper end, and this end is held together above the pivot by a spring clamp. This clamp tends to hold the legs outward against the adjusting nut and on the pivot. The working tips of the legs should be kept in line to preserve the accuracy of the tool. This nut is usually of the split type, so that when released from the cone shaped washer which holds it together, it opens sufficiently to slip over the screw-thread, thereby allowing the calipers to be quickly opened or closed.

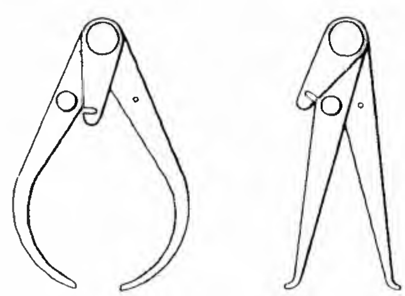
The spring type of calipers shown in Fig. 8e is used for measuring the outside diameters of threads. It has broad ends which span two or more threads, so that the diameter across the tops of the threads can easily be obtained by first adjusting the caliper to just touch the threads and then measuring the distance between the ends with a machinist's rule.

The Vernier calipers shown in Fig. 9 take inside as well as outside measurements direct. They are graduated to read on one side for outside and on the other side for inside measurements. By means of the vernier scale, accurate measurements may be made to within one thousandth of an inch.



VERNIER CALIPERS

FIG. 9.



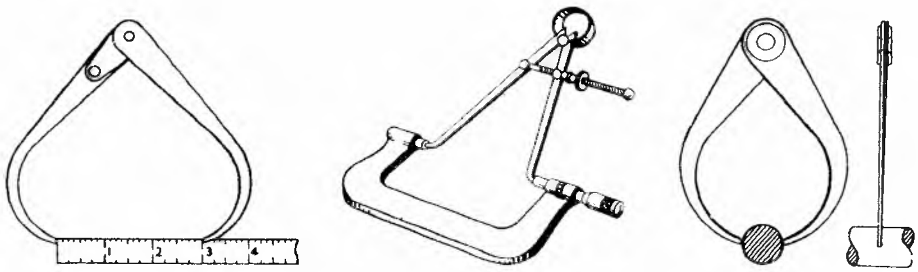
Outside Transfer Inside Transfer

TRANSFER CALIPERS.

FIG. 10.

Outside and inside transfer calipers are shown in Fig. 10. They are used to obtain sizes on work, where, once the measurement was taken, it would be impossible to remove them without losing the setting. After the dimension is obtained the caliper joint is locked. One leg is released from the short auxiliary leg shown and swung in from the surface so that the calipers can be removed. The caliper leg can now be returned to its correct position in the auxiliary leg to show the exact size measured.

3.3 Using Calipers. The accurate use of calipers depends upon the "feel" which is developed through use and experience. They should never be forced over or into the work. Likewise, they should always be used square with the axis of the work and the surface being measured. Calipers may be set to a rule, a micrometer, a gauge, or a vernier slide caliper. Fig. 11a shows a rule being utilised in conjunction with an outside type.



(a) OBTAINING MEASUREMENT ON TRANSFER CALIPERS.

(b) TRANSFERRING MEASUREMENT FROM OUTSIDE MICROMETER.

(c) USING OUTSIDE CALIPERS.

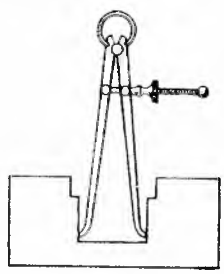
HOW TO USE CALIPERS.

FIG. 11.

In Fig. 11b the inside type is shown being used along with an outside micrometer caliper. When setting calipers to micrometers or vernier calipers, first adjust the instrument to the correct size. Then gently retain one caliper point on one of its surfaces and move the other caliper point until the faint contact is felt against the second measuring surface.

The calipers can be used in two general ways to make a measurement. They can be set over or into the job and then tested on some measuring instrument or scale, or they can be set from the scale etc., and that measurement used to check a piece of work.

Fig. 11c shows a pair of outside firm joint calipers being used, while Fig. 12 shows a use for the inside pattern. Calipers are made in a variety of sizes depending upon the type of work on which they are to be used.



USING INSIDE CALIPERS.

FIG. 12.

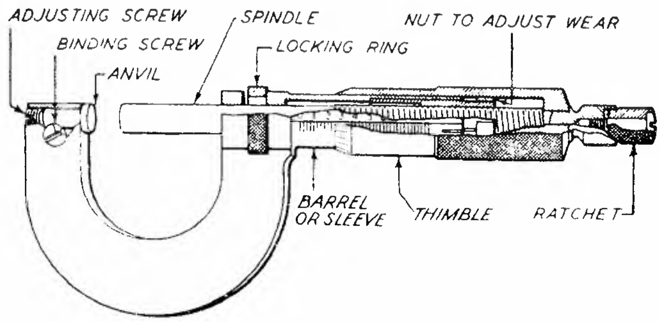
Do not hold the calipers in such a manner that there is any danger of altering the setting. Never attempt to take an accurate caliper measurement of work that is rotating or moving in a machine.

4. MICROMETER.

4.1 The smallest measurements which can be made with the use of the ordinary caliper and steel rule are, in the case of common fractions, 64ths of an inch, and in decimal fractions, hundredths of an inch. To measure finer than this (thousandths and ten-thousandths of an inch), a micrometer is used.

4.2 The micrometer is an indispensible workshop tool where accurate work is being done, and various types and forms are made to suit the different work in which a micrometer may have to be used. In the ordinary type readings to 1/1000th" or 0.001" can be obtained, while the vernier type is provided with graduations to enable measurements in 1/10,000th" or 0.0001" being carried out. They are also made and graduated for metric measurements. All these types can be obtained to read inside or outside measurements as required, while measurements of depth are obtained with the Depth gauge.

An outside micrometer caliper graduated to read in thousandths of an inch is shown in Fig. 13.



OUTSIDE MICROMETER CALIPER.

FIG. 13.

The micrometer uses the principle of the screw to control the movement of the spindle. The screw has 40 threads to the inch, so 40 turns of the spindle moves it one inch. One complete turn of the spindle moves it exactly 1/40th of an inch, that is, 0.025" or 25 thousandths. Two complete turns of the spindle moves it 2/40ths, that is, 0.050" or 50 thousandths. Three complete turns of the spindle moves it 3/40ths, that is, 0.075" or 75 thousandths. Four complete turns of the spindle moves it 4/40ths, that is, 0.100" or 100 thousandths which is 1/10th (Fig. 14a). To simplify reading the micrometer, each fourth graduation is numbered 1, 2, 3, etc., and so indicates measurements of 0.100", 0.200", 0.300", etc.

The bevel edge of the thimble is divided into 25 equal parts (Fig. 14b), each fifth part being numbered. One division on this scale represents 1/25th of the travel of the screw as it makes one complete turn. Since one complete turn makes the spindle travel 25 thousandths of an inch, it is evident that each division represents 1/25 of 25/1000 or 1/1000 of an inch, or 0.001". When 25 of these divisions have passed the horizontal line on the barrel, the spindle has made one complete revolution and so has moved 0.025" (see Fig. 14).

(a) Graduations on Barrel Showing Fortieths (0.025").

(b) Graduations on Thimble Showing Thousandths (0.001").

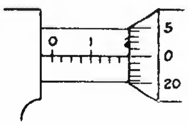
READING THE MICROMETER.

FIG. 14.

4.3 To Read an Inch Outside Micrometer Caliper. Note the last figure visible on the graduations of the horizontal line along the barrel, which represents tenths of an inch (0.100").

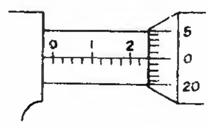
Add the number of twenty five thousandths of an inch beyond this figure (0.025" , 0.050" or 0.075").

Add the number of the division on the bevelled edge of the thimble that coincides with the line of the graduations on the barrel. These represent thousandths of an inch (0.001" , 0.002" , 0.003" , etc). Examples of micrometer readings are shown in Fig. 15.



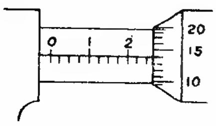
2 Tenths ... .200"
0 Fortieths ... .000"
0 Thousands ... .000"
.200"

(a) Reading Set for 0.200".



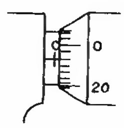
2 Tenths ... .200"
2 Fortieths ... .050"
0 Thousandths ... .000"
.250"

(b) Reading Set for 0.250".



2 Tenths ... .200"
2 Fortieths ... .050"
14 Thousandths ... .014"
.264"

(c) Reading Set for 0.264".



0 Tenths ... .000"
0 Fortieths ... .000"
23 Thousandths ... .023"
.023"

(d) Reading Set for 0.023".

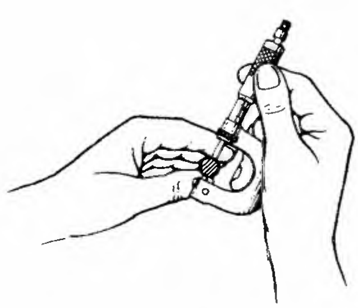
READINGS.

FIG.15.

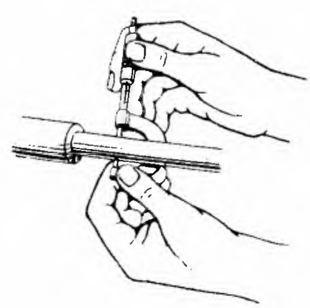
4.4 How to Use A Micrometer. The ability to take accurate measurements with a micrometer depends on skill in its use. There is a feel to a micrometer that tells the skilled technician when he is using the right pressure in turning the thimble. Precise measurements only result through proper use of the micrometer and constant practice is the only way to acquire the necessary skill to obtain the right feel. Until the operator is skilled in the use of the micrometer he may measure the same piece at the same point and get different readings. As the spindle reaches the work the drag of the fingers over the knurled surface of the thimble tells the operator when he has the right measurement.

Some micrometers are fitted with a ratchet, the use of which eliminates any difference in personal touch, and ensures the same pressure for every measurement.

To measure a piece of work with the micrometer when the work is held in the hand, hold the micrometer in the palm of the right hand by the little finger or the third finger (whichever is more convenient), allowing the thumb and forefinger to be free to revolve the thimble for the adjustment (Fig. 16a). Place the work between the anvil and the spindle and turn the thimble until its movement has brought the spindle and the anvil in contact.



(a) Held in Hand.



(b) Mounted in Machine.

MEASURING WORK.

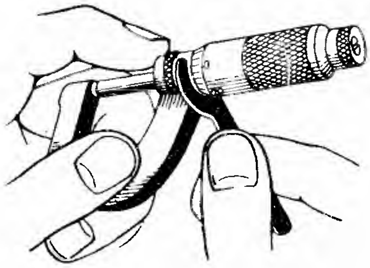
FIG. 16.

To measure with the micrometer when work is mounted in a machine, grasp the frame with the thumb and forefinger of the left hand. The frame is steadied with the second and third fingers of the right hand while the thumb and forefinger are used to rotate the thimble (Fig. 16b). Take the reading while the micrometer is held on the work but always open the micrometer before removing from the part being measured.

The micrometer should never be used to measure rotating work, or while the machine is running, as personal injury may result or the micrometer may be damaged.

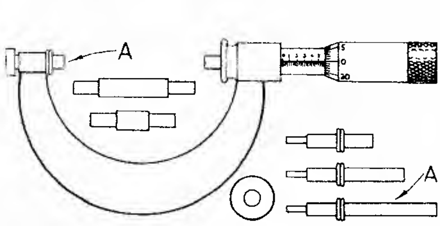
Before using a micrometer care should be taken to see that the faces of the spindle and anvil are free from dust or dirt. When the spindle and anvil are just touching each other under a normal pressure applied by the ratchet, the zero of the thousandths scale should exactly coincide with the datum line. If it does not, the amount of error should be noted and rectified by the means provided.

To correct the error, a small spanner may be used as in Fig. 17, being inserted in the hole provided on the barrel. This enables a slight movement of the barrel to be made until the zero and datum line coincide. Some micrometers have an adjustable anvil which may be turned towards or away from the spindle to correct the error.



MAKING ADJUSTMENT FOR ZERO ERROR.

FIG. 17.



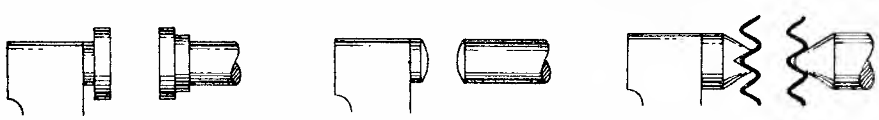
LARGE FRAME MICROMETER WITH EXTENSIONS.

FIG. 18.

4.5 Special Type Micrometers. Micrometers to Measure Over One Inch. Although the measuring capacity of the measuring head is usually only one inch, these micrometers are provided with frames of increasing capacity and interchangeable anvils (A in Fig.18), thereby enabling a large range of measurements to be carried out. The anvils increase in standard lengths and when secured in their proper position in the frame, enable correct readings to be taken according to the capacity of the micrometer frame.

Deep Frame Micrometer. These types are used where measurements are required on work some distance from the edge or outside surface, which would not be obtained with a micrometer provided with a standard size frame.

Micrometers Fitted with Special Anvil and Spindle Faces. Special anvil and spindle faces fitted to micrometers for special work, such as measuring thin sheets, curved surfaces, threads, etc. are shown in Fig. 19.



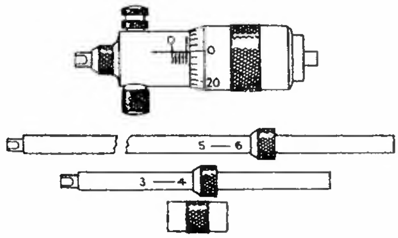
For Paper, Thin Sheet, etc. For Curved Surfaces. For Thread.

SPECIAL ANVIL AND SPINDLE FACES FOR MICROMETERS.

FIG. 19.

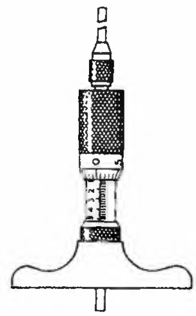
4.6 Inside Micrometers. These are used to obtain direct measurements of internal sizes, such as diameters of tubes and distance between two parallel surfaces (see Fig. 20). There is usually a minimum reading capacity of 1-1/2" or 2" , depending upon the length of the measuring head, in the usual type of this micrometer.

When a size is required beyond the capacity of the head, a series of standard extension rods is used. These increase in standard lengths and, when secured in position, the length is added to the reading on the micrometer head, which reads in the same direction as an ordinary micrometer.



INSIDE MICROMETER WITH EXTENSION RODS.

FIG. 20.



MICROMETER DEPTH GAUGE.

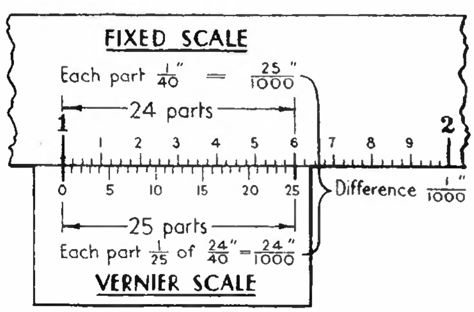
FIG. 21.

4.7 Micrometer Depth Gauge. This micrometer is used in the measurement of depths or recesses. The measuring capacity of the head (Fig. 21) is only 1/2" , but a range is obtained by means of the graduated rod passing through the gauge. These graduations are in half-inches and any additional measurement from the nearest 1/2" would be obtained on the head itself, and added to the length already obtained with the rod. With the gauge at zero, all graduations will be shown.

5. PRINCIPLE OF THE VERNIER.

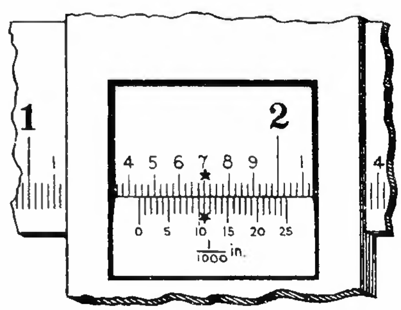
5.1 The principle of the vernier has been applied to many kinds of measuring instruments, such as micrometers, calipers, height gauges and protractors, enabling accurate measurements to be made of ordinarily imperceptible differences in length.

The vernier consists of a fixed scale and a vernier scale which moves along it. In Fig. 22 each inch of the fixed scale is divided into forthieths of an inch or 25/1000ths. The vernier scale has a distance of 24 fortieths divided into 25 equal parts, so each division is 1/25th of 24/40ths or 24/1000ths of an inch. The difference between the width of a space on the vernier scale and one on the fixed scale is, therefore, 1/1000th of an inch.



VERNIER SCALE TO MEASURE IN THOUSANDTHS OF AN INCH.

FIG. 22.



READING OF 1.436" ON VERNIER CALIPER.

FIG. 23.

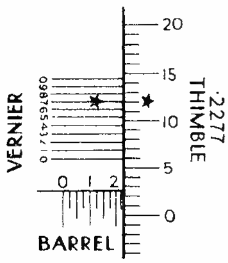
If the instrument is set so that the 0 lines on the vernier and the fixed scales coincide, the line to the right of the 0 on the vernier will differ from the line to the right of the 0 on the fixed scale by 1/1000th of an inch; the second line by 2/1000ths of an inch and so on. The difference will continue to increase 1/1000th of an inch for each division until the line 25 on the vernier coincides with the line 24 on the fixed scale.

To read the instrument, note how many inches, tenths (or 0.100) and fortieths (or 0.025) the 0 mark on the vernier is from the 0 mark on the fixed scale, then note the number of divisions on the vernier from 0 to a line which exactly coincides with a line on the fixed scale.

In the example shown in Fig. 23 the vernier has been moved to the right, one and four tenths, and one fortieth inches (1.425) as shown by the position of 0 on the vernier. The eleventh line on the vernier coincides with a line on the fixed scale as indicated by the stars. Eleven thousandths of an inch must be added to the above reading and the total reading is now one and four hundred and thirty six thousandths inches (1.436").

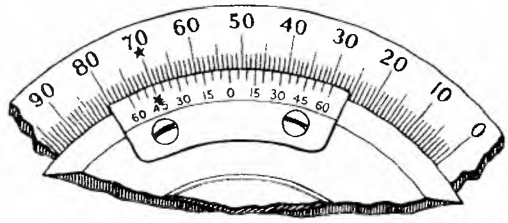
Vernier scales are not necessarily 25 units long; they may have any number of units. In the vernier scale on the ten thousandths micrometer, there are only 10 graduations on the barrel which occupy the same space as 9 graduations on the thimble. It will be obvious, therefore, that the difference in width between each division on the thimble and each division on the barrel is one tenth of a graduation. As the graduations on the thimble are thousandths, the difference is therefore, on tenth of a thousandth. An example of a reading is given in Fig. 24, which shows a reading of 0.225 (on barrel) + 0.002 (on thimble) + 0.0007 (on vernier) = 0.2277.

In the case of a protractor with a vernier, the disc of the protractor is graduated in degrees from 0 to 90 each way, so that the reading may be made in either direction. The vernier plate is graduated so that 12 divisionson it occupy the same space as 23^{o} on the disc. Each space on the vernier is 1/12 of 23^{o} = $23/12^{o}$, while the space between two divisions on the disc = 2^{o} or $24/12^{o}$. The difference between a vernier scale division and two on the disc is, therefore, $1/12^{o}$ or five minutes.



MICROMETER READING OF 0.2277".

FIG. 24.



VERNIER PROTRACTOR READING OF 52^{o} 45'.

FIG. 25.

If a line on the vernier coincides with a line on the disc and the protractor is rotated until the next line on the vernier coincides with the next line but one on the disc, the vernier has been moved through an arc of 1/12 of a degree or five minutes. In the example given in Fig. 25 the number of degrees between 0 on the disc and 0 on the vernier is 52. Proceeding in the same direction, the line 45 on the vernier coincides with the line 70 on the disc as indicated by the stars so the protractor, therefore, reads 52 degrees, 45 minutes.

6. TEST QUESTIONS.

1. Name four types of rules and explain when each is used.
2. For what purpose are calipers used?
3. What precautions should you take when using calipers on a cylindrical bar?
4. What fraction of an inch does one revolution of the thimble of a micrometer move the spindle? Why?
5. What precautions should you take when using a micrometer?

END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

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COURSE OF TECHNICAL INSTRUCTION.

ENGINEERING WORKSHOP PRACTICE I.

TESTING TOOLS.

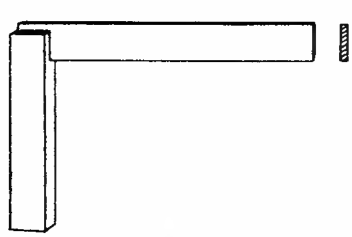
CONTENTS.

1. STEEL SQUARE.

1.1 A square is used for testing the accuracy of surfaces which have to be at a certain known angle to each other (usually 90°), and different types are made to suit varying requirements.

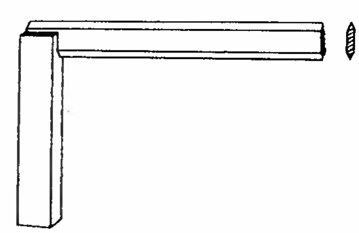
1.2 Types of Squares. The Common Try square is shown in Fig. 1. The blade is fitted into a slot provided in the stock, and both are rivetted together at 90°. The stock is made of larger section than the blade, and being heavier, allows the square to be used on the marking-off table etc. without falling over.

It is sometimes fitted with a blade having a bevelled edge, Fig. 2, which allows a more accurate line to be scribed along the edge of the blade.



TRY SQUARE.

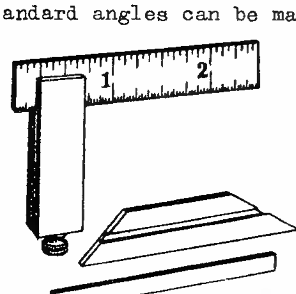
FIG. 1.



TRY SQUARE WITH BEVELLED EDGES.

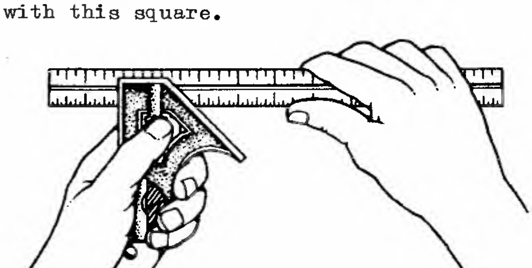
FIG. 2.

A toolmaker's square is shown in Fig. 3, and consists of a stock to which different blades can be attached. These blades provide angles of 30°, 45° and 60°, so that these standard angles can be marked off with this square.



TOOLMAKER'S SQUARE.

FIG. 3.



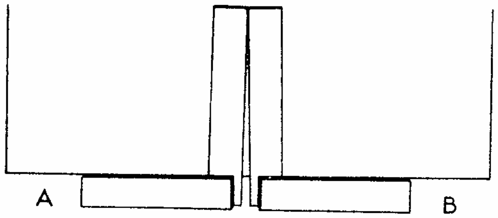
COMBINATION SQUARE.

FIG. 4.

The Combination square (Fig. 4) is one of the most useful and convenient tools for lay-out work. The stock or head can be moved along the steel blade and clamped in any desired position. It can be used as a square to check angles of 45° and 90°, as a depth gauge, and also for marking off lines.

By setting the end of the steel rule flush with the head, it may be used as a height gauge directly or in conjunction with a surface gauge. To further assist in marking out operations, a spirit level is mounted in the head as shown.

1.3 Testing a Square. The square is held with the stock against the edge of the surface plate and a light mark is scribed along the edge of the blade when in position A as in Fig. 5.



METHOD OF TESTING A SQUARE.

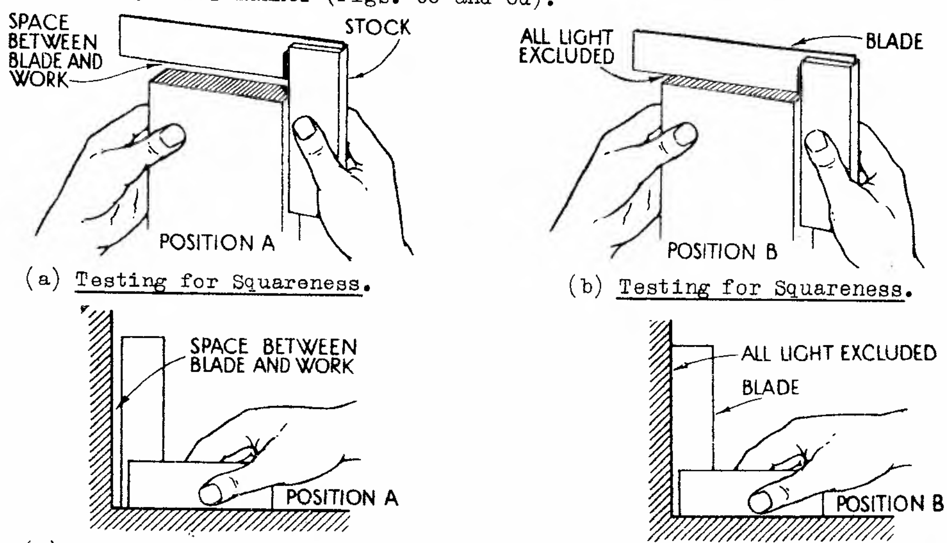
FIG. 5.

It is then reversed to position B and a similar line drawn. If the square is truly square 90°, these two lines will coincide, but if not, may show as two converging lines as in Fig. 5.

1.4 Using the Square. The try square will check two faces intended to be at right angles to each other. Remove all burrs from the surface of work to be checked and clean and draw edges to be used over the palm of the hand to ensure absolute freedom from small particles.

Face the light so that it will shine on the work, and hold it with the left hand, grasping the stock of square with the right hand. Place inside of square against a finished surface of the work so that the stock is in full contact with one side, and a slight space remains between the blade and the other surface of the job, Fig. 6a.

Now lower the blade carefully until it comes in contact with the surface of work and, if the angle is square, all light will be excluded (Fig. 6b). An inside right angle is tested in a similar manner (Figs. 6c and 6d).



(a) Testing for Squareness. (b) Testing for Squareness.

(c) Testing an Inside Right Angle. (d) Testing an Inside Right Angle.

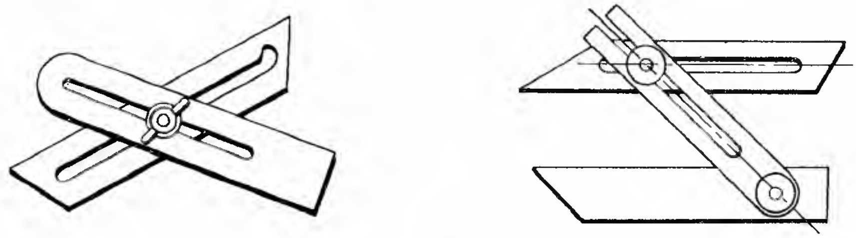
FIG. 6. HOW TO USE A SQUARE.

2. BEVELS.

2.1 Bevels are used in the workshop for marking off and testing sizes of angles and for transferring angles from one job to another.

2.2 Types. The Universal type is shown in Fig. 7a. It has a blade and stock secured together by means of a screw and winged nut. Both these members are slotted as shown so that the tool can be set at any angle. The ends are finished off at definite angles such as 90°, 60°, 45°.

The Combination type, Fig. 7b, consists of a solid stock to which is freely pivoted a blade slotted for most of its length. A second blade with an internal slot as shown is pivoted to the first, thereby allowing a large variety of angles to be set on the bevel.

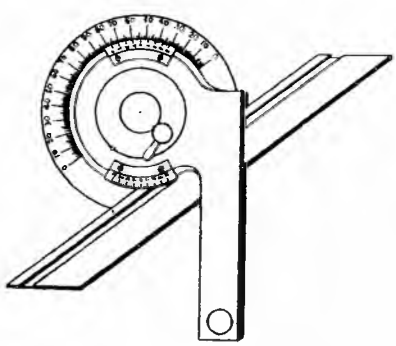


(a) Universal Type Bevel.   (b) Combination Type Bevel.

BEVELS.

FIG. 7.

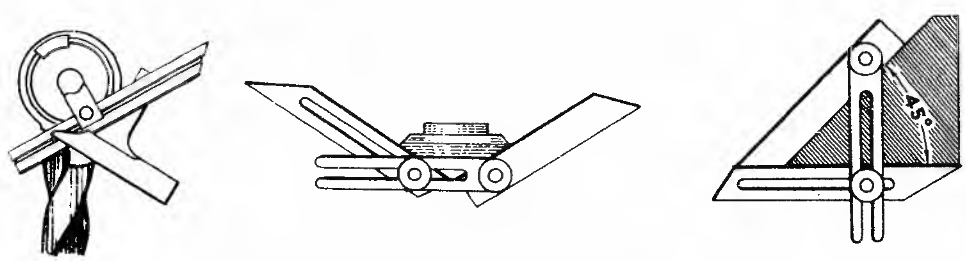
The bevel protractor, Fig. 8, is made up with a blade and stock pivoted together at the centre of the protractor, and this protractor directly indicates the size of the angle between the blade and stock.



BEVEL PROTRACTOR.

FIG. 8.

2.3 Using the Bevel. The uses of bevels are many and varied, some examples being shown in Fig. 9.



(a) Testing Cutting Angle of a Drill.   (b) Testing Angles of Pinion Wheel.   (c) Testing 45° Angle of Template.

USING THE BEVEL.

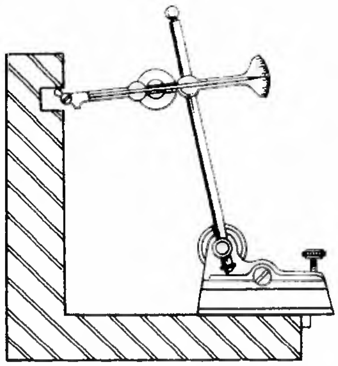
FIG. 9.

3. INDICATORS.

3.1 Indicators are used by fitters and machinists to test for small irregularities of a flat or curved surface by magnifying deviations on a scale or dial. Many types of indicators are available, the dial test type being the most adaptable.

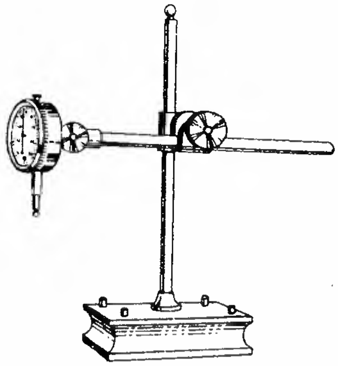
3.2 Types of Indicators. The Lever type (Fig. 10) may be fitted to a pillar and stand in a similar manner to the scriber of a surface gauge. The pivoted lever is moved by pressure on the point, and tension is kept on this lever by means of a spring. Any movement of the lever is multiplied and indicated on the graduated scale.

The Dial indicator (Fig. 11) may be secured to a pillar and base for surface work or to pillar and stock for machine testing.



LEVER TYPE INDICATOR IN USE.

FIG. 10.



DIAL INDICATOR.

FIG. 11.

When pressure is applied to the point of the indicator, the movement of the lever attached actuates movement in a train of small gear wheels which are in such a ratio that the direct reading in thousandths or ten thousandths of an inch is shown on the scale. A milled rim is fitted to the dial which enables it to be turned until the zero graduation is exactly under the pointer, before any testing is carried out.

3.3 Uses of Indicators.

(i) On Fitting Work -

(a) Testing for irregularities of a flat surface and measuring the extent of error.
(b) Setting up, checking, and aligning on the surface plate or marking-off table.
(c) Testing spindles etc. for straightness.
(d) Testing machine parts and components.

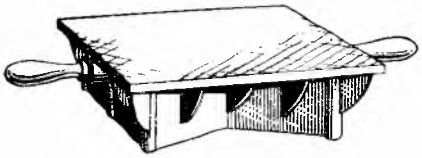
(ii) On Machining Work -

(a) Testing machine parts and components.
(b) Setting up work or machines.
(c) Testing work being machined.

4. SURFACE PLATES.

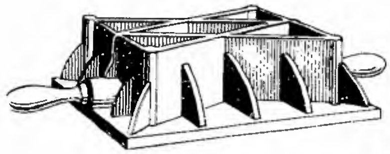
4.1 The surface plate (Fig. 12), previously discussed as being used in conjunction with scraping, is an appliance used for testing the accuracy of a flat surface. It is made of a special grade of close-grained cast iron, and is well ribbed on the under side to prevent warping of the surface. (Fig. 13).

After being carefully machined, the plate is hand-scraped to a smooth surface making it an expensive piece of equipment which must be used with great care. Besides being used for scraping purposes, it is also used for precision lay-out work, and for checking accurate work such as gauges, jigs, fixtures, etc.



SURFACE PLATE.

FIG. 12.

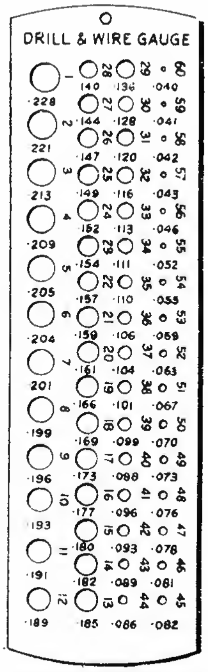


UNDER SIDE OF SURFACE PLATE.

FIG. 13.

5. GAUGES.

5.1 Drill gauges are used to check the sizes of twist drills. These gauges are generally made for fractional sizes 1/16" to 1/2" or gauge number sizes from 1 to 60. In the example shown in Fig. 14, the gauge can be used to check both drills and wires. Some types of wire gauges are provided with slots along the edges to measure the diameters, and may be circular in shape instead of as shown in Fig. 14. A gauge of this type may also be used to measure sheet metal.



DRILL AND WIRE GAUGE.

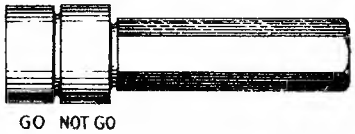
FIG. 14.

5.2 Feeler gauges are used to test small gaps or clearances, or to build up sizes in conjunction with other dimension gauges. They are made up with a series of blades ranging in thickness from 0.0015" to 0.025". These blades are pivoted at one end, which enables them to be radially pushed out of the case, either singly or in the required number, to give the size required.

5.3 Thread Pitch gauges are used to determine the pitch of screw-threads, or number of threads per inch. The blades generally range in pitch from 4 to 60 threads per inch. To determine the pitch of a thread, the teeth of the gauge should be tried against the threads until a blade is found which matches exactly.

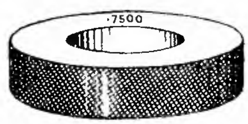
5.5 Radius gauges are used to test the radii of curves, fillets, etc. The blades usually range in radius from 1/32" to 1/2" and are housed in a case in a similar manner to those of the feeler and thread pitch types.

5.6 Plug and Ring Gauges. These gauges furnish accurate and convenient standards for the production of duplicate parts of machines. The ring gauge is used largely to check the external diameter of shafts, arbours, pins, studs, etc. They are used more often in the inspection of finished parts than parts in process. Plug gauges may be either cylindrical, tapered or flat. A cylindrical plug gauge is shown in Fig. 15 and a ring gauge in Fig. 16.



CYLINDRICAL PLUG GAUGE.

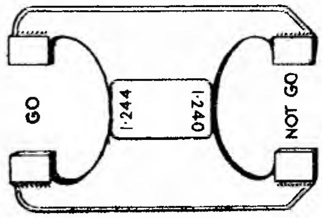
FIG. 15.



RING GAUGE.

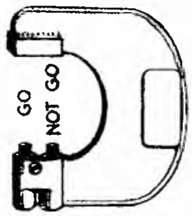
FIG. 16.

5.7 Snap Gauges. These are used for testing external dimensions, and may be either of the solid double-ended type as shown in Fig. 17 or of the adjustable type shown in Fig.18.



SOLID TYPE SNAP GAUGE.

FIG. 17.



ADJUSTABLE TYPE SNAP GAUGE.

FIG. 18.

6. TEST QUESTIONS.

1. How is a square used?

2. How are squares tested?

3. How can an angle be measured with a bevel?

4. Describe the use of indicators on -

    (i) Fitting Work.
    (ii) Machine Work.

5. How is a surface plate finished?

6. For what sizes of drills are gauges made?

7. What is the range of thickness of feeler gauges?

END OF PAPER.

[redacted]

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COURSE OF TECHNICAL INSTRUCTION.

ENGINEERING WORKSHOP PRACTICE I.

DRILLS AND DRILLING MACHINES.

CONTENTS.

1. DRILLS.

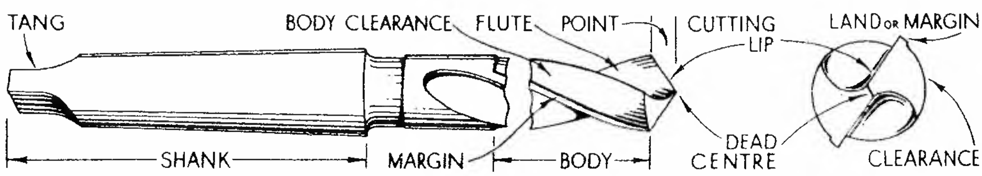
1.1 Drills are among the earliest tools used by man, and originally consisted of a piece of flat steel pointed at one end. The drill is one of the most commonly used tools in the workshop and is made in a number of forms. These different forms have two essential and common characteristics.

(i) There must be one or more edges which either scrape or cut off small particles of material.

(ii) There must be a central leading point about which the cutting edges revolve and it should guide the drill through the material in the required position. This is obtained by tapering the cutting edges towards the centre to suit the material being worked on.

1.2 Parts of a Twist Drill. A Twist drill (Fig. 1) may be classified into three principal parts, the "Point", the "Body" and the "Shank".

The point is the cone shaped surface at the end of the drill.



The Point

PARTS OF A TWIST DRILL.

FIG. 1.

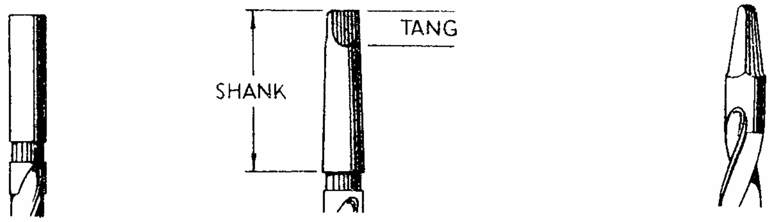
Special grooves known as flutes are cut in the body. These flutes serve three purposes.

(i) Allow lubricant to reach the cutting edge.

(ii) Allow metal cuttings to escape.

(iii) Curl the metal chips.

The shank is the end of the drill which fits into the drilling machine socket or drill chuck. The most common types are straight shank (Fig. 2a), taper shank (Fig. 2b) and ratchet shank (Fig. 2c).



(a) Straight Shank. (b) Taper Shank. (c) Ratchet Shank.

PARALLEL SHANK

DRILL SHANKS.

FIG. 2.

The Tang is portion of the taper shank which fits into a socket or spindle. The tang exists merely to assist the taper shank in driving the drill. It is not designed to withstand the entire driving strain.

1.3 Types of Drills. The Twist drill (Fig. 1) is the commonest type and is used for general work. Other types of drills are -

Straight Fluted drill (Fig. 3) is advantageous for drilling thin plates and brass. The twist drill has a tendency to gouge into the metal, particularly if it is of a soft nature but this tendancy is overcome by using a straight fluted drill.

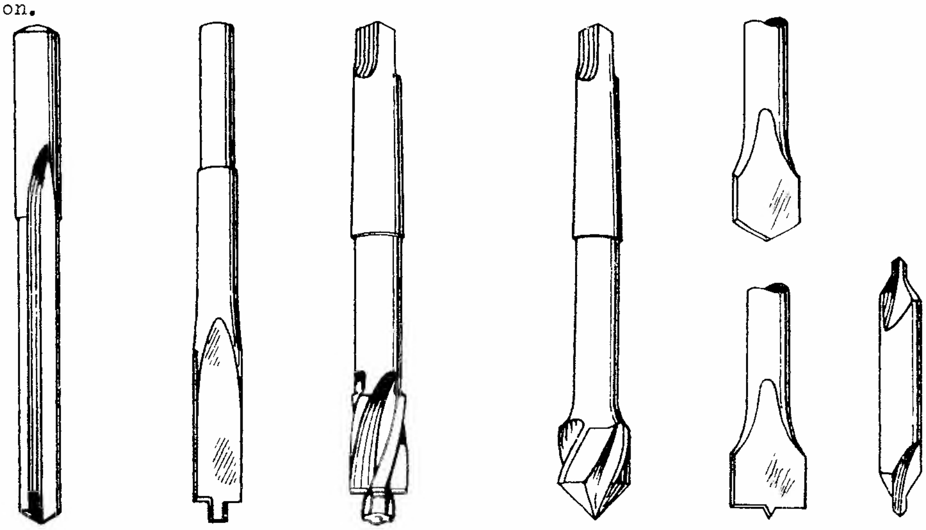
Pin drill is most efficient when large diameter holes are being drilled in metal of small section. If a large size drill is used on this type of work it may be found that the centre of the drill is through the metal before the outer edges of the drill are near enough to come in contact with its surface. This results in a ragged and irregular hole being drilled, with the added danger of the work swinging round and breaking the drill.

Counterbore drill is for enlarging cylindrically the mouth of a hole for receiving bolt heads, etc.

Countersink drill (Fig. 3) is used to taper ends of holes to suit countersunk head-screws.

Flat drill is usually made in the workshop from round tool steel drawn out wide and thin. It is an improvised drill of an earlier type only used in special circumstances.

Centre drill is usually a combination type which drills and countersinks at a single operation.



Straight Flute Pin Counterbore Countersink Flat Centre

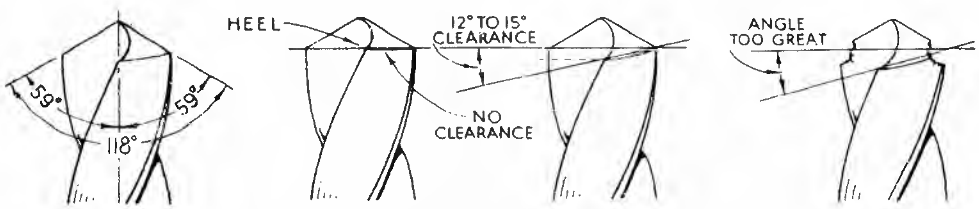
FIG. 3. TYPES OF DRILLS.

1.4 Grinding of Drills. In grinding a drill, three things must be considered -

(i) Cutting Angles.
(ii) Lip Clearance.
(iii) Dead Centre.

Cutting Angle. For general workshop practice, an angle of 59° to the axis of the drill, that is, an included angle of 118° , is satisfactory (Fig. 4a). For special conditions, the cutting angle may be increased or decreased as necessary. Approximate cutting angles for different materials are as follows - soft cast iron 90°, brass 130°, copper 100° , aluminium 136°, mild steel 118° , hard steel 150°. The cutting angle may be checked by means of a bevel or a specially cut template.

Lip Clearance. This is the grinding back of the point of a drill between the cutting edge and the heel. Clearance is necessary, otherwise the whole of the point would rub against the metal setting up excessive friction (see Fig. 4b). It has been found that for general work a lip clearance of 12° to 15° is most satisfactory. If lip clearance is too great, there is not sufficient support for the cutting lips, and chipping or breaking may occur (Fig. 4c) while on the other hand, if insufficient clearance is ground, the trailing edge will rub on the metal instead of the cutting lips drilling the hole.

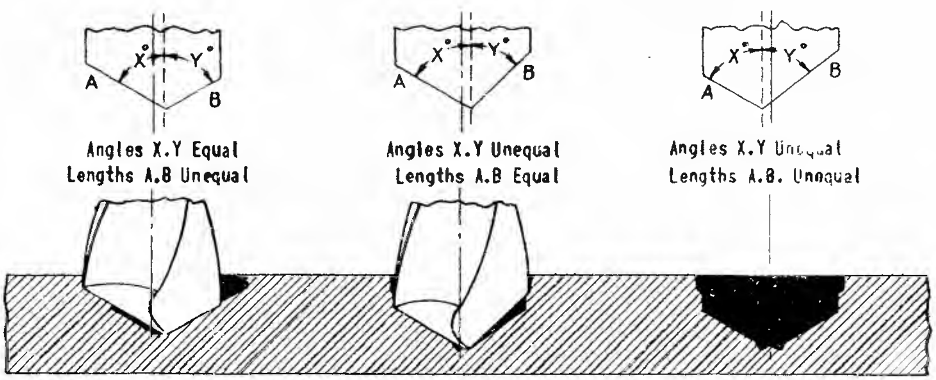


(a) Cutting Angle For General Use. (b) Lip Clearance For General Use. (c) Too Much Lip Clearance.

DRILL GRINDING.

FIG. 4.

Dead Centre. Always make certain that the dead centre is in the axis of the drill, otherwise drilling oversize will result. Fig. 5 shows how oversize holes are drilled owing to the cutting lips being incorrectly ground.

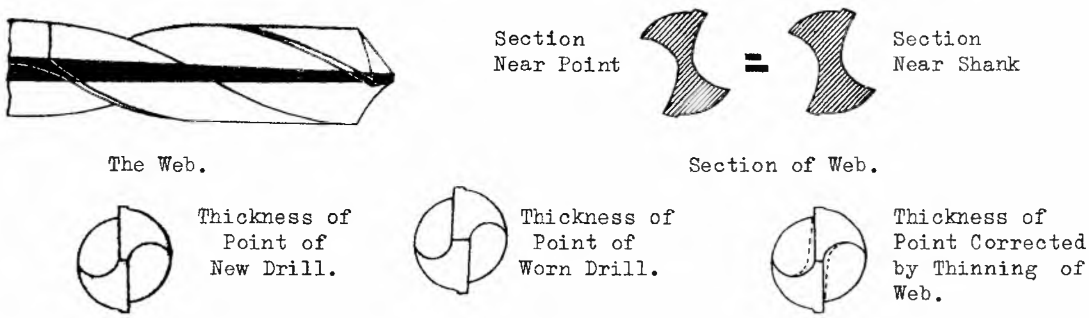


(a) (b) (c)

RESULTS OF INCORRECTLY GROUND CUTTING LIPS.

FIG. 5.

The Web is the metal column which separates the flutes. It runs the entire length of the drill and gradually increases in thickness towards the shank as shown in Fig. 6. As the drill is pointed back, it is necessary to thin the web at the point to obtain maximum results as far as ease of penetration and wear are concerned. This may be done in several ways, the most commonly used method being with a round faced emery wheel.



WEB OF A DRILL.

FIG. 6.

1.5 Drill Speeds. The speed of a drill is generally referred to as the pheripheral speed, which is the distance a drill would travel if it were laid on its side and rolled along a surface. Thus a drill with a pheripheral speed of 30 ft. a minute would roll a distance of 30 ft. in a minute.

Cutting speeds of drills depend upon -

(i) The toughness and nature of the material being drilled.

(ii) The diameter of the drill.

(iii) The class of steel from which the drill is made.

Suggested speeds for high speed drills in surface feet per minute -

Stainless Steel	30-40	Mild Steel	80-110
Carbon Tool Steel	50-60	Soft Cast Iron	100-150
Malleable Iron	80-90	Brass, Bronze, Aluminium	200-300

Ordinary carbon drills should be run at speeds from one third to one half the figure given above. It is good practice when drilling to start operations with the drill running at a moderate speed and then increase if necessary, after observing the drilling conditions. A general rule for speed is - The harder the metal, the slower the r.p.m., and the smaller the drill the greater the r.p.m.

1.6 Drill Feeds. "Feed" is the advance per revolution measured in fractions of an inch. It depends upon two factors -

(i) The size of the drill.

(ii) The metal being drilled.

Once the r.p.m. of a drill has been decided upon, the necessary feed can be calculated in inches per minute.

A general rule for feed is as follows -

Diameter of Drill	Feed per Revolution in Inches
Under 1/8"	0.001" to 0.002"
1/8" to 1/4"	0.002" to 0.004"
1/4" to 1/2"	0.004" to 0.007"
1/2" to 1"	0.007" to 0.015"
Over 1"	0.015" to 0.025"

Alloy and hard steels may be drilled with a lighter feed than above, while a heavier one can be used on cast iron, brass and aluminium.

1.7 Drill Lubrication. To maintain the speeds and feeds necessary for efficient drilling, many materials require that a suitable cutting compound or lubricant be used.

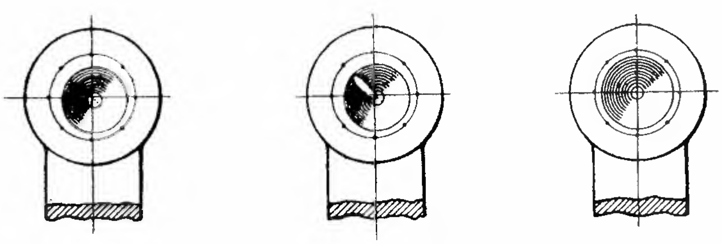
Suggested lubricants for drilling -

Soft Cast Iron	Dry or Air Jet
Hard Cast Iron	Turpentine or Kerosene
Soft Steel and Wrought Iron	Soluble Oil
Hard Steels	Turpentine,Kerosene or Soluble Oil
Malleable Iron	Soluble Oil
Brass and Phosphor Bronze	Dry
Aluminium	Kerosene, Soluble Oil
Copper	Lard Oil, Turpentine.

Care should be taken that the lubricant reaches the point of the drill during the operation, otherwise its value is lost and the drill ruined by excessive heat which is also likely to draw the temper of the steel.

1.8 Precautions When Drilling. When drilling holes, especially of large diameter, there is always the danger of the hole not being cut in exactly the required position, and this error can be minimised by first drilling a pilot hole, say 1/8", exactly in the centre of the position where the finished hole is desired. This small hole acts as a guide and usually ensures a satisfactory job being carried out.

When commencing to drill there may be a tendency to run out of centre as shown in Fig. 7a. This may be corrected by chipping a groove or grooves on the opposite side as shown in Fig. 7b to "draw over" the drill, thereby causing it to drill a hole in the correct position as in Fig. 7c.



(a) (b) (c)

METHOD OF DRAWING BACK DRILL ON CENTRE.

FIG. 7.

1.9 Faults in Drilling.

Symptom	Probable Cause	Remedy
Broken Drill	Work not rigid.	Test for rigidity and alignment.
	Not enough lip clearance.	Give more lip clearance.
	Speed too slow for feed.	Adjust speed.
	Speed too fast for feed.	Decrease feed.
	Speed too fast for metal.	Decrease speed.
	Drill point dull.	Resharpen drill.
	Improperly hardened.	Reharden and retemper.
	Fracture in drill.	Replace drill.
	Metal cutting clogging in hole (brass or wood).	Use drill designed for brass or wood.
Wearing Away Of Cutting Edge	Speed too fast.	Reduce speed.
	Material has hard spots.	Use proper cutting compound.
	Wrong cutting compound.	Use proper cutting compound.
Chipping Of Cutting Edge	Feed too fast for speed.	Reduce feed.
	Too much lip clearance.	Regrind with less lip clearance.
Chipping Of Margin	Undersized jig bushing.	Use proper bushing.
Broken Shank	Imperfect fit of taper shank due to – (i) Dirt. (ii) Burrs on shank. (iii) Wrong socket.	Replace socket. Ream old one.
Hole Too Large	Unequal length of cutting lips.	Regrind.
	Unequal angles.	Regrind.
	Loose spindle.	Test spindle for rigidity.
	Oversize drill.	Replace drill.
Only One Lip Cutting	Unequal angle of cutting edge.	Regrind with proper angles.
	One lip not properly ground.	Regrind drill.
Roughly Finished Hole	Dull cutting edge.	Regrind drill.
	Lack of lubricant.	Change lubricant.
	Feed too fast.	Reduce feed.
Drill Will Not Cut	Dull cutting edge.	Regrind drill.
	No lip clearance.	Allow lip clearance.
	Running wrong direction.	Reverse direction.

2. DRILLING MACHINES.

2.1 The drilling machine is the second oldest known machine tool having been invented shortly after the lathe, and is probably the most used of any machine. Drilling machines vary from the tiny bench machine used in the finest jeweller's operations to the huge heavy duty machines that bore large holes in steel forgings at an astonishing rate.

2.2 The Vertical Spindle drilling machine (Fig. 8) is a typical drilling machine and may be of three types - heavy duty, plain or sensitive.

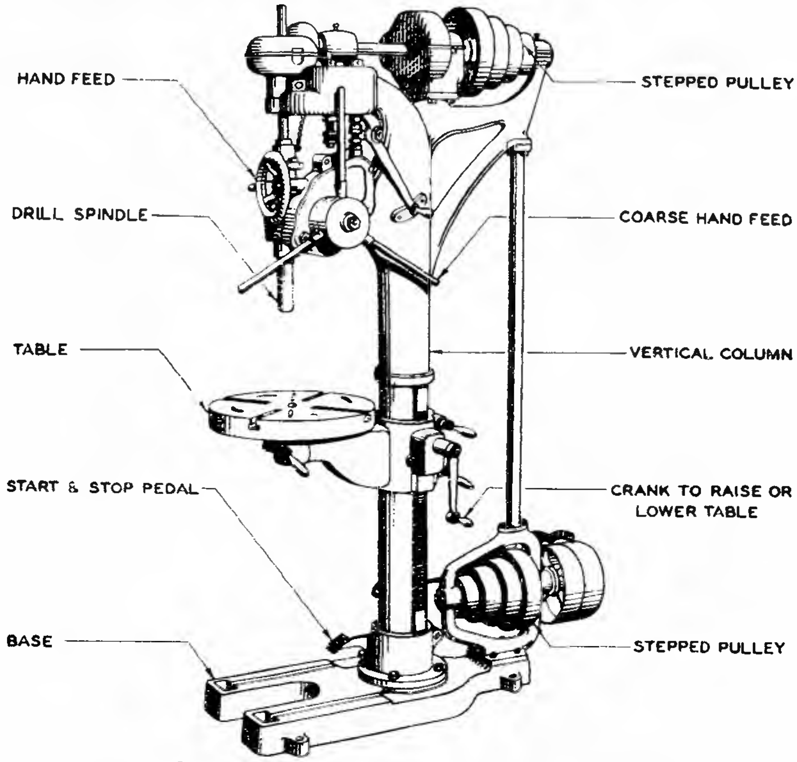


FIG. 8. VERTICAL SPINDLE DRILLING MACHINE.

The spindle can be moved up and down on the column and the table can be adjusted to any desired height. The spindles are sometimes arranged in groups of three or more and called Gang drills. On the plain machine, the table is located on an arm attached to the column and can be swung in an arc of 180° at right angles to the column. The table itself is free to revolve 360° and may be clamped in any position, making it easy to locate a lay out hole in line with the spindle.

2.3 Portable Drills. These are operated by means of a switch fitted into the hand grip, which controls a small high speed electric motor geared down to drive the spindle and chuck (see Fig. 9). Three core flexible wire must be used on portable machines. The third wire is connected to the frame of the machine and provides a low resistance path to earth through the earth wire connected to the three pin socket. This necessary precaution protects the technician should any leakage develop in the machine.

FIG. 9. HAND ELECTRIC DRILL.

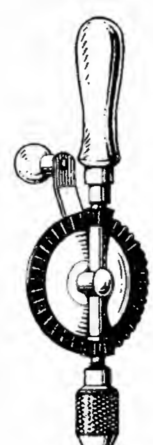


FIG. 10. HAND DRILL.

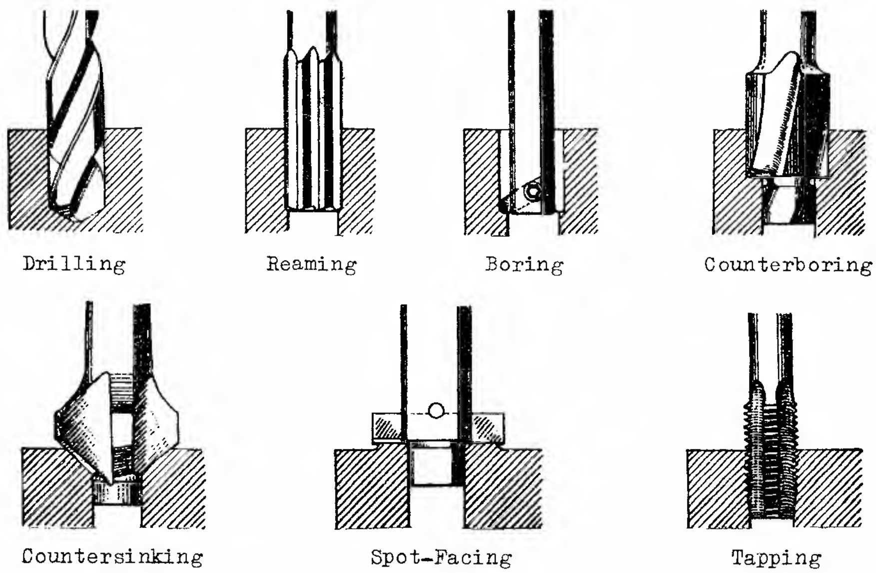
2.4 Hand Drill (Fig. 10). This is fitted with a chuck suitable for small straight shank drills and the rotation is obtained by turning the large wheel which is geared to the small ones as shown. Some types are fitted with ratchet movement, right and left hand, and also with different gear ratios to provide a range of spindle speeds to suit different drilling requirements. Heavier machines are fitted with a breast plate instead of the handle shown which enables more pressure to be applied when drilling.

2.5 Drill Chucks. The drill is held firmly in the drilling machine by means of a drill chuck which usually has three jaws. A special key engages in the rack of the chuck and evenly opens or closes the hardened jaws. When these are properly tightened the drill is automatically centred and it should run true.

2.6 Operations Possible On Drilling Machine. (See Fig. 11)

Drilling. This is the operation of producing a circular hole by removing solid material. The cutting tool used is a drill.

Reaming. This is the operation of sizing and finishing a hole by means of a cutting tool, called a reamer, having several cutting edges. Reaming serves to make a hole smoother, straighter and more accurate.



DRILLING MACHINE OPERATIONS.

FIG. 11.

Boring. This is the operation of enlarging a hole by means of an adjustable cutting tool with one cutting edge.

Counterboring. This is the operation of enlarging the end of a hole cylindrically, as for a recess for a fillister head-screw.

Countersinking. This is the operation of making a cone-shaped enlargement of the end of a hole, as for a recess for a countersunk head-screw.

Spot-Facing. This is the operation of smoothing and squaring the surface around the end of a hole as for the seat for a nut or the head of a cap-screw.

Tapping. This is the operation of forming internal screw-threads by means of a master tool called a tap. Machine tapping is used extensively on production work but usually with a special chuck which is freed from the turning motion and automatically reversed, when a hole has been tapped to the correct depth.

2.7 Points to Remember When Drilling.

Always use a drift to remove taper shank drills from sockets, sleeves, etc.

Never hold work by hand when drilling. Always use a drill vice or secure job in position on the machine.

When drilling is being carried out heat is generated, and unless there is some means of cooling there is a risk of drawing the temper of the steel and thereby softening the point of the drill.

If the drills are kept sharp they will require but slight pressure to cut. Many of the troubles experienced in drilling are caused by dull tools.

If necessary, grind drills frequently. The operator can save loss of time by keeping a few sharpened drills on hand.

If the cutting lips are unequal in length, the hole will be larger than the drill.

If the cutting lips are not ground at the same angle, the lip having the greater angle will do all the cutting.

A cutting angle of [illegible] and a clearance angle between 12° to 15° are suitable for general workshop purposes.

3. TEST QUESTIONS.

1. Name the three principal parts of a twist drill and explain the purpose of each part.

2. Explain the uses of a flat drill, a straight fluted drill and a pin drill.

3. By means of a sketch show the angle you would grind the cutting lips of a drill for general use. How would you check this?

4. Explain with the aid of sketches what is meant by lip clearance.

5. What is meant by the web of a drill? Why is it necessary to thin the web?

6. What is meant by the speed of a drill? On what do the cutting speeds of a drill depend?

END OF PAPER.

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COURSE OF TECHNICAL INSTRUCTION.

ENGINEERING WORKSHOP PRACTICE I.

SCREWS AND SCREW-THREADS.

CONTENTS.

1. SCREW-THREADS.

1.1 A screw-thread is a helical ridge of uniform section formed on the inside or outside of a cylinder or cone. The helix is the curve formed by the thread as it advances a uniform amount for each revolution.

Threads are either internal or external. Internal threads are cut on the inside of work as in the case of a nut, while external threads are cut on the outside diameter.

Threads may either be right-hand or left-hand. A thread is said to be right-hand if it can be advanced by turning clockwise. A left-hand thread is advanced by turning to the left or counter-clockwise.

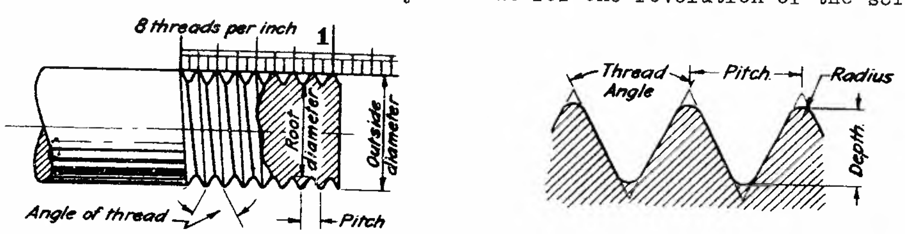
1.2 General Uses of Screw-Threads. Screw-threads have three general applications, namely for -

(i) Fastening - as in the case of screws and bolts.
(ii) Transmitting power or motion - as a lead-screw and cross feed-screw of a lathe or the elevating screw for raising the table on a milling machine, shaper or drill press.
(iii) Obtaining measurements - as in the case of a micrometer-screw or the feed-screw of a milling machine.

It is the use to which the thread is put that determines the degree of accuracy and quality in the manufacture, and this in turn partly determines the method that will be used to manufacture the screw.

1.3 Standard Screw-Threads. A number of standard thread-forms are in common use, each thread being designed for and having its own particular sphere of service. The thread-forms given herewith have been selected as being common world-wide types.

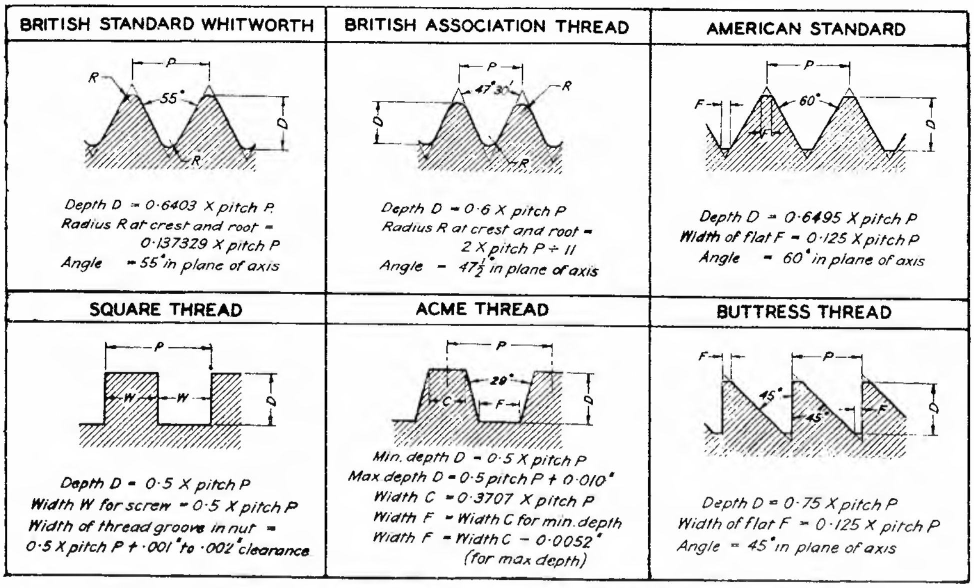
When dealing with threads, it is important to remember that "pitch" is usually taken as the distance between any two adjacent threads, that is, from the crest of one thread to the crest of an adjoining thread, or again, speaking of a single start-thread, the distance travelled by the nut for one revolution of the screw (Fig. 1).



TERMS APPLIED TO SCREW-THREADS.

FIG. 1.

The British Standard (Whitworth) and the American Standard (Sellars) are the forms of screw-threads mostly used for bolts, nuts and set-screws. The two systems provide a basis for other thread systems where those standards are accepted (Fig. 2).



STANDARD SCREW-THREAD FORMS AND GENERAL DIMENSIONS.

FIG. 2.

The Whitworth thread is triangular in section, the angle being 55°. One sixth of the thread is rounded off at the top and bottom to facilitate the cutting of the thread and to render it less liable to injury.

The screw surface not being at right angles to the force, due to screwing up, has the effect of bursting pressure on the nut. This causes greater friction between the two threads than is the case with a thread of square section and, therefore, less tendency to become unscrewed by vibration. The pitch of the V-thread can be less per strength than a square thread, therefore, the inclination will be less and also the tendency to become unscrewed. For this reason fine threads are used very frequently on parts of machines, automobiles, etc.

American (Sellars) Screw-Thread. In the American or Sellars system of screw-threads, the sides of the thread are inclined at 60°, and the angles at the top and bottom are truncated to form a flat 1/8th of the pitch in width. The number of threads per inch for the different meter diameters of screws very nearly corresponds with the Whitworth. This thread system is adopted by the American Government and is termed the United States Standard Thread.

1.4 Thread Systems Based on Whitworth System.

(i) British Standard Screw-Thread. Adopted on general engineering work, bolts and nuts.

(ii) British Standard Fine Screw-Thread. Threads used on automobile engineering are cut in tough metals and do not require to be as course as threads cut in mild steel. A screw or bolt of given size and finer pitch has greater root diameter and, therefore, greater strength in section. A fine pitch thread may be set up tighter and does not shake loose so readily as one of the coarse pitch.

[redacted]

(iii) British Standard Pipe-Thread. Screw-threads for water, gas and steam pipes are the same form as for bolts, but differ in diameter and pitch. The bore diameter is the normal size, that is, a 1/2 inch pipe is 1/2 inch in the bore. Pipe-threads are finer pitch than bolts of the same nominal diameter because of the comparatively thin metal and to enable a tight joint to be made.

(iv) British Standard Brass-Thread. The standard thread for brass tubing is of Whitworth Standard 55° form, the number of threads per inch being 26 for all sizes to 1" diameter. Brass and copper tubing nominal sizes are outside sizes of the tubing. To obtain the tapping size subtract 3/64 inches from the outside diameter. Thus, the tapping size for 3/4 inch brass tubing would be -

$$3/4'' - 3/64'' = 48/64'' - 3/64'' = 45/64''.$$

1.5 Comparison of British and American Standards. The British (Whitworth) and the American (Sellars) standard screw-threads are the same number of threads per inch and diameter for each standard, with the exception of 1/2 inch when the British is 12 and the American 13 per inch respectively.

1.6 British Association Standard Thread. This thread is commonly known as BA and is widely used in relatively small articles of British manufacture, such as optical work, scientific instruments, telephone and telegraph instruments, electrical apparatus, etc. The thread has an angle of 47-1/2 degrees and is rounded off top and bottom with a radius of 2/11th of the pitch.

Although the BA is a British designed thread the diameter and pitch are given in terms according to the metric scale, and the thread is designated by numbers, the largest size being O.B.A. (6 mm.) and ranging down in size to No. 25 (0.25 mm).

It is important to remember the difference in notation between this standard and the other standard thread systems which are given generally in terms of equivalents in inches or by the metric scale.

1.7 United States Standard Thread. This thread is used generally by American manufacturers for automatic telephone parts and electrical apparatus, etc. The sizes mostly used are found on the twist drill gauge. In comparison to the BA the thread is coarser, but the notation by number is similar, with the addition of the number of threads per inch for each thread size. It will be noted that there are a range of five different diameters with the same number of threads per inch.

1.8 Square-Thread. The surface of the thread is normal to the axial force, against which the screw acts, and there is no oblique or bursting pressure on the nut as with the triangular or V-thread. There is also less friction and less wear with threads of this form, but they are much more expensive to cut in the lathe. They are chiefly used to transmit motion.

1.9 Acme Standard Screw-Thread. The Acme Standard Screw-Thread is a modification of the square-thread used very frequently where a disengaging nut is required, and is known as the 29 degree thread. It has the same depth, but an addition of 0.010 inch clearance top and bottom, has a square-thread and is also stronger. The sizes are at an inclination of 14-1/2 degrees or 29 degrees included angle, which angle is the same as now generally adopted in cutting worm-threads.

1.10 Buttress-Thread. When a screw has to resist a force always in one direction the modified triangular thread, termed the Buttress-Thread, is sometimes used. It has one surface normal to the axis of the screw, like the square-thread, and it should be noted that the shearing strength for a given length of nut is twice as great as that of a square-thread.

1.11 Screw Proportions. The standard screw-threads owe little to theoretical deductions. It is mainly a compromise, a means adopted from an exhaustive comparison of threads in long use. Whitworth in England and Sellars in America are the names chiefly associated with the standardising of screw-threads. Both being practical engineers, the labours of both consisted mainly in comparing and averaging the work of their predecessors and contemporaries. In the standard threads now in use to which all screwing tackle is now made, exact relationships are not necessary. Adaptability of means to ends is the only essential condition. In the abstract, or apart from extensive previous experience, no theoretical deductions would have been of any value in determining the proportions of standard screw-threads.

Questions of pitch, of relations, of diameters at points and roots of threads, and of thread sections cannot be settled except by long experience. Yet the consensus of experience has resulted in the standardising of threads which are not very dissimilar in either of these respects. For the conditions which have to be fulfilled are of an opposite and contradictory character. Any one element, if unduly developed, diminishes the strength or efficiency due to other elements. If the angle of thread is increased too much, stress is thrown upon the nut; if the thread is deepened, the strength of the bolt is weakened. If the threads are made of fine pitch and section to increase holding power, their durability is lessened for wearing purposes. If threads have keen angles they are not only more liable to injury than those with the top and bottom angles obliterated, but the tools used in their formation are more difficult to make, especially in the smaller sizes.

There is little to choose between the Whitworth and the Sellars threads, both are a mean between extremes. Each has desirable points, which the other has not. Little need be said about the difference in the angle of the threads, 55 and 60 degrees.

There is no reason why one should not be as good as the other. The Sellar is slightly stronger and the friction due to the increased angle is greater. There is no important difference in pitches, some in fact are identical. The difference in depth of the thread, due to the fact that one-sixth is taken of top and bottom of the Whitworth and one-eighth only of the Sellars, is in favour of the strength of the latter. On the other hand, the flat in the root of the Sellars is more likely to invite fracture than the rounding in the root of the Whitworth. Yet, since bolt threads are always stronger than the cross-section of the body of the bolt - in other words, since a bolt will become torn asunder at the roots of the threads before the threads will strip - this is not a real objection. Against the Whitworth root and point it is urged that the exact rounding is more difficult to obtain than the more flattening of the root and point. There is some basis for this, and in fact it is omitted in the smaller screws, the threads of which are left keen. The interference of points and roots which are not of the exact depth and curvature will prevent exact fitting of the sides of the thread.

2. TEST QUESTIONS.

1. State three different applications of screw-threads.
2. What is the pitch of a thread?
3. What is the main difference between the American (Sellars) and the British (Whitworth) Standard threads?
4. What is the B.A. thread?
5. Why are left-hand threads used?
6. Name three threads based on the Whitworth system.
7. Describe a pipe-thread.
8. When is the buttress-thread used?

END OF PAPER.

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COURSE OF TECHNICAL INSTRUCTION.

ENGINEERING WORKSHOP PRACTICE I.

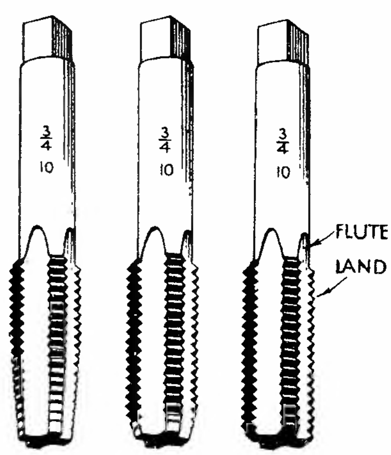
TAPS, THREADING DIE, NUTS AND BOLTS.

CONTENTS.

1. INTRODUCTION.

1.1 To cut an internal thread a tool called a "tap" is used. Taps are made from high carbon steel hardened and tempered a medium straw colour. Taps are made in a great variety of sizes and thread-forms. Portion of the body of the tap is cut with a suitable thread and the threaded portion has three or four flutes (according to the diameter of the tap) cut into the thread in a longitudinal direction. The flutes serve three purposes - they form the cutting edges for the threads, the channels for the clearance of the chips and permit a lubricant to penetrate. The shape of the flute is important as it affects the cutting quality and strength of the tap.

Hand taps are made in sets of three and are known as taper, plug and bottoming. These are American terms. English terms are taper, intermediate and plug (see Fig. 1). The first tap or "taper tap" is tapered or "chamfered" back from the end at least six thread, the plug is chamfered about three or four threads, while the bottoming tap is backed off on the end teeth. To tap a through hole, it is only necessary to use the taper tap. Where the hole does not go through the piece ("blind hole") and the hole is deep enough, the taper tap is used first, followed by the plug and, if necessary, threaded to the bottom of the hole with the bottoming tap.



Taper Intermediate Plug

TAPS.

FIG. 1.

1.2 Relief of Taps. The cutting edges of the chamfered portion of the tap are given clearance, that is, they are backed off the whole width of the land, otherwise the tap will not "bite". Further, in order to reduce the friction between the teeth of the tap and the work being tapped, the threads not chamfered are "relieved" about two-thirds of the width of the land. The remaining third of the land-back of the cutting edge remains the full cutting size, so that the tap may be ground "sharpened" on the face of the teeth without affecting the size of the tap.

1.3 Tapping - Size Drills. The diameter of the hole to be drilled in a piece where an internal thread has to be cut is theoretically the minor diameter of the corresponding screw size. This size of hole will give a full thread, but it is not always practical or desirable to cut a full thread when tapping tough metals, such as mild steel, cast steel, copper, etc. Tapping a full thread in tough metals puts an excessive strain on the tap and, unless great care is exercised, a broken tap will result.

It is the general practice, when a hole has to be tapped in tough metal, to use a drill slightly larger than the core or "root" diameter of the tap, but the drill must be of the size that will give a depth of thread of at least three-fourths of the standard thread depth. This arrangement relieves the strain on the tap when cutting and, in the case of the softer tough metals, the thread during the cutting process becomes worked up to nearly a full thread. In following out this practice, regard must be given to the thickness of the metal, because the thinner the metal, the less the number of teeth that can be formed and the holding power of a full thread then becomes necessary. The number of threads per inch decreases as the diameter of a tap increases. The thickness of a standard size nut is equal to the outside diameter of the thread of a bolt or screw.

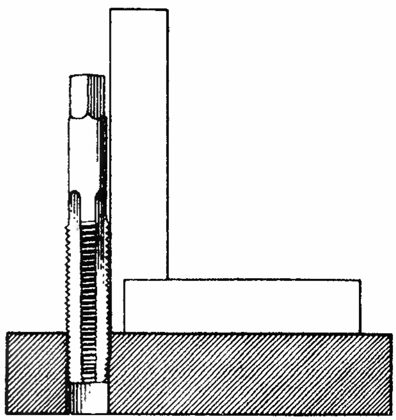
In the case of a piece of metal three-sixteenths of an inch thick, which has to have a hole drilled in it to be tapped, a full depth of thread is necessary. Therefore, the size of the drill should be equal to the root diameter of the thread. This is to provide the maximum holding power in the tapped metal as the number of threads is less than is the case when a three-sixteenths diameter is required in metal of the same thickness. Likewise, when a thread of smaller diameter than the thickness of the metal is to be tapped, the full depth of thread is usually not necessary because the number of threads is increased relative to the thickness of the metal.

When tapping the soft but brittle metals such as brass and cast iron, and a full thread is required, the metals, being brittle, do not resist the cutting action of the tap as the tougher metals do, but break away freely as the tap cuts.

1.4 Operation of Tapping. A certain pressure, varying according to the size of the tap, is needed to start the taper tap, and care must be taken to make the tap "catch the thread" and not ream the mouth of the hole taper. When the tap has well started cutting the thread, it feeds itself and requires only to be turned.

When tapping tough metals, the tap is given a quarter or less turning movements and then reversed slightly more than the width of the flute. The tap will be felt to catch. This is due to the back edge of the forward cutting edge striking the chip formed during the cut, and the reverse motion is continued until the chip has been broken off. If the tap is not reversed, the chips will curl in the flutes and jam the tap, causing it to break.

Care must be taken to start the tap cutting square and to keep it cutting square (see Fig. 2). When the tap has caught the thread, it should be checked to see if it is entering the hole square. If it is found to be slightly inclined to one side, this must be corrected by slight pressure in the opposite direction when next turning the tap.



CHECKING A TAP WITH A SQUARE.

FIG. 2.

When the tap has been corrected and has well entered the hole, further checking is unnecessary, but care must be taken to see that the chips do not crowd in the flutes. Unscrew the tap and clean out the chips.

Fig. 3 is the Standard Screw Thread Tables.

B.A. STANDARD ANGLE 47½°

SIZE OF TAPS	0	1	2	3	4	5	6	7	8	9	10
DIA. IN D.G.	15/64	4	13	20	27	30	34	40	44	48	51
THREADS PER 1"	25·4	28·25	31·4	38·84	38·5	43·1	47·9	52·9	59·11	65·2	72·56
CLEARANCE D.	1/4	2	12	19	26	30	32	38	43	48	50
	12_{0}	19_{0}	26_{0}		34_{1}	40_{0}		48_{0}			
TAPPING DRILLS	11_{2}	18_{3}	25_{2}	$\frac{1}{8}{}_{0}$	33_{3}	39_{1}	44_{1}	47_{2}	51_{1}	54_{0}	55_{2}
	10_{4}	$\frac{11}{64}{}_{5}$	24_{5}	30_{2}	32_{6}	38_{3}	43_{4}	46_{5}	50_{4}	53_{3}	54_{5}

BRASS THREADS ANGLE 55°

SIZE OF TAPS	1/8	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
DIA. IN D.G.				PITCH		1/26					
THREADS PER 1"											
CLEARANCE D.	9/64	13/64	17/64	21/64	25/64	29/64	33/64	41/64	49/64	57/64	1 1/64
	47_{2}	27_{5}	$\frac{13}{64}{}_{3}$	$\frac{17}{64}{}_{3}$	$\frac{21}{64}{}_{2}$	$\frac{25}{64}{}_{2}$	$\frac{29}{64}{}_{3}$	$\frac{37}{64}{}_{2}$	$\frac{45}{64}{}_{2}$	$\frac{53}{64}{}_{2}$	$\frac{61}{64}{}_{3}$
TAPPING DRILLS	45_{7}	26_{8}	4_{9}	I_{9}	Q_{6}	X_{9}	EI_{12}				
	42_{11}	24_{13}	3_{13}	J_{14}	$\frac{11}{32}{}_{13}$	$\frac{13}{32}{}_{16}$	$\frac{15}{32}{}_{15}$	$\frac{19}{32}{}_{18}$	$\frac{23}{32}{}_{18}$	$\frac{27}{32}{}_{15}$	$\frac{31}{32}{}_{18}$

WHITWORTH THREADS ANGLE 55°

SIZE OF TAPS	1/16	5/64	3/32	7/64	1/8	9/64	5/32	11/64	3/16	13/64	7/32	15/64	1/4	17/64	9/32	5/16
DIA. IN D.G.	52	47	42	35	30	28	22	17	12	6	2					
THREADS PER 1"	60	60	48	44	40	40	32	32	24	24	24	20	20	20	20	18
CLEARANCE D	5[illegible]	46	41	34	30	27	21	18	12	5	2	[illegible]	[illegible]/64	[illegible]/32	[illegible]/64	[illegible]/64
	57_{2}	53_{3}	50_{3}	45_{2}	41_{4}	34_{3}	31	29_{4}	28_{6}	$\frac{5}{32}{}_{6}$	$[illegible]_{6}$	16	11_{5}	5_{4}	2_{4}	D_{5}
TAPPING DRILLS	56_{5}	$\frac{1}{16}{}_{6}$	48_{9}	42_{9}	39_{7}	32_{8}	$\frac{1}{8}{}_{9}$	$\frac{9}{64}{}_{8}$	27_{10}	21_{9}	17_{8}	15_{10}	9_{10}	4_{8}	1_{11}	$\frac{1}{4}{}_{9}$
	55_{11}	51_{11}	47_{11}	$\frac{3}{32}{}_{11}$	37_{12}	31_{12}	30_{12}	26_{15}	25_{15}	19_{16}	16_{12}	13_{15}	7_{15}	3_{12}	$\frac{15}{64}{}_{17}$	F_{16}

SIZE OF TAPS	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/8	1 1/4	1 3/8	1 1/2
DIA. IN D.G.															
THREADS PER 1"	16	14	12	12	11	11	10	10	9	9	8	7	7	6	6
CLEARANCE D	25/64	29/64	33/64	37/64	41/64	45/64	49/64	53/64	57/64	61/64	1 1/64	1 9/64	1 17/64	1 25/64	1 33/64
	$\frac{9}{64}{}_{2}$	S_{2}	X_{4}	$\frac{29}{64}{}_{0}$	$\frac{1}{2}{}_{0}$	$\frac{37}{64}{}_{7}$	$\frac{5}{8}{}_{3}$	$\frac{11}{16}{}_{3}$	$\frac{47}{64}{}_{2}$	$\frac{51}{64}{}_{1}$	$\frac{27}{32}{}_{3}$	$\frac{15}{16}{}_{0}$	$1\frac{1}{16}{}_{0}$	$1\frac{5}{32}{}_{0}$	$1\frac{9}{32}{}_{0}$
TAPPING DRILLS	N_{8}	T_{12}	Y	EI_{7}	$\frac{23}{64}{}_{7}$			$\frac{45}{64}{}_{19}$				$\frac{61}{64}{}_{11}$	$1\frac{5}{64}{}_{11}$	$1\frac{11}{64}{}_{10}$	$1\frac{19}{64}{}_{10}$
	$\frac{5}{16}{}_{10}$	$\frac{23}{64}{}_{13}$	$\frac{13}{32}{}_{13}$	$\frac{15}{32}{}_{13}$	$\frac{17}{32}{}_{23}$	$\frac{19}{32}{}_{22}$	$\frac{41}{64}{}_{18}$		$\frac{3}{4}{}_{18}$	$\frac{13}{16}{}_{17}$	$\frac{55}{64}{}_{16}$	$\frac{31}{32}{}_{26}$	$1\frac{3}{32}{}_{26}$	$1\frac{3}{16}{}_{26}$	$1\frac{5}{16}{}_{26}$

A.S.M.E STANDARD THREADS / **S.A.E. STANDARD THREADS**

TAP SIZE	0	1	2	3	4	5	6	7	8	9	10	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	7/8	1
THREADS PER INCH	80	56	56	48	32	36	32	30	30	24	24	28	24	24	20	20	18	18	16	16	14	14
" " "		64	64	56	36	40	36	32	32	30	28											
" " "		72			40/48	44	40	36	36/40	32	30/32											
CLEARANCE DIA	52	49	44	39	33	30	28	24	19	16	11	17/64	21/64	25/64	29/64	33/64	37/64	41/64	45/64	49/64	57/64	1 1/64
TAPPING DRILL	3/64	54	50	47	45/4	40	36	31	30	29	25/3	3	17/64	21/64	25/64	29/64	33/64	37/64	5/8	11/16	13/16	15/16
FOR FINEST THREAD THIS	LINE	53		45	43/2	38/9	34/3	1/8	29/8	27/6	22/1											

SCREW-THREADS, AND TAPPING SIZES.

FIG. 3.

1.5 Lubricants for Tapping. Lard oil (cutting compound) should be used on steel and iron. Cast iron should be tapped dry, but if the thread is too deep, soap or a little oil may be put on the teeth. When tapping copper, a mixture of turpentine and lard oil should be used. Aluminium should be tapped with methylated spirits or a mixture of kerosene and lard oil.

1.6 Tapping Size for Whitworth Bolts. A method for obtaining the tapping size for Whitworth standard bolts is –

When there are a complete number of 1/8ths contained in the required size such as 3/8", 1/2", 5/8", etc., multiply the 1/8ths by 7 and subtract 2 from the product, the result will be the tapping size in 1/64" for a full thread.

Example. Required the tapping sizes for 3/4", 1/2" and 1" Whitworth Standard.

Solution. 3/8" = 3 eighths, $3 \times 7 - 2 = 19 = 19/64"$.

1/2" = 4 eighths, $4 \times 7 - 2 = 26 = 26/64" = 13/32"$.

1" = 8 eighths, $8 \times 7 - 2 = 54 = 54/64" = 27/32"$.

For sizes such as 5/16", 7/16", 9/16" multiply the full number of 1/8ths by 7 and add 2 to the product, the answer will be in 1/64ths of an inch.

Example. Tapping sizes for 5/16" and 9/16" are -

5/16" = 2 × 7 + 2 = 16 = 16/64" = 1/4".

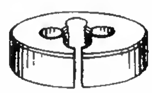
9/16" = 4 × 7 + 2 = 30 = 30/64" = 15/32".

2. THREADING DIE.

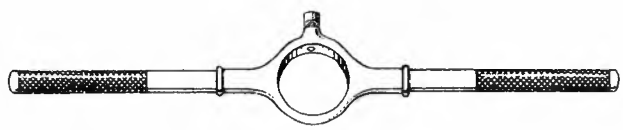
2.1 A die is a tool for cutting external threads. In general, the threading die is so arranged as to permit the cutting edges to do an equal share towards cutting their shape (the form of the thread) into a cylindrical rod.

2.2 Types of Dies. Some dies are made in two halves and are held in a body or "head" ; others are made in round form (button dies) and are split and have an adjustment screw (see Fig. 4). Both these types have four cutting faces, excepting the dies with very small threads. These have three cutting faces. Dies are held in a holder or die-stock which in some cases holds the dies together. Another type of die has four separate chasers, usually used for threading pipes. A great advantage with this type of die is that the cutting faces of the chasers can easily be removed and sharpened. The chasers are held in a head which contains mechanisms which provide a considerable amount of adjustment, and is a decided advantage when a screw slightly oversize or undersize is required or when a roughing or finishing cut is necessary. The chasers when locked have all the advantage of a solid die.

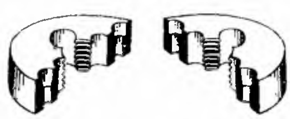
When threading a piece by hand, the end of the rod should be chamfered for at least the depth of the thread and care must be exercised in starting the die cutting true. As in starting the tap, pressure must be applied when starting the die to cut the thread, but after it has started it will feed itself. Similar reverse movement of the die, as with the tap, is necessary to break off the chips. Lubricate the same as for tapping.



Button Die.



Die Stock for Button Die.



Divided Die.

Die Nuts.

DIES AND STOCK.

FIG. 4.

3. BOLTS AND NUTS.

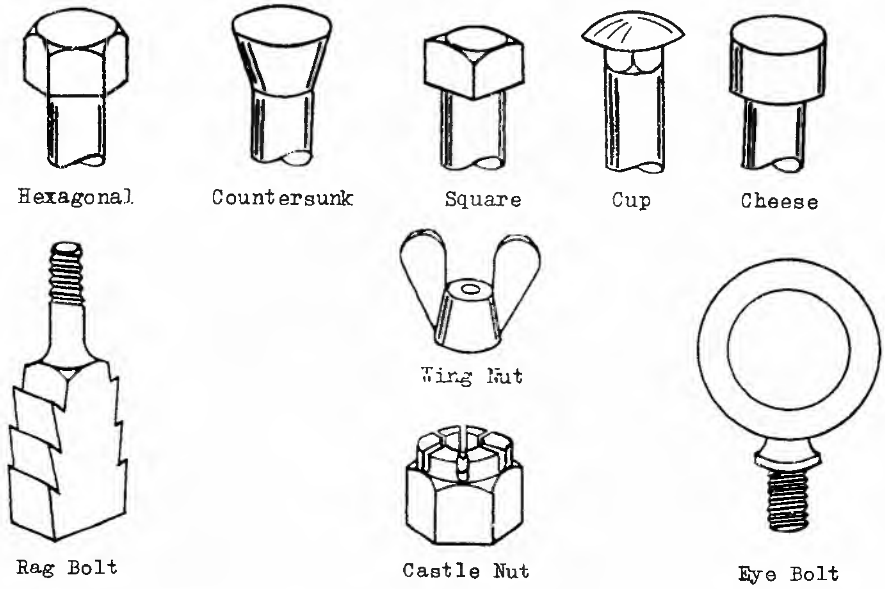
3.1 Bolts and nuts, set-screws and studs are used to secure machine parts etc. together, the principal advantage of their use being ease with which the parts may be dismantled at any time.

3.2 Bolts. (See Fig. 5.) Most types of bolts may be obtained "black",that is, not machined in any way - head and shank left as formed by heading dies, or "bright", that is, machined all over from the solid. Some of the various types are -

Hexagonal Head. Used for all general engineering purposes.

Square Head. Used generally, but more particularly in carpentry,coachwork, wooden bridge building, etc.

Cup Head. Used mainly for woodwork and for positions where other type heads would be unsuitable (dangerous). The shank is generally made square in section for a short distance directly under the head. This prevents rotation when the nut is being tightened.



TYPES OF BOLT HEADS.

FIG. 5.

Cheese Head. Used mainly for ornamental work where the head must present a finished appearance. This type and the following type are often fitted with a short pin under the head to prevent rotation.

Countersunk Head. For use in positions where the top of the head must be flush with, or below, surface of the job. Length measured from top of head.

Eye Bolt. Used for lifting purposes, the "eye" taking the hook of a crane.

Rag Bolt. This type of foundation bolt which is used for holding down machinery, supporting awnings, etc., is made with a long tapered head, generally square or rectangular in section, the section diminishing in size towards the shank. Additional holding power is obtained by means of deep nicks which are formed in the long edges of the head. In use, the head is placed in a previously prepared tapered pocket (larger at the bottom than at the top) in the foundations, the space between the bolt head and the walls of the pocket being filled with molten lead or cement grout.

3.3 Set-Screws (see Fig. 6). Set-screws, which are also often known as "machine screws", are very similar in appearance to bolts, one essential difference being that whereas a bolt is usually screwed for a length of 2-1/2D, (D = diameter of bolt), a set-screw is customarily threaded right up to the head and used without a conventional type nut.

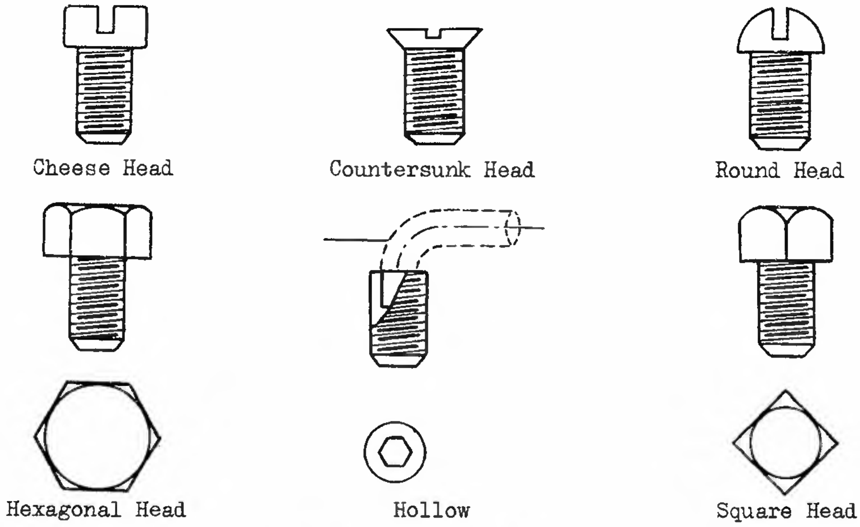


FIG. 6. SET-SCREWS.

The usual types are - "Hexagonal", "Square", "Round", "Cheese" and "Countersunk Head", the three last named being furnished with slotted head to provide for their rotation by means of a screw-driver. Set-screws are used to secure collars and small pulleys to shafting (in this case the end is "cupped" or "coned" and case hardened), and also when the work is of such a nature that one of the parts being secured together can be tapped, the other component being drilled with a clearance hole to enable the shank of the screw to pass through it.

3.4 Studs. A stud is a length of metal rod screwed at both ends, one end (threaded 1-1/4 to 1-1/2D) being securely screwed into a tapped hole in one of the parts to be assembled, whilst the other end (threaded 2-1/2D) passes through a clearance hole in the other component and finally carries a standard nut. Studs are used in position where it is undesirable to use a bolt or set-screw, for example, boiler fittings and motor car cylinder heads.

3.5 Nuts. These, like bolts, may be obtained "black" or "bright", the usual types being "hexagonal" and "square". The hexagonal nut is almost universally used in engineering practice, the main reason for this being that, whereas a square nut requires a turning angle of 90°, the hexagonal only requires an angle of 60°, besides which the hexagonal is lighter in weight for any given size. "Wing" and "Knurled" nuts are used on light work where no great tightening force is required or where it would be inconvenient to use a spanner.

3.6 Lock Nuts. Nuts that are subject to excessive vibration are generally "locked", that is, prevented in one of several ways from working loose. A common method much used in steam practice is to use two nuts, the first one usually being half bolt diameter in thickness.

Another method adopted as standard practice in motor car work is to use a "castle" nut, this consisting of a hexagonal nut thicker than the standard type and having shallow slots milled across the flats on the outside end of the nut. In use, a hole corresponding in diameter to the width of the slots is drilled through the end of the bolt, and when the nut is tightened in position, a split pin is inserted (and afterwards opened out) through the slot that is in line with the hole. Other methods sometimes used consist of drilling a hole through both the nut and bolt or through the bolt only, outside, but close up to the nut and then inserting a split pin.

4. TEST QUESTIONS.

1. Name the tool used for cutting a thread on a bolt.
2. In a Tapping Set there are three taps. Name them.
3. What size drill is used for a tapped hole?
4. Describe a tapping operation.

END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

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COURSE OF TECHNICAL INSTRUCTION.

HEAT TREATMENT OF METALS.

CONTENTS.

1. INTRODUCTION.

1.1 This Paper refers to the process of annealing, hardening, tempering and case-hardening.

1.2 Annealing. This term as applied to metals means softening, that is, reducing the state of brittleness to one of softness. The property of malleability depends upon softness. During the process of manufacture of metals, such operations as welding, drawing-out, bending, rolling or twisting, cause brittleness on account of internal or external strains. When metal is worked the molecules are forced into unnatural positions, but by heating the metal and allowing it to cool it can be brought back to its natural state.

The common practice of annealing steel is to make the metal blood-red hot, 1400°F-1700°F. in a forge or muffler, or in a gas blow-pipe and allow to cool either in the hot ashes or in powdered lime. This method is quite suitable if the substances used are dry and well heated before the steel is buried. If, however, it is cold and damp, especially if the piece of steel is small and thin, the effect is opposite to that desired, as the steel is chilled and the outside is hard. In order to avoid this the ashes or lime may be heated by burying in it a piece of scrap iron or steel. This may be removed when the piece to be annealed is ready. This method is not suitable for complicated work. In this case, especially if the work is of high carbon steel, it should be packed in a box with granulated charcoal, care being taken to see that charcoal covers every part of the job. The box should be heated to a cherry-red colour in an oven or the forge, then it should be allowed to cool by withdrawing the heat. To get good results, steel must be uniformly heated for all operations of forging, annealing and hardening. But it must not be left in this condition too long. As soon as it is uniformly heated to the proper temperature, it should commence to cool and should not be long in cooling to a point where the red disappears, but it should be a long time cooling from this temperature. When annealing, steel should not be heated too hot, as high heat makes the steel porous by separating the molecules, and the closer these minute particles the stronger will be the steel. If steel is heated to an extremely high heat it becomes very brittle and weak, and breaks as easily as a piece of iron (cast), and it also resembles cast iron in texture.

Wrought and cast iron can be annealed by a similar process, except that the charcoal must be replaced by cast iron turnings when packing the work in the box.

To anneal copper and copper alloys, the metal is heated to blood-red colour in a gas flame or clean fire and then plunged into clean, cold water or it may be allowed to cool slowly. When cooled in water there is an additional advantage, the surface of the metal being cleaned in the process by the removal of the scale by the water. In the case of copper this is especially so if the surface of the metal is sprinkled with common salt and then heated. If copper is over-heated it quickly oxidises.

Aluminium is annealed by rubbing the surface with common soap and then heating slowly. When the soap turns black the heat is withdrawn and the metal allowed to cool.

Zinc, tin and lead can be annealed by heating in boiling water and then cooling in air. This method is also suitable for aluminium.

1.3 Hardening. The process of hardening is very important and, although the process is simple, a wide amount of knowledge is necessary in order to understand fully what takes place.

The hardening of carbon steel is the result of a change in the internal structure, which takes place in the steel when heated properly to the correct temperature.

The carbon content in tool steel varies according to the manufacturers specifications. The following are the names given to some carbon tool steels - Austenite, Cementite, Martensite and Pearlite.

Austenite. Name given to a solid solution of carbon in iron. Named after W.C.Roberts-Austen, the metallurgist. Steels containing austenite are termed "austenitic" (Austenite steel).

Cementite. In a 1.25 per cent. carbon steel, carbon of iron is first deposited at above 855°C. and this continues down to 695°C. This iron thus precipated, is known as Cementite in order to distinguish it from the carbide in the Eutectoid. Additionally, the term cementite is applied to any carbide in steel, even though it may contain manganese, chromium etc. It is thus a carbide of iron (Fe_3C) and is a constituent of most carbon steels.

Martensite. Name given to a solid solution of carbon in that variety of pure iron known as "beta-ferrite". It has a typical constituent of steel which has been hardened by quenching. Called after A.Martens the metallurgist.

Pearlite. The "pearly" constituent of steel. It is a mixture of cementite (an iron carbide) and pure iron, and under the microscope it has an appearance resembling mother of pearl. Annealed steel contains a large proportion of pearlite.

1.4 Hardening of Carbon Tool Steel. The hardening of steel consists in heating to a predetermined temperature and afterwards cooling in a medium which is an effective conductor or extractor of heat.

To understand the principle which governs the hardening of steel, it is desirable to be acquainted with the changes which occur when steel is heated and subsequently cooled.

When heat is applied to tool steel of approximately one per cent. carbon, its temperature gradually rises to a point at which, although heat is still applied, the steel remains at a stationary temperature or only increases in heat very slowly.

This is the critical point on heating and is known as Galescence (Ac, 1) and is the temperature which must be exceeded in order to harden the steel.

On being allowed to cool in air, cooling takes place gradually until a further point is reached (austenite to pearlite change) when it appears to be arrested, and if observed in the dark, an apparent increase in temperature takes place and the steel will be seen to glow.

The point at which the steel is seen to glow is described as Recalescence (Ar. 1) and is the temperature below which steel will not harden.

The temperatures given in the following table are those recommended for average sized tools, and in each case have sufficient allowance over the Ac. 1 point to permit of satisfactory hardening in water.

Whenever possible, it is desirable that all tools should be heated in a furnace with a Pyrometer attached. The temperaturesfor the various tempers of steel given should be adhered to as closely as possible.

Temper No. 1 - Medium Cherry-Red	...	750° Centigrade.
Temper No. 2 - Medium Cherry-Red	...	750° Centigrade.
Temper No. 3 - Cherry-Red	...	780° Centigrade.
Temper No. 4 - Cherry-Red	...	780° Centigrade
Temper No. 5 - Cherry-Red	...	800° Centigrade.
Temper No. 6 - Cherry-Red	...	800° Centigrade.

The Hardening Temperatures Given for Tools with Thin Edges After Forging to Shape. When solid tools are machined from annealed steel, the above temperatures may require taking a little higher according to the size of the tool (generally not over 10°C to 20°C.).

In the absence of an electric, gas, oil or coal fired furnace, the old-fashioned method of heating in a coke or coal fire must be resorted to.

Should the temperature previously be exceeded, the steel when fractured is liable to present a coarse bright crystalline structure - a sure indication of overheating.

The heat should be applied very slowly at first, until the tool is heated well through, and then should be brought up to the proper temperatures as quickly as possible, without brining the edges or sharp corners of the tool to a higher heat than the body.

When heated in a blacksmith's hearth (or open fire), steel has a tendency to become a little hotter on the outside than in the body, and it is advisable to allow the tools to remain in still air for a few seconds before quenching in the hardening medium.

In heating for hardening, the following five points should be carefully noted -

(i) The steel must not be overheated.
(ii) The steel must not be too quickly heated.
(iii) The steel must be heated well through and not superficially.
(iv) The steel must not be oversoaked.
(v) Do not quench at higher temperatures than those given above.

The Effect of (i). If the steel has been very much overheated it is described as "burnt", that is, oxides have been formed and the steel is ruined. If only slightly overheated, it can be partially restored, but will not give the same good results as if correctly heated on the first occasion.

The Effect of (ii). Is to cause irregular movement, and tools treated in this way never give uniform satisfaction and will be liable to burst after quenching.

The Effect of (iii). Causes breakages in hardening through uneven contraction when plunged in water.

The Effect of (iv). Results in the decarburisation of the surface, hard and soft places in hardening, and in the general deterioration of the steel.

The Effect of (v). Quenching at a higher temperature than those recommended produces distortion. Where large masses fail to harden satisfactorily at given temperatures, the only alternative for successful hardening is an increase of quenching speed, such as the use of a strong stream of water, localised if necessary, or in a brine solution. When a brine solution is required, the strength is important - maximum efficiency being obtained with a concentration of 10 to 15 per cent. in weight.

If the strength is below 5 per cent., quenching is slower than in plain water, and if 20 per cent. solution is reached it has no advantage over plain water.

In the case of machine parts or delicate tools which have to be hardened all over, it is better to normalise by reheating before hardening to a temperature not exceeding 20° above the hardening temperature, as this treatment relieves strains set up in machining and reduces the risk of cracking and distortion and also assists in uniform hardening.

Centigrade	Colour
565°	Brown-Red.
600°	Dark-Red.
700°	Blood-Red.
730°	Blood or Low Cherry-Red.
740°	Low to Medium Cherry-Red.
750°	Medium Cherry-Red.
760°	Medium Cherry-Red.
770°	Cherry-Red.
780°	Cherry-Red.
800°	Cherry-Red.
825°	Bright Cherry-Red.
850°	Full Red.
900°	Bright Red.
920°	Bright Red.
955°	Full Bright Red.
980°	Yellow-Red.
1250°	White.
1300°	Full White.
1330°	Full White.
1350°	Incandescent White.
1360°	Incandescent White.

When taking hold of a tool which is heated all over, it is important that the tongs are not cold or damp. They should be brought to a black-red heat. It is also advisable to use tongs that have sharp points or grips, so that they grip as little of the tool as possible, otherwise, when quenching in water, the portion of the steel gripped by the tongs does not cool with the same rapidity as the remainder, the result being soft spots through uneven quenching.

The hardening liquid should be placed as near as possible to the furnace, and care must be taken that the quantity of fluid is ample in proportion to the size of the tools being hardened. The hardening fluid should be in circulation, where possible, to ensure a constant temperature.

Where oil-hardening is carried out on an extensive scale, it is most advisable to surround the oil bath with a water jacket (preferably with a circulatory system) to keep the oil as uniform in temperature as possible. If any appreciable deposit of mud accumulates in the oil tank, it should be cleaned out, otherwise the hardening is liable to be patchy.

A wire basket should be suspended in the oil bath to prevent tools being lost in the deposit which invariable collects at the bottom of the tank.

1.5 Examination Before Hardening. Too much importance cannot be attached to the careful examination of tools when ready for hardening, for -

(i) Sharp scratches or tool marks.
(ii) Rough holes, drill marks or countersink marks.
(iii) Unnecessary sharp angles or shoulders.
(iv) Unnecessary deep centre holes.

Note. Where any of the above are observed they should be removed where possible, but where unavoidable, centre holes should be filled with fire cement or other similar material, otherwise they form starting places for cracks in heating and hardening. Where doubt exists as to whether marks on tools are machine marks or cracks, this may be readily determined by immersion of the tool into petrol. The petrol will rapidly evaporate from the surface of the tool but will remain for some period in actual cracks.

See that tools, when ready for heating for hardening, are clean and quite dry.

1.6 Defects in Hardening. Uneven heating and overheating is the cause of most of the defects in hardening and must be carefully avoided.

(i) When cracks or breakages of a circular form occur from corners or edges of a tool, it is an indication of uneven heating in hardening or too low a temperature when quenching.

(ii) When cracks of a vertical nature and showing dark coloured fissures are found, the steel has been burnt and should be put on the scrap heap.

(iii) Tools which have hard and soft places have been either unevenly heated, unevenly cooled or soaked. A tool not thoroughly moved about in the quenching fluid will show hard and soft places and have a tendency to crack.

(iv) Tools which are hardened by simply dropping them to the bottom of the tank sometimes show soft places, owing to contact with the floor or sides of the tank. They should be thoroughly quenched before letting them sink to the bottom of the tank.

(v) When a tool appears soft, and will not harden, it is probable that it has been decarburised on the surface by too much heat or soaking too long. It must have the surface ground or filed off before it will harden properly.

(vi) Tools are sometimes soft because the quantity of liquid used in hardening is not sufficient for the size of the tools being hardened. It is important that sufficient volume of water or other quenching fluid is used (preferably in circulation to ensure a constant temperature), otherwise, after quenching the first few tools the water will become too warm and will not carry off the heat rapidly enough from the tools.

These remarks especially apply to cases where oil is used.

(vii) Round tools, such as milling cutters, reamers, taps, etc., especially when long, if heated in a smith's fire, must be constantly turned during heating for hardening to ensure an even temperature at the time of quenching.

1.7 Overheated Steel. Overheated steel or steel not actually burnt can be partially restored by heating to the correct temperature and being allowed to cool slowly in hot ashes or sand; then hardened again at the proper hardening heat. Tools treated in this way are not so good as when treated at the correct heat throughout, but they are, as already stated, partially restored, and if the overheating originally took place in forging, by adopting the above process, the risk of cracking in hardening will be lessened.

Care should be taken to see that tuyeres in the blacksmith's forge are well covered when heating tool steel; a tool coming in direct contact with the blast will become surface burnt, show soft places in hardening and wear badly in use. Overheating is more easily detected than uneven heating and the risk of breakage in hardening is actually greater through the latter course.

1.8 Quenching. Cooling baths should be large enough to maintain a constant temperature, and the liquid should be distilled water or rain water. Salt water (brine) is a very good hardening medium and is used to obtain extra hardness.

The red hot steel when immersed must not remain stationary, but should be immersed gradually deeper. This is to expel the steam vapour that forms around the work, and, if allowed to remain, would change the cementite carbon into pearlite, and a soft tool or work would result.

All work to be hardened should be heated according to its shape, the work being so manipulated in the fire that the thin parts do not reach the required heat before the thick parts do, then, in quenching the work in water, the thick part should be immersed first and the operation be performed slowly. The work should be lowered perpendicularly in the water and immersed deeply, and not, under any circumstances, moved sideways. Uneven heating warps the work in the fire and careless dipping warps and fractures it in the hardening. Always use water that is lukewarm - never below 60°F. - and if the article has one part thinner than the other or is very slight, make the water "warm to hot" according to the size of the work and dip the work edgeways, the heaviest side downwards. The rapidity with which the work is cooled and the rate the heat can be absorbed has an effect on the hardness of the steel.

1.9 Tempering. Steel properly hardened is as hard as its peculiar quality permits it to become. In this state it is generally too brittle to be of any use, and it is necessary to temper it before it is exposed to any strain or tenacity.

After a tool is quenched right out, that is, hardened, it is ready for tempering. The temper is then drawn down or let down by slow heating until the grain of the steel is in the strongest or keenest form for its particular use or purpose. The temper is gauged by the colours formed on the surface of the steel as the heat progresses, and it has been proved by numerous experiments that the colours thus formed are an unvarying guide to the condition of the hardened steel. Hardening and tempering should, where possible, be carried out in normal daylight, not in strong light.

It will be noticed that the colours assume the following appearance as the heat increases. Colours are indicative of temperature for straight carbon steels only.

Colour	Centigrade	Fahrenheit	Type of Tool
Light Straw	220°	426°	Lathe tools for brass, scrapers.
Straw	230°	446°	Light turning tools for steel.
Dark Straw	245°	464°	Taps, drills, milling cutters.
Brown Yellow	255°	491°	Cutters for hardwood, punches and dies.
Red Brown	265°	509°	Large twist drills, stone cutting tools.
Purple	275°	527°	Hot sets.
Purple Blue	285°	545°	Cold chisels for cast iron, screw-drivers.
Full Blue	295°	563°	Circular saws for metals.
Light Blue	300°	572°	Springs.

The hardness is all gone when the black colour is reached. Tempering may be effected in several ways, but the two most generally adopted are as follows -

For tools that require the same hardness throughout, the tool is heated for hardening and quenched right out until cold. Then the surface of the tool is cleaned by emery cloth or ground until bright. This is necessary as the temper colours do not appear clearly on impure (oxidised) surfaces.

Heat is then applied to the tool, and according to its size or shape, either placed in a soft gas flame or on a hot plate heated by gas, and in a very short time, according to the size of the work, the colour on the surface of the steel will be observed to gradually change. When the desired colour is reached, the work must be quickly quenched right out and it is then in the best condition for its particular purpose.

Where the body of a tool is not required to be of the same hardness as the cutting point (Turning, Planing, Slotting Tools, Chisels, Sets, Picks, etc. come under this definition), these tools are heated for hardening, but instead of being quenched right out, only part of the heated end is quenched in the water, leaving enough red to carry the temper slowly to the point. The hardened portion must be very quickly cleaned by rubbing with a piece of sand stone, so that the temper colour will be seen as it runs back to the point, then quench right out.

When hardening or tempering tools, etc. the points of the tools which are slender in comparison to the body should not be immersed in the flame. The flame should be applied below the point of the slender part so that the colour will creep towards the point uniformly. This will prevent burning and destroying the properties of steel at the point when hardening, and will also prevent the slender part from developing the temper colour before the body is tempered to the correct degree. Generally the body of the tool is tempered to a lower degree than the cutting point.

1.10 Case-Hardening. Mild steel contains a very small percentage of carbon, while wrought iron should contain no carbon and consequently neither of these metals can be hardened. The process of case-hardening gives a very thin case or covering on the surface; it really converts the surface into carbon steel.

The best results are obtained with steel containing from 0.1 to 0.2 per cent. carbon.

The material used for case-hardening must be rich in carbon, for example, charred leather, powdered bone, wood and animal charcoal, powdered potassium cyanide or prussiate of potash or one of such patent compounds as "Hardite" or "Kasenit". These substances, being very poisonous, require careful handling. The metal to be case-hardened is heated to a cherry-red in the medium (usually termed compound) which has been powdered, and then plunged into cold water. Sometimes the compound is melted and the red hot metal placed in the molten liquid, the heat being continued throughout the process. By this means the case-hardening is of greater depth, especially if the metal remains in the molten liquid for some time and the heat is maintained.

Where it is necessary to case-harden large articles of these complicated shapes, the articles are placed in an iron box sufficiently large enough to allow a sufficient space between the work and the sides of the box. The job is packed around with powdered bone or with one of the patent case-hardening compounds. The box is then placed in an oven where it is brought to a cherry-red heat and allowed to remain for a period, the heat being continued according to the depth of the case required and also the size of the work. The pieces are then plunged into cold water.

In some instances where more accurate results are desired, the double heating process is employed. In this process the articles are first subjected to a temperature of 1600°F. bright red, and quenched, then reheated to 1400°F. medium cherry-red and quenched. The double-heating process refines and strengthens the interior of the uncarbonised part, and refines the exterior of the carbonised part.

The boxes are constructed to provide a margin around the lid, the margin being with fire-clay. This is to exclude the air from the work, as air has an injurious effect on the case-hardening process.

By cleaning the surface of case-hardened work, any of the temper colours can be obtained by carefully reheating. The process is similar to that of tempering carbon steel.

At this stage it will be to your advantage not to think this is all there is to be learnt about steel.

2. TEST QUESTIONS.

1. Define annealing, case-hardening and tempering.

2. Name two types of carbon tool steel.

3. State the five important points to observe when hardening steel.

4. How can overheated steel be restored to normal?

5. State the causes of defects when hardening.

6. State the tempering colours for -

   (i) Cold chisels.

   (ii) Drills.

   (iii) Screw-drivers.

END OF PAPER.

COMMONWEALTH OF AUSTRALIA.

Engineering Division,
Postmaster-General's Department,
Treasury Gardens,
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COURSE OF TECHNICAL INSTRUCTION.

ENGINEERING WORKSHOP PRACTICE I.

MISCELLANEOUS ITEMS.

CONTENTS.

1. SCREW-DRIVERS.

1.1 A screw-driver, an important telecommunication tool, is a lever tool and is applied mechanically by pressure towards the blade and a turning movement. There are many varieties of types and sizes, the smallest being the watchmaker with a width of blade approximately 1/16" and increasing in section and length to the engineers' screw-driver with a width of blade approximately 1/2". The sizes in general use in the Department are - 1/2" watchmakers, 3-1/2" and 6" "Yankee" type, and others suitable for general work such as the 10" for fixing wall telephones or brackets for handsets etc.

A screw-driver is selected to suit the diameter of the head of a screw and the width of the slot. As the slot in the screw-head has parallel sides, and a screw-driver blade is slightly tapered, the screw-driver when torsional stress is applied would lift out of the slot if pressure towards the blade was not exerted, therefore, pressure towards the blade must equal approximately the torsional stress, or damage will result to the mouth of the slot in the screw-head. The blade point should seat along the entire bottom of the slot.

A screw-driver with a long shaft will more easily tighten a screw which has to be seated very tight, or loosen a screw that has rusted in, than will a short shaft driver, although the section of shaft, width of blade and size of handle are the same.

The explanation is that the longer shaft will provide the operator with greater torsional stress, namely, the shaft will twist, thus imparting a snap action at the blade end.

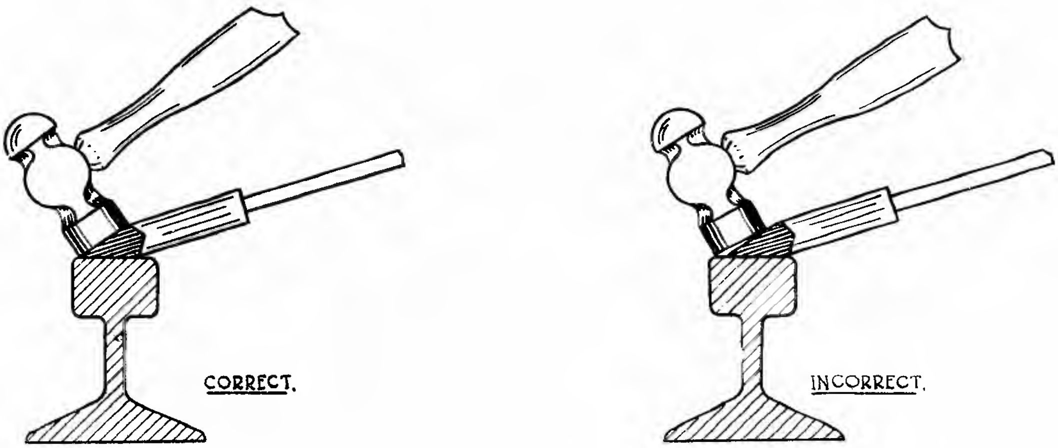
A screw-driver after much use becomes worn, the edges of the blade becoming rounded and thin. A driver in this condition will damage the slot in the screw -heads, therefore, it should be reconditioned. This can be carried out by grinding, taking care to conform to the standard shape, or by annealing and filing to shape, hardening and tempering to a purple blue.

2. FORGING.

2.1 The art of forging plain tools consists of hammering them down to shape from rods of suitable section. It is simply a case of tapering down under the hammer; there is no upsetting or welding or really difficult work about it. The real art lies in the observance of three cardinal matters, namely, heat suitable for forging, proper control of the hammer, and the heat as indicated by colour, suitable for hardening and tempering.

There are two extremes of heat equally injurious to tool steel. One is white heat, at which the steel becomes burnt, and the other is the black heat, at which, if hammered, it becomes very weakened. The range of temperature for forging, therefore, lies between a red, or full red, and at which the last faint tints of red disappear. If a tool becomes burnt - a not infrequent occurrence - the burnt end must be cut off, and the tool reheated and forged. Carefully heat the steel in order that the outside will not become overheated before the heat has penetrated to the centre.

2.2 When forging flats, the angle at which the stock is held in relation to the surface of the anvil is important. The stock should be held so that the desired angle of the flats will be hammered without bending the flats. Commence hammering from the point and work back. It is better to hammer rather lightly at first, until one has a little practice. (See Fig. 1.) The hammer should be held with the thumb on the top side of the hammer handle with an easy grasp but with full control. Strike snappy blows with the face of the hammer - not the edge - hold the hammer so that at the end of the stroke it strikes the face of the stock squarely. Do not forge the end fish-tail shape. After flattening the end somewhat, turn the stock a quarter turn and, holding the stock horizontally, hammer the narrow sides to make them parallel. Alternate blows, four or six on the wider surface, then a few blows on the narrow surface, until the work is worked up into the shape desired, taking care during forging not to imprint hammer marks on the surfaces. When forging do not allow the heat to get below a dull red, because hammering steel after it has cooled off too much will set up strains that may crack the steel when it has hardened. As the work gets thinner on the forged end, it will cool quickly when placed on the anvil, so it has to be frequently reheated taking care not to burn the point.



ANGLE FOR FLATS.

FIG. 1.

After forging has been completed the next operation is annealing, followed by hardening and tempering.

The foregoing notes on forging should be applied when making screw-drivers, wood screw awls, chisels or any work of a similar type.

3. SOLDERING OF METALS.

3.1 Soldering forms a very important part of the work of a technician. The object of soldering is to unite two pieces of the same or different metals by means of a more fusible metal or metallic alloy, applied when melted, and known as solder. As the strength of the soldering depends on the nature of the solder used, the degree required for the joints must be kept in view when choosing a solder. The parts to be joined must be thoroughly cleaned and free from oxides. This can be effected by filing, scraping, or by the use of emery cloth.

3.2 Soldering is divided into two classes - soft and hard. The soft solders have a lead-tin base and are usually applied by means of a soldering bit. The hard solders have generally a copper and zinc base, and melt at a much higher temperature obtained by a blow-lamp or a gas blow-pipe and is known as brazing.

A good mixture for soft soldering for general use is 50-50 lead and tin. The mixture for lead soldering (cable jointing) is 34-66 tin and lead. The addition of lead makes solder less fusible but cheaper, while bismuth lowers the melting point. Bismuth is, therefore, added in the production of a very soft solder such as is used in heat coils and is known as fusible alloy.

3.3 Fluxes. To remove the layers of oxide which form during the process of soldering, various fluxes are employed. The fluxes are applied to the joints and act partly by keeping out the air from the joint, thus preventing oxidation and partly by reducing and dissolving the oxides themselves. The choice of a flux depends on the metals to be soldered and the quantity of heat required for soldering. Fluxes for soft soldering are numerous. Some have a resin or chloride of zinc base, also fats, salts and pure resin. Liquid compounds are also widely used for certain purposes. A particular brand used by the Department is Baker's Solution. This consists of hydrochloric acid with a little zinc and ammonia.

The function of fluxes -

(i) Cleansing of base metals to be joined or keeping clean surfaces which have already been cleaned, including the removal of oxides produced by the heat of soldering.

(ii) Removal of solder oxides formed during soldering.

(iii) Aiding the wetting power and improving the flowing qualities of the molten solder.

The actual processes which take place during the functions are somewhat obscure, and since published explanations are far from unanimous, it would appear that a satisfactory theory to cover all the known facts has still to be advanced.

Fluxes in common use can be divided into two broad classes, the chemically active and the non-corrosive. The first class may be divided into strong and weak type . The strong type includes such fluxes as hydrochloric acid (spirits of salts), chloride of zinc (killed spirits), ammonium chloride, and various combinations of these. The weak type includes tallow, stearine, etc. Resin is, at present, the only flux of the non-corrosive type.

The best fluxes to be used on various metals are -

Copper - Resin (small job) Killed Spirits (big job).
Brass - Resin or Baker's Solution.
Gunmetal - Resin or Chloride of Zinc.
Lead - Stearine or Tallow.
Iron - Chloride of Ammonia.
Old Galvanised Iron - Raw Spirits.
New Galvanised Iron - Killed Spirits.

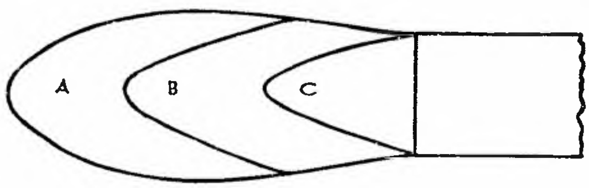
Zinc chloride is prepared by digesting chips of zinc in hydrochloride acid to saturation. To this add 1/3 spirits of salammoniac and 1/3 part rain water, and filter the mixture. This soldering flux is specially adapted to the soft soldering of iron and steel because it does not make rust spots. Another soft soldering flux is known as "Fluxite".

This can be used for nearly all metals except aluminium. None of the foregoing fluxes except "resin" should be used on instrument wiring (telephones, switchboards, mainframes or any wiring of apparatus used by the Department). Fluxes other than resin are liable to cause corrosion even months after being applied. Resin cored, or tube solder composed of 50-50 lead and tin, is supplied for the purpose of soldering wire connections, etc.

3.4 Soldering Bits. Soldering bits are made of copper as it is easily heated, is a good conductor of heat, and also retains its heat longer than do most metals. The point of the "bit" must be tinned, that is, facing one side at the point with a film of solder. This provides good conduction of heat from the bit to the joint, as the tinned surface of the bit does not readily become oxidised.

3.5 General Soldering. Before solder will flow on metal, the metal must be hot enough to melt the solder. It is, therefore, apparent that a small soldering bit is of no use on large work, as it would become cold before the mass of metal became heated.

Large articles too big for the copper bit are soldered by a process known as sweating. The surfaces to be joined are thoroughly cleaned and then heated in a bunsen burner or, if too large, with a gas blow-pipe or blow-lamp. (See Fig. 2.)



BLOW-PIPE AND BUNSEN FLAME.

"C" is composed of unburnt gas and air.

"B" active combustion has taken place.

"A" combustion is incomplete.

The point of part "B" will give the greatest heat.

FIG. 2.

If a liquid or paste flux is to be used, the surfaces to be sweated are given a slight film of the paste flux and then heated. When the liquid "bubbles" rod solder is applied, and if the solder does not flow freely, it should be assisted by a further application of the flux until the surface is completely covered. Then all surplus solder is wiped off leaving a smooth surface. The two pieces are then placed together and, if necessary, clamped. The flux is then run around the joint and the work is heated. Apply rod solder to the joint and when the work is hot enough the solder will flow along and through the joint. Joints made by this process should be allowed to cool out slowly, not quenched in water, because the steam generated would penetrate the joint and fracture the solder. The work should then be washed in soap and water to prevent future corrosion.

4. HARD SOLDERING OR BRAZING.

4.1 The Compositions of Hard Solder are -

Hard brazing solder - 3 parts copper - 1 zinc or 1 copper 1 zinc.
Soft brazing solder - 4 parts copper - 1 zinc or 1 tin.
Soft silver solder - 70 parts silver, 30 parts copper.
Hard silver solder - 50 parts silver, 34 parts copper - 16 zinc.

4.2 This is a method of uniting by means of a fusible alloy, above red heat, for example, copper, brass, iron, etc. It gives a strong substantial job. The alloy used for this purpose is known as "Spelter", and is especially useful for joining iron, steel, copper and brass. It is very important to remember that the melting point of the spelter must be always lower than that of the metals to be joined; otherwise the job will melt before the spelter. This is particularly true when brazing brass. Spelters, like soft solders, vary in proportions of the metals of which they are composed. The flux is borax, or a compound of boracic acid, chlorate of potash and carbonate of iron. (Boron.)

4.3 A gas blow-pipe is the best method for brazing, although a clean charcoal fire can be used for large work. The parts to be joined should be heated to a cherry-red and then a small amount of flux sprinkled on. When this flows, the spelter can be added by means of an iron spoon. The heat should then be increased and the work watched to see the spelter begin to melt and fill up the space in the joint. If the pieces to be joined are thick metal, care should be taken to see that the spelter runs through the joints, otherwise the pieces will only be partly united. In the case when the form of the work to be brazed does not allow the spelter to be sprinkled on the work, rod spelter is used and, if the work is of small proportions, the end of the rod of spelter should be hammered down to a suitable thickness and applied to the joint, when the correct heat is attained and allowing the flame to play on the spelter. Care must be exercised so that only the amount of spelter required to unite the pieces is melted.

Work to be brazed is often fitted first by means of a dovetail joint, which should not necessarily be a tight fit, or the spelter will not have sufficient room to run between the joints. Also, the top edges of the joints should be slightly champered in order to allow the spelter to run into the joints freely.

For silver-soldering, the same method as for spelter brazing may be adopted, but the job is heated to a lower temperature because of the lower melting point of silver-solder.

5. ALLOWANCES FOR BENDING SHEET METAL.

5.1 When bending steel or brass sheet metal, add from 1/3 to 1/2 of the thickness of the stock for each bend, to the sum of the inside dimensions of the finished piece to obtain the length of the straight blank. The harder the material the greater the allowance (1/3 of the thickness for soft stock and 1/2 of the thickness for hard material). Absolutely accurate data for this work cannot be deduced as the materials vary considerably as to hardness, etc.

6. TEST QUESTIONS.

1. What points would you observe in the selection of a screw-driver for a job?

2. Why is flux used in soldering?

3. What flux is used for -

   (i) Copper.
   (ii) Lead.
   (iii) Galvanised Iron?

4. What is the difference between soft and hard solder?

5. Why are soldering bits made of copper?

6. Define forging.

END OF PAPER.